

Biomed Certification Study Guide



Dave Harrington

Contents

ELECTRICAL SAFETY.....	1
Electrical Safety Testing.....	1
General Equipment.....	2
Computer or Microprocessor Controlled Devices.....	2
Patient Connected Devices, Diagnostic.....	2
Patient Connected Devices, Therapeutic.....	2
Devices in the Patient Vicinity.....	3
Electrical Safety on Permanently Wired Equipment or Over 115 Volts.....	3
Personal Safety.....	3
REVIEW QUESTIONS.....	4
INTRODUCTION TO CARDIAC DEVICES.....	5
The heart's pumping action.....	5
Basic hemodynamics in the heart.....	5
ECG amplifiers.....	6
Isolation.....	6
Switches.....	6
Gain.....	6
Frequency response.....	7
Electrodes.....	7
ECG recording.....	7
Waveform Display Methods.....	8
Electronic Display.....	8
INK Paper.....	9
CLAY paper.....	9
WAX paper.....	9
Chemical - Thermal.....	9
Recorder Presentation.....	10
Blood Pressure.....	11
Mercury Manometers.....	11
Aneroid Manometer.....	11
Electronic Blood Pressure Measurement.....	12
Invasive Blood Pressure Measurement.....	12
Cardiac Output Measurement.....	13
Pulse Oximeter.....	14
Pulse Oximeter.....	14
Defibrillators.....	15
Cardioversion.....	16
Implanted Pacer.....	16
REVIEW QUESTIONS.....	16
PERINATAL DEVICES.....	19
Ultrasound.....	19
Fetal Doppler.....	19
Fetal Monitor.....	19
Presentation.....	20
Common Problems.....	20
Fetal Monitoring Systems.....	20
BIRTH.....	21
Infant Incubator.....	21
Heater Controls.....	22
Infant Warmer.....	22
Billi Lights (also known as Phototherapy Unit).....	23
Transilluminator.....	24
Apnea Monitor.....	24
REVIEW QUESTIONS.....	24

Biomed Certification Study Guide
By Dave Harrington

OPERATING ROOM EQUIPMENT.....	26
Anesthesia	26
General Anesthesia unit, inhalation.....	26
Vaporizer.....	26
Flow tube.....	26
Purge button	27
Pin index.....	27
Absorber.....	27
Scavenger	27
Anesthesia circuit	27
Bellows.....	27
Reservoir bag.....	27
Capnograph	28
Anesthesia depth monitor	28
Other monitoring	28
Injectable anesthetic agents	28
Explosive agents.....	28
Tables	28
Lighting	29
Electrosurgery	29
Electrodesiccation.....	30
Electrofulguration.....	30
Electrosection	30
Electrocoagulation.....	30
Electrosurgical Burns	31
Fires.....	31
Cryosurgery	31
Lasers	32
Suction.....	32
Autotransfusion	33
Fluid warmers.....	33
Cardiac Bypass Pump.....	33
Hypo/Hyperthermia	34
Power Tools.....	34
Tourniquets.....	35
Scopes.....	35
Scope disinfecting and sterilizing units	36
Insuflator	36
Surgical microscope	37
Operating room environment.....	37
Clothing.....	37
Hands.....	37
Tools and test equipment.....	38
Movement.....	38
Speaking	38
Hazards.....	38
Isolated power system	38
Laminar Flow	39
Germicidal lights	39
REVIEW QUESTIONS	39
CRITICAL CARE/INTENSIVE CARE UNITS	41
Physical requirements.....	41
Electrical.....	41
Emergency power.....	42
Gas and Suction.....	42
Lighting	43

Biomed Certification Study Guide
By Dave Harrington

Air handling and filters.....	43
Noise levels	44
Monitoring Systems.....	44
Ventilators	45
Volume limited	45
Pressure limited	45
Time cycled	45
Jet-High Frequency-Ultrasonic.....	46
Controlled ventilation	46
Assisted ventilation	46
Assister/Controller.....	46
Humidification.....	46
General information on ventilators.....	46
Intra-Aortic Balloon Pump	47
Left Ventricular Assist Device	47
Extra Corporeal Membrane Oxygenation.....	47
Leg Compression units	47
Pulse Doppler	48
ICU beds.....	48
Stryker Bed, (Frame)	48
Circoelectric bed.....	48
Century Bed.....	48
Sand bed or Air bed.....	49
Water mattress	49
Air mattress	49
Fluid pumps	49
Volume displacement	50
Linear peristaltic pump.....	50
Roller peristaltic	51
Feeding Pumps	51
PCA Pump.....	51
Syringe Pump	51
Dialysis	52
Hemodialysis	52
Peritoneal Dialysis.....	52
Refractometer	53
REVIEW QUESTIONS	53
LABORATORY EQUIPMENT.....	55
The Basic Functions	55
Sample prep.....	55
Detector	55
Processor	55
Flush	56
Display/printer.....	56
System Connector.....	56
Self-check/calibration.....	56
External power conditioner or UPS.....	56
Blood Gas/pH Analyzer.....	56
Common Problems	57
Bilirubinometer.....	57
Common problems	57
Clinical Chemistry Analyzer	58
Common Problems	58
Centrifuge	59
Rotation Speed	59
Timer	60

Biomed Certification Study Guide
By Dave Harrington

Brushes	60
Braking system	60
Cover interlock	60
Gaskets	60
Feet/casters	61
Common problems	61
Cell Washer	61
Common Problems	61
Coagulation Analyzers	61
Clot timer.....	61
Automatic Coagulation Analyzers.....	62
Common problems	62
Hematology analyzer.....	62
Cell counter	62
Common problems	63
Automated Systems	63
Histology Devices	64
Tissue Processor	64
Microtomes.....	64
Slide Strainer	65
Microscopes.....	66
Incubators	66
Laboratory Ovens	67
Bench Top Devices.....	67
Common Problems, all devices	68
REVIEW QUESTIONS	69
INTRODUCTION TO IMAGING DEVICES	70
Background Information.....	70
X-Ray Generation.....	70
General Radiation.....	71
Characteristic Radiation	71
X-Ray Tube and Housing	71
Collimators, Filters and Grids	72
Film and Film Cassettes	74
Power Supply	74
Fluoroscope	75
The video chain	76
The Table.....	76
The over head tube	77
The Console.....	77
Processors, Multiloaders and Dry Imaging.....	78
Dark Room Films	78
Day Light Films.....	78
Film Processor.....	79
Specialty units, Mammo, Tomo, Bone Density and Interventional Radiology	80
Mammo	80
Tomo	81
Bone Density	81
Interventional Radiology or Special Procedures Rooms	81
Cysto Room	82
Portable C-Arm	82
Management of Imaging Devices	82
REVIEW QUESTIONS	83
TROUBLESHOOTING MEDICAL EQUIPMENT	85
Before you start.	85
Rules of engagement	85

Biomed Certification Study Guide
By Dave Harrington

Rule 1	Look at the device/procedure/process	85
Rule 2	Listen, Listen, Listen	86
Rule 3	Smell	86
Rule 4	The application of the device/process/procedure	87
Rule 5	Is there power to the device? The most common problem.	87
Rule 6	Is there an input to the device? A common failure point.	88
Rule 7	Is the processor working? A rare failure point.	88
Rule 8	The output	89
Rule 9	Memory or Program	89
MEDICAL EQUIPMENT FUNCTION AND OPERATION		90
1	Test Equipment	90
2	ECG both monitors and recorders	90
3	EEG	91
4	Blood Pressure measurement, direct and indirect.....	91
	Systemic arterial	91
	Pulmonary artery	91
	Pulmonary capillary.....	91
	Right atrial or central venous.....	91
	Right ventricle	91
	Left ventricle	91
	Points to remember	91
	Indirect, Automatic	92
5	Pulse Oximeters.....	92
6	Infusion Devices.....	93
7	Defibrillator, external	93
8	Fetal Monitors	94
9	Hypo-Hyperthermia Units	94
10	Infant Incubators, Warmers and Billi lights	94
11	Nerve and muscle stimulators	95
12	Dialysis.....	95
13	Electrosurgical Generator (ESU).....	95
14	Anesthesia Machines	96
15	Ventilators	96
16	Intra-Aortic Balloon Pump	97
17	Centrifuge.....	97
18	Sterilizers.....	97
19	Lasers	98
20	Ultrasound	99
21	Capnograph	99
BMET TEST CODES, STANDARDS AND SAFETY		101
REVIEW QUESTIONS		110

PREFACE

Dave Harrington compiled this biomed study guide for classes in the Northeast, using some of the material for his ICC prep column in 24 X 7. He offered it to the California Medical Instrumentation Association (CMIA) for posting on their web site, cmia.org, to assist those studying for the certification exams.

Dave Harrington has been involved with medical instrumentation since 1964, right after he blew out his knee playing hockey. First he was doing design work on IV and ventilator products and some physiological recording systems that was followed by time as a product manager and then sales of medical devices before going to the Tufts New England Medical Center for close to 20 years. While there he was the instructor on Biomedical Technology at the Franklin Institute in Boston, for over 17 years, and also presented courses at Wentworth Institute, Tufts, MIT and various community colleges in the New England area. After retiring from Tufts he managed a program that sent devices and provided training to medical personnel around the world. Harrington has done projects in over 50 countries around the world. After a 10 year stint at Technology in Medicine, he retired again to concentrate on international development work. He has over 90 publications, many in 24 X 7 where he wrote the ICC prep series for about 5 years and over 100 presentations to biomedical meetings around the world.

ELECTRICAL SAFETY

Electrical safety testing is one of the most common procedures that are done by a Biomed. Every patient related device must be tested for electrical safety before it is initially put into use and on some basis after that, it could be at regularly scheduled intervals or just after repairs. All electrical/electronic devices have a current leakage ranging from a few micro amps, (millionths of an amp) up to 0.50 amp. Various agencies have set current limits for electrical leakage currents in medical devices. Not all agencies have the same limits. The National Fire Protection Agency, NFPA, AAMI, (Association for the Advancement of Medical Instrumentation), or IEC, (International Electrical Commission) are some of the many agencies setting safe current limits for electrically operated medical devices.

In the late 1960's and early 70's there were several publications stating that up to 10,000 people per year were electrocuted in hospitals because of defective electronic equipment that was applied to patients. In various studies it has been shown that as little as 3 micro amps applied directly to a portion of the heart during a critical part of the cardiac cycle can cause an arrhythmia, (an abnormal beat). If this abnormal beat triggers additional abnormal beats a potential for a lethal arrhythmia is present.

Over the years many techniques have been developed to limit the "risk current" that a patient is exposed to. They ranged from shortening the power cords; there is 1 micro amp of leakage per foot of cord, to isolation transformers so the device was not grounded, diodes, chokes and all sorts of other "fixes". In the early 1970's it became evident that none of these "fixes" really worked so the designers started to isolate the patient from the device. This was done by using isolation transformers, light emitting diodes or infra-red links between the patient connections, (leads), and the device. These techniques are still in use. There should be no non-isolated input devices left in a modern hospital as that design technique was dropped by 1975.

Almost everyone has received an electrical shock at some point in their life. Working with 115 volts at 60 Hertz you can feel a tingle at 1 milliamp, (one thousandth of an amp). At 15 to 16 milliamps you may not be able to let go of the contact, at 50 milliamps there is pain and muscle contraction and from 100 ma to 3 amps ventricular fibrillation can occur. Above the 3 amp level serious burns and death can occur. One benefit of working with DC voltage is that fibrillation is very uncommon however burns can happen quickly. Electrical safety covers from the 3 micro amps up. Particular concern is the range from 10 to 500 micro amps, which can cause major problems to a sick or injured patient. As with most other hazards the skin is the first line of defense for electrical hazards. If there is a direct conductive path to the heart, remember blood is conductive, a patient is at risk from any device that may be connect to them or one that that be touched by a care provider and the patient at the same time.

What is considered "the patient vicinity" or area? There are as many definitions as there are people writing about electrical safety in hospitals. A common definition is "any device that is attached to the patient via lead wires or can be touched by a care giver while touching the patient is considered in the patient vicinity", this is generally considered as 6 feet. Everything else is considered as general hospital equipment. Many portable devices are brought into the patient vicinity and must be tested as "patient vicinity" and should not be considered as general hospital equipment.

Electrical Safety Testing

There are various methods of performing electrical safety tests, ranging from a DVM with a test load to a specially designed test instrument. The safety analyzer can either be an automatic or manual unit. The automatic units are programmed to perform all the measurements and indicate test results that are over the limits established by the user. The manual units require the person doing the testing to switch from grounded to ungrounded, read the results and interrupt each reading as to be in compliance with the standard being used. Reverse polarity tests should not be done as they can damage equipment.

General Equipment

Equipment found through out the hospital or clinic that is not directly connected to patients, it includes both medical and non-medical devices. In some facilities non-medical devices are only tested when they are purchased and after major repairs. In other facilities they may be part of the continuing PM testing program. There is not national standard for safety testing on an ongoing basis after the incoming inspection. There are suggestions but no legally binding rules.

Computer or Microprocessor Controlled Devices

The majority of these devices are in Clinical Laboratory or Specialty Testing areas of the hospital. These units are only tested for electrical safety before installation and after major repairs. If power is disconnected from this type of a device it may take several hours to get them back on line. This is why they are not tested for leakage during the normal cycle of inspections. Ground checks should be done.

Patient Connected Devices, Diagnostic

These devices amplify and process signals detected in the body by electrodes. The signals travel over the lead wires and patient cables to the device where they are amplified, processed and displayed. The key points on this type of a device is that it detects a signal and has wires between the patient and the device. This category of equipment contains such devices as EKG, EEG, EMG recorders and patient monitors. In the case of patient monitors there may be several “plug in modules” that make up the total device. A patient monitor is tested as one device as there is only one power cord. The lead wires of the various modules are tested to the power cord ground.

- 1 Disconnect the device from the wall power **AND** from any other connection to other products or the central station. Perform the normal cleaning and visual inspection steps including the power cord and cap plus any missing or loose hardware. Correct as needed.
- 2 Plug the device into the safety tester, and attach patient leads to the correct terminals of the safety tester. If the safety tester does not have lead contacts consult with your supervisor for how to test the lead leakage. Test the ground resistance; perform the power off leakage tests, including leads in the grounded and ungrounded modes. Return to the grounded mode power the unit up, allow it to perform its self-diagnostic tests and perform the power on tests both in the grounded and ungrounded modes. Any failures must be repaired and documented before returning the device to use. If the device passes all modules contained in that device are deemed to have passed.
- 3 If the device has a power conditioner or isolation transformer attached, they should be tested as one device.
- 4 When returning the device to use reconnect any data or interface cables that were disconnected from the device before the testing started.

Patient Connected Devices, Therapeutic

These devices deliver energy, fluids or gases to a patient. The delivery can last for a few milliseconds, as with a defibrillator to years for a ventilator or IV pump. In the case of an IV pump the fluids are contained in a non-conductive plastic so any electrical contact requires that there be a hole in the tubing. On ventilators the tubing is non-conductive, as are most of the gas mixtures that would be administered. Because energy is delivered to the patient it is not required to test the lead isolation while the unit is delivering that energy, it could also be dangerous to test.

The same testing procedures as with diagnostic devices is followed except that lead leakage is only tested in the power off condition, with and without ground. Devices such as diathermy units, ultrasound therapy and stimulators fall into this category and may have special units for testing their outputs, check with your supervisor on availability of this special test equipment.

Devices in the Patient Vicinity

These are generally portable devices. The common definition of "Patient Vicinity" is anything in an area that a clinical person can touch and still maintains contact with the patient. This is generally 5 to 6 feet around the patient. These devices do not have direct patient contact, via leads or probes. On these devices the ground is very important as it reduces or eliminates any leakage on the chassis. Included in this category are portable X-Ray units, C-Arms, Diagnostic Ultrasound and other specialty testing devices.

Electrical Safety on Permanently Wired Equipment or Over 115 Volts

These devices are generally found in clinical laboratories, central processing and radiology. If the device is powered by 115 volts, it is tested for leakage at the time of installation. Once it is installed only ground testing is done during the inspection cycle.

For devices powered by over 115 volts there is no method of performing true electrical leakage unless there is a special meter available. In addition some devices will use 3-phase power. Ground testing becomes very important in these areas. One technique that is commonly used is to select one ground point in the area and measure the ground resistance of all exposed surfaces to that point. The problem with this method is that one lead wire may have to be as long as 20 feet to reach all surfaces in that area. A variation of this technique is to select a point, such as the x-ray table as the ground and measure everything in the "patient vicinity" to that ground point. With either technique the ground resistance should not exceed 0.5 ohms.

A key point to remember in performing this type of ground resistance testing is to select your starting point and document it so that the test can be repeated. A small dab of nail polish next to the ground point is one method of documenting where the ground point is. While it may be very difficult to control because of outside vendors doing some of the repairs or PM's, but the grounds should be verified after every major repair or vendor provided PM.

Personal Safety

While working in healthcare facilities you will be exposed to a number of hazards that can affect your health. There are the normal exposures that you have in any type of work, slips, falls, strains and fire. In healthcare you can be exposed to infectious agents, both viral and bacterial, in body fluids, both by direct contact or airborne, tissue and even smoke from laser surgery. These exposures can be limited by following the Universal Precautions procedures that are in place. Be aware of your surroundings at all times, you do not need to beware of your surroundings.

A good rule to follow is **WASH YOUR HANDS BEFORE AND AFTER ANY PATIENT CONTACT, EITHER DIRECTLY OR INDIRECTLY.** Another good rule is to look at and around the door leading into a patient's room or an area that patients are treated or where research is being conducted on tissue or body fluids for warnings. These warning could be as simple as colored diamond shaped signs, divided in quarters indicating the hazards present. It could simply be the symbol for biological hazards or radiation. It could also indicate that the patient in the room is under "precautions" and may have another word like reverse, respiratory, enteric. When you observe such a sign do not enter the area without checking with the person in charge. You may be required to put on protective garments, gown, hat, gloves, mask and eye protection before entering the area. When the area touch as little as possible, be very careful as you move around to avoid hitting anything or causing any spills. **No devices or attachments, tubing etc. should be removed from the area without first being decontaminated.** If tools or test equipment are brought into a restricted area they also must be decontaminated **before** leaving the area.

Always follow the hospital's policies on Universal Precautions, plus all other policies and procedures relating to blood borne pathogens.

In most healthcare settings radioactive material is under close supervision and presents little problem to the Biomed. Occasionally a patient with a radioactive implant will be connected to other devices that may require your expertise. Again follow the posted procedures on that patient's room door. If in doubt ask questions. Never assume that it is safe to enter.

Biomed Certification Study Guide
By Dave Harrington

REVIEW QUESTIONS

- 1 According to ANSI standards what is the high frequency cut off for electrical leakage tests
 - A 60 Hz
 - B 100 Hz
 - C 1,000 Hz
 - D 10,000 Hz

- 2 What is the maximum resistance allowed between the chassis of a device and ground pin of its power cord?
 - A 0.5 Ω
 - B 0.05 Ω
 - C 0.01 Ω
 - D 0.10 Ω

- 3 What is the current level consider the “let go” point?
 - A 15mA
 - B 150mA
 - C 1.5mA
 - D 15 μ A

- 4 If a portable device is defective and you cannot fix it right away what should you do?
 - A Tape a sign “Broken” on the device
 - B Use the hospital “lock-out-tag out” procedure
 - C Remove it from the area
 - D B and C

- 5 What are the U.S. power cord colors for hot, neutral and ground?
 - Black is Hot
 - White is Neutral
 - Green is ground

For international power cords brown is hot, blue is neutral and green/yellow is ground.

When wiring plugs or out outlets the hot wire goes to the “gold” post.

- 6 The latest US electrical code requires Isolated Power Supplies in which area?
 - A The ICU
 - B Clinical Labs
 - C Operating rooms with no explosive agents allowed
 - D None of the above.

INTRODUCTION TO CARDIAC DEVICES

In this section both the physiological and electronic aspects of devices used to diagnose, monitor or treat cardiac events are discussed.

In most humans the heart is located slightly to the left of the chest's midline. It is a hollow muscle that is divided into 4 parts. The first division is right to left. A thick muscle called the septum separates the sides of the heart. In the muscles are bundles of nerves that conduct impulses and tissue that acts as a pacemaker regulating the contraction of the heart. Each half is further divided into top and bottom sections. To further confuse you there are 3 layers of tissue that make up the heart. Each chamber has a thin lining called the endocardium, the muscle is called the myocardium and the sac surrounding the heart is called the pericardium.

The heart's pumping action

Blood enters the relaxed top chambers, (atrium), of the heart from the superior and inferior vena cava veins on the right and pulmonary vein for the left side. This is called the diastole phase. When the chamber fills the SA, (sinoatrial), node located at the top of the right atrium sends an impulse for the upper parts heart to start to contract. The lower part, ventricles, of the heart is relaxed. On the right side blood is forced through the Tricuspid valve into the right ventricle and on the left side through the Mitral valve into the left ventricle. At this point the AV, (atrioventricular), node, located at the bottom of the right atrium sends its signal down the Bundle of His and into the Purkinje fibers which causes the ventricles to contract, this is called the systole phase. The Tricuspid and Mitral valves close, preventing backflow into the atrium, the Pulmonary and Aortic valves open which allows the blood from the right ventricle to move to the lungs and from the left ventricle to the rest of the body. At the end of the contraction the ventricular valves close and diastole starts again. This is called a normal sinus rhythm. Any contraction that does not follow this sequence is called an arrhythmia. There is more information on the electrical activity of the heart in the suggested readings that are part of this module.

An ectopic beat occurs when the SA node is not functioning or some other part of the heart tissue assumes the role as a pacemaker. A multifocal beat is when both the SA and AV nodes are not properly working and contractions originate elsewhere in the heart. See the section of the readings covering arrhythmias.

Structural faults in the heart can cause the mixing of oxygenated and non-oxygenated blood. These defects are generally holes in the septum that did not close after birth. Many babies will have this type of a defect and it self corrects after a few days. Sometimes these holes can be patch using special catheters without the patient going through an open heart procedure.

Basic hemodynamics in the heart

The blood pressure in the right atrium is the lowest of all the chambers and is generally the same as the central venous pressure, (CVP), of the patient, 2 to 10 mmHg is the common range, some sources say 0 to 8 and this is a mean pressure. (Mean pressure is 0.707 of the highest pressure; think of it like an RMS Voltage). The right ventricle pressures during contraction, (Systolic) ranges between 15 and 30 and at end diastolic, (at rest) it is the same as the right atrium. The left atrium pressure ranges between 5 and 12 mmHg but is almost never directly measured in a clinical setting. The left ventricle systolic pressures range between 90 and 140 while the end diastolic is 5 to 12 all in mmHg.

While not part of the heart the pressure in the pulmonary artery is of clinical importance and is often monitored. Typical pressures in the pulmonary artery are systolic 15 to 30, diastolic 4 to 12 and mean 9 to 16 again all in mmHg. Also measured is the pulmonary capillary wedge pressure, which is a mean pressure and ranges from 1 to 10 mmHg. When monitoring the pulmonary artery pressures it is possible to get a negative blood pressure if the catheter is not correctly placed, too far down the artery. What happens as the patient inspires they create a vacuum at the catheter tip, which will show up as a negative pressure on some monitors. The key troubleshooting point on this is that the negative blood pressure only shows up at the same frequency that the patient is breathing. Some monitors will not show a negative pressure but will flat line at the zero pressure point. It is extremely rare that the computed reading (numeric display of systolic,

Biomed Certification Study Guide
By Dave Harrington

diastolic and mean pressures) will show a negative number as they are averaged over 3 to 5 contractions. The clinical staff may complain about low numbers, but the key is to look at the waveform for negative going or cut off at the zero line on the screen. If this is present the catheter is too far into the pulmonary artery. Also remember that the pulmonary artery contains venous blood while the pulmonary vein has oxygenated or arterial blood.

Problems with valves in the heart are generally found via listening with a stethoscope or by the use of ultrasound scans. If the valves do not properly close blood will regurgitate between chambers. The cardiac valves can thicken from various illnesses and some drugs, both legal and otherwise can affect them. The common term for thickening or narrowing of valves is stenosis. Sometimes the term prolapse is used for valves not totally closing properly.

Take time to review and learn the common medical terminology that is included in the reading material

ECG amplifiers

An ECG amplifier, (EKG is a German term that is widely used), is a multi-input amplifier, from 3 to 12 inputs. Each input is for an electrode placed on the skin to detect the electrical activity of the heart. One of the electrodes will act as the signal ground reference point, (usually the right leg electrode). A patient monitor will use 3 or 5 electrode inputs, while an ECG recorder will use 5, 10 or 12 inputs. Not many units will use the 12 inputs as these extra 2 inputs are for electrodes placed on the patient's back and are called Frank leads. Terminology can get confusing between inputs, which have leads, and data outputs, which are also, called leads. Also there are limb leads and modified limb leads. Limb leads have the electrodes placed on the limbs, typically wrists and just above the ankles, used on ECG recorders. Modified limb leads have the electrodes placed on the shoulders and just above the patient's waist, used for monitoring in an ICU setting. To further confuse you there are augmented leads, resistors are switched into the inputs of 2 limbs and the resulting voltage is amplified. See figure 5 of Electrocardiography part 2 in suggested readings for this module.

Isolation

All inputs are isolated from the power supply of the amplifier by an isolation transformer. This prevents any power supply fault from putting voltage on the electrodes and potentially giving an electrical shock to the patient. Also each input has a diode, resistor or spark gap circuit that will short any high voltage/high current pulses to ground so the amplifier is not damaged. These pulses come from defibrillators and electrosurgical devices. The input impedance of an ECG amplifier is sometimes listed as db, ohms or CMRR. Typical numbers are 100 megohm and -66db for the input impedance.

Switches

Amplifiers, both those used for monitoring and recorders, have a switching mechanism that selects the waveform, (lead) to be displayed. The switch may be rotary, pushbutton or flat panel. On some recorders there is an automatic button, which switches the output through all 5, 12 or 14 leads depending upon the mode. On some units there is a calibrate position on the switch which has to be selected if the 1 mV signal is to be displayed. The 1 mV calibration signal is used to confirm the gain of the amplifier and is a good way to do a quick check to see if the amplifier is properly functioning. If the output shows the 1 mV signal the amplifier is working. This signal can also be used to check the communications between a bedside and central monitor in an ICU without connecting a simulator to the amplifier.

Gain

The standard gain of an ECG amplifier is 1,000. The typical ECG input signal is 1mV, which means that the output is 1 volt, which translates to a 1cm deflection on the screen or chart. Remember that this is ideal and very few conditions in a human body are ideal. The amplifier may have an automatic gain control circuit to assure that 1 mV becomes 1CM. There may be a switch where the gain can be selected. The switch will generally have settings of 0.25, (gain of 250), 0.5, (gain of 500), 1.0, (gain of 1,000 Standard) 3.0, (gain of 3,000) and 5.0(gain of 5,000).

Biomed Certification Study Guide
By Dave Harrington

As with any amplifier saturation can become a problem, even at the lowest gain setting. This is common when the patient is small and with a very strong heart, neonates can fall into this category as can thin athletic adults. A distorted waveform, usually with some peaks or valleys flat lined, (clipped off).

There also can be a voltage offset caused by the electrodes placed on the patient. This offset voltage can move the base line up or down and can cause saturation of the amplifier. To correct the problem the electrode with the high offset voltage has to be located and repositioned or replaced. Offset voltages normally occur but generally, with modern electrodes are minimal. Basically the electrode is acting like a battery. Stainless steel electrodes have high offset voltages and should be avoided.

Frequency response

ECG amplifiers have two frequency responses that are selectable, monitor and diagnostic. The monitor frequency response is for long-term observation of the patient's ECG, as in an ICU setting, and is 0.5 to 35 Hz. This number may vary between manufacturers up to as high as 50 Hz. The monitor frequency response is for observation not diagnosing a patient's cardiac activity. The diagnostic frequency response is from 0.1 to 100 Hz with a notch filter to not pass frequencies of 50 and 60 Hz. The notch filter prevents noise from the power lines from being amplified and possibly distorting the waveform. The diagnostic frequency response is used on recorders but will sometimes be included in an ICU monitor.

The upper number in the frequency response (35 or 100) is also called the 3db point of an amplifier. Simply the 3db point is the frequency at which the gain of an amplifier is reduced by half. (In a stereo system the 3db point is generally 20,000 Hz).

Electrodes

Electrodes are placed on or in the patient to detect the electrical voltages generated by the heart as it goes through a cardiac cycle. These electrodes range from short to long-term duration in contact with the patient. Problems can occur when the wrong electrodes are used for the particular application. The type of metal or conductive material used in an electrode can react with certain patients and create noise or offset voltage problems.

Types of electrodes

Monitoring electrodes are single use items with a central column of conductive material surrounded by a plastic foam or paper tape disc or square to hold the conductive column in place. At the top of the conductive column is a snap that the lead wire is attached to, that goes to the patient cable that goes to the amplifier. These electrodes cost between \$0.05 and \$0.11 each. If the conductive column has dried out the trace from that electrode will be noisy and has to be replaced.

ECG recording

Single use recording electrodes come in 2 styles, one similar to the monitoring electrode with conductive gel center and the other with conductive adhesive. Connection to the conductive adhesive electrode is done with an alligator clip between the silver-plated backing that the adhesive is placed on and the input cable. Not all clips are the same between manufacturers and sometimes they will get mixed causing a bad connection. On patients that are sweaty these conductive adhesive electrodes may not stick well causing noise.

Multi use recording electrodes come in several styles. The most common is the plate electrode that is held on to the patient with a rubber belt. Between the electrode and the patient's skin a conductive gel is placed to assure good electrical contact. A common problem is that the wrong gel is used, the ultrasound gel which is an acoustic coupler not an electrical coupler. You can test the gel by putting a small amount on your finger and rub the finger, if you feel grit it is an electric coupler if not it is acoustic. In some institutions a saline soaked gauze pad is used instead of the gel, it works but only for a short time. Plate electrodes will corrode over time and dried gel will build up on the surface making the contact impedance increase which makes the trace noisier. If plate electrodes are in use they should be checked and cleaned on every PM inspection that is done to the machine. The connection between the electrode and the patient cable is usually a slip fit of a solid banana pin at the electrode, again subject to corrosion.

Biomed Certification Study Guide
By Dave Harrington

The other common multi use electrode is called the “Welch cup”. This is a cup shaped silver-coated electrode with a suction bulb on the top of it. These are used for obtaining the chest or “V”, leads. Corrosion is a common problem as is the lack of suction as the suction bulb ages. It is not unusual to find the suction bulb full of conductive gel and fungus has been known to grow in the bulbs. The connection to the patient cable is made via a screw clamping onto the solid banana pin at the end of the patient cable.

The positioning or placement of the electrodes on the patient is a critical step, if not properly done it can compromise the quality of the diagnostic information obtained, which often results in the clinician think that the equipment has malfunctioned. Points to remember

- * Electrodes should not be place on scar tissue
- * Electrodes should not be placed over a lot of body hair; it not only affects the information but it hurts when the electrodes are removed.
- * Follow the manufacturer's guidelines for electrode placements.
- * Electrodes placed closer than 2 inches from each other may start “cross talk”
- * If more than one devices requires that electrodes be placed on the patient there will be problems, the best solution is to have each device in a different lead selection position, Such as Leads I, II, and III. The clinical need for all the electrodes should be challenged, in a diplomatic fashion, by explaining that there probably will be cross talk between the devices that could affect the clinical outcome of the procedure.

After the electrode the weakness link in an ECG system is the lead wire, connection between the electrode and patient cable. While this is a multi-use wire the grip system to the electrode can be loose or corroded, which introduces noise into the system. Sometimes the connection to the patient cable is also effected. If a lead wire is found defective it should be discarded, **but first pull off one end so it will not be used again.**

The patient cable should last for many years. They often look to be in poor condition because of tape residue on the cable. This residue can be removed using alcohol or other solvents. The end of the patient cable that the lead wires connect will sometimes contain a 10K resistor in series with the lead. If this occurs it must be on all connections in that cable. Some cables designed for the operating room may have a choke in series, or to ground with the lead wire to reduce the effect of electrosurgical events. It should be noted that there is a US and International Standard for the amplifier connector of the ECG cable, it is a 6-pin connector. Unfortunately many manufacturers have seen fit not to follow the standard so there may be many different connections to ECG amplifiers in a hospital. This can cause confusion with the clinical staff and create some very unusual efforts to make those connections.

Waveform Display Methods

There are two general methods of displaying the ECG waveforms, electronically or on paper. In certain applications the waveforms may be stored on tape or in RAM for later display, (Holter Monitoring). The storage systems will be discussed in later sections.

Electronic Display

The most common form of electronic display is on a CRT. The size of the display and the type of phosphor used in the manufacture of the CRT can enter into the quality of the waveform. The presentation of the ECG trace should be in the same format as a paper/chart presentation with the newest data closest to the left edge of the display, often called a moving or solid trace display. Some manufactures use an ERASE BAR presentation, sometimes called a stationary trace. In this presentation the waveform is stationary and a blank space, or bar, moves across the CRT with the newest data being to the left of the space/bar.

In some older displays the trace is not continuous but only last as long as the phosphor glows after excitation. This is called a “bouncing ball” display.

The phosphorus will slowly burn off the CRT over years and the trace will dim. To prevent this the traces should be repositioned on the CRT at least once per year. It is not uncommon for a CRT to last for many years. Unless damage either physically or internally the CRT rarely has to be replaced.

Biomed Certification Study Guide
By Dave Harrington

In addition to the standard CRT display manufacturers are now using liquid crystal and capacitance displays that present data like a CRT does but are only a CM or less thick. These displays have life expectancies of 5 to 7 years and getting longer each year. In 10 years these displays will probably replace the CRT in most medical devices.

All of the electronic presentation methods can be setup for TOUCH SCREEN applications. In a Touch Screen the perimeter of the display has LED's, (light emitting diodes) which when the beam is interrupted a command is sent to the microprocessor. This system is not part of the CRT or other type of display but a separate component that may have a higher failure rate. If one of the diodes is blocked it will affect the display in some manner which will prompt a service call. It is usually resolved by removing the blockage, generally tape or a "Post-it Note". In rare cases dust will affect the action of the Touch Screen.

The other common method of waveform presentation is the Hard Copy. This is paper based with the size and shape of the paper varying between manufacturers. There are four general types of paper used for waveform presentation, ink, clay, wax and chemical/thermal. Each has specific benefits and problems.

INK Paper

These papers have a shiny surface, with grid lines pre-printed. They can be single sheet or continuous strip, roll or z-fold, or a continuous strip that can do a single sheet. In most cases there are a multi channels of waveform presented with one or more ECG lead configurations per channel. The marking of the leads is done with alpha characters or dots and dashes. If the stylus is not properly maintained their can be blotching or smudging on the waveforms. **WILL NOT WORK WITH HOT STYLUS OR PRINT HEAD PRESENTATIONS.**

CLAY paper

This paper, for hot stylus recordings, is very rarely used as the wax and chemical papers have replaced it. You will only see this paper on old units. This paper has grit on its surface and will wear the stylus point/edge over years causing a wide trace and poor readability of the information. This paper only comes in rolls for continuous strip recording. This paper has pre-printed grid lines. Leads are marked with a series of dots and dashes along the top edge of the paper. **MUST NOT BE USED WITH PRINT HEAD PRESENTATION METHODS.**

WAX paper

This paper, for hot stylus recordings, is not common but is still in used in some locations. One this paper the stylus heat and pressure most affects the clarity and quality of the trace. The paper has pre-printed grid lines and only comes mostly in rolls but in certain applications may come in z-fold. Leads are marked as on the CLAY paper. **MUST NOT BE USED WITH PRINT HEAD PRESENTATION METHODS.**

Chemical - Thermal

This is the most common paper; it comes in roll and z-fold. Its distinguishing feature, in most cases, is no grid lines. This looks like thermal fax paper, which it basically is. This is the only paper that should be used with PRINT HEAD systems. If the paper has grid lines it can be used with in place of CLAY and WAX papers.

These papers come in varying widths and varying number of channels. Unfortunately single channel papers can vary in width. Paper that fits H-P may not fit in Spacelabs or Marquette etc. If the paper is too wide it will not fit into the holder, if too narrow will probably not track correctly and data will be lost. It is not uncommon to find wrong paper in units. The "standard" channel width is 50mm, for ECG and Pressure recordings. Other parameters may be greater or less which makes keeping track of the correct paper for recorders a problem for everyone. **GENERAL TROUBLESHOOTING TIP** look at the paper first on any recorder problem.

The chart speeds on most recorders and electronic displays are 25 and 50 mm/sec. Some may have additional speeds. When the chart speed is 25 mm/sec each mm on the horizontal axis is 0.04 seconds.

Biomed Certification Study Guide
By Dave Harrington

The baseline of the ECG trace should be on the centerline of the channel, 25 mm up from the bottom of the channel. With a pressure trace the bottom line of the channel should be 0 mm Hg, the top line of the channel should be the range selected for the pressure waveform, 10, 150 or 300 in most cases.

With either presentation method a key troubleshooting tool is the 1mV calibration button. This signal is used to calibrate the ECG waveform for amplitude or gain. With standard gain (1000 or 1 on the selector switch) the pulse should be 1cm in height. If not you need to look at the gain, is it set on the standard, is the unit properly amplifying the signal or is the waveform damped. On some units the lead selector switch must be in the calibrate setting but on most the 1mv signal can be injected on any switch selection. If the waveform is damped, especially on paper presentations you should check the stylus pressure to the paper. If it is too great it will dampen the waveform. If the stylus pressure is too light there could be an overshoot on the leading edge and missing information on the ECG traces. This is not a problem with print head systems.

In an ICU system the 1mv signal can be used to assure that the bedside units are communicating with the central station. Simply push the 1mv calibration button several times at the bedside, observe the bedside trace presentation if the waveform is not present there the unit is not working properly and needs to be troubleshot. If the cal pulses appear on the bedside but not at the central display there is a communication problem. If the waveform is present at both locations the system wiring is correct. Note the calibration pulse should also appear on the recorder at the central station.

Recorder Presentation

As previously covered there are various methods of recording waveforms on to paper. One of the older methods is the heated stylus. Here as the paper is moved over a platen point, the stylus, which is deflected with both positive and negative pulses, burns the top surface of the paper leaving the waveform. As covered before the pressure of the stylus to the paper can affect the width of the trace and its frequency response. If too much heat is used the trace will also be widened.

With inks system the stylus is longer and touches a flat surface. The ink is carried via small-bore tubing from a central supply to the stylus. These tubes sometimes become blocked and can be cleaned by removing and flushing them with alcohol. This is a messy process and care should be taken to protect clothing. The tips of the stylus, (pens), may also pick up lint and bits of paper that will widen the trace, these should be clean off the tip using a lint free cloth or paper. The tip may wear in an uneven manor and require re-flattening, commonly referred to as lapping. This is done using a very fine piece of emery paper and lightly running the tip over the paper. One favorite way of doing this is to put the emery cloth under the tip, hold it in place while moving the position control so the stylus moves across the emery cloth. Only 2 to 3 swings across the cloth are generally needed to flatten the tip.

Ink cartridge systems have a specifically shaped "felt tip marker" instead of a heated stylus or ink reservoir. These systems have the potential of drying out and not making full traces. The system is used for both stationary paper, (x-y plotter) and continuous roll paper. The system has a lower frequency response and may lose some clinical data because of that lower frequency response. Spare cartridges should be with the unit as the user can replace them easily. With age the writing tip may widen and should be replaced.

The print head system is the newest and will be found on the majority of devices in use. These units require a special paper, described above, and care must be taken to assure that wax and clay paper is not used with these units. From time to time segments on the print head may become dirty and require cleaning. This can be done with alcohol preps. Just expose the print head side closest to the paper and clean by rubbing the surface, gently with the alcohol prep. Let the area fully dry before testing. The trace should be of uniform darkness across the complex.

Blood Pressure

The measurement of blood pressure has been commonly used for over a century and is often misunderstood. The non-invasive measurement of blood pressure is accomplished by occluding an artery, in the upper arm, with an inflatable cuff that is connected to a mercury manometer. With the use of a stethoscope to listen for the Korotkoff sounds of blood flow, as the cuff is deflated pressure measurements are obtained. The first sound heard is the systolic pressure and the last sound heard is the diastolic pressure. The ideal pressure is 120 mmHg systolic and 80 diastolic. Systolic pressures above 150 or diastolic pressures above 100 are of clinical concern. The difference between the systolic and diastolic pressures is called the pulse pressure. This generally runs between 40 and 50 mmHg. The mean pressure can be computed multiplying the systolic pressure by 0.707. An estimated means pressure can be obtained by adding one third of the pulse pressure to the diastolic pressure.

Mercury Manometers

A plastic or glass column with graduations from 0 to 300 mmHg is connected to the cuff via latex or rubber tubing. To get accurate reading the tube must be exactly vertical. At the top of the tube, under the cap is a calfskin diaphragm that allows air to move in both directions. If this diaphragm is dirty the mercury in the column will not move smoothly, either up or down.

MERCURY IS A HAZARDOUS MATERIAL and must be handled with care. It never should be used on children, as mercury vapors are toxic to developing nervous systems.

MERCURY MANOMETERS SHOULD BE REPLACED IN HOSPITALS AND CLINICS AS SOON AS FUNDS ARE AVAILABLE

The EPA has set 2005 for all mercury being out of hospitals.

Aneroid Manometer

This is a bellows based system that has a dial calibrated in the range of 0 to 300 mmHg. At the resting point of the needle on the dial is a rectangular box. If the needle is in that box the manometer is calibrated and can be used. The use is the same as with mercury except the dial does not have to be vertical.

The blood pressure cuff is a problem area. If the cuff is too small there could be an artificially high reading too big could produce a low reading. If the cuff is put on the wrong arm it can produce erroneous readings. It is not unusual to take blood pressures using a thigh cuff. It can be difficult to pick up the sound of blood flow but in some patients it is not possible to use the arms. A thigh pressure reading is also useful in working with patients that have compromised blood flow to the lower extremities.

A new technique is to take the blood pressure in the lower leg, just above the ankle; reports in literature indicate that this pressure is reflective with the Carotid artery pressure leading to the brain.

The cuff should be inspected on a yearly basis to assure accuracy and repeatability in measurements. The following points need to be checked.

Tube to bladder connection	stretch the tube and observe the junction with the bladder looking for cracks and pinholes. If present replace.
Tubing	stretch tubing looking for cracking, if present replace
Fittings	check to be sure that they are tight and proper, stopcocks should not be used.
Total cuff	inflate to 250 mmHg and allow to stand, the pressure should slowly decrease at a rate not exceeding 5 mmHg per minute. If greater there is a leak somewhere in the system
Inflation bulb	Flex bulb looking for cracking at the junction with the bleed valve or vent. If present replace
Bleed valve	when inflated the valve should hold pressure as described in the total cuff section. Also adjust the valve so that the bleed down rate is 3 mmHg per second to test linearity of the valve.

Biomed Certification Study Guide
By Dave Harrington

Also fully inflate the system and open the valve fully, the system should totally deflate in less than 3 seconds.

The inspection process for the blood pressure cuffs is the same for manual and electronic blood pressure measurement systems where a cuff is used. With certain electronic systems the cuff may contain a microphone, which is discussed later.

Electronic Blood Pressure Measurement

There are devices that automatically and electronically measure blood pressure. The in these system electronics replaces a human in the inflation/deflation of the cuff and the listening for or sensing Korotkoff sounds. The results are displayed in digital format on separate displays or on a screen. The units can be programmed to take blood pressures on a set cycle, 1, 5, 15, 30 minutes, trend the data, sound alarms if the results are outside of preset limits all without a clinical person being present.

These devices may be stand alone, combined with other functions such as pulse oximetry and temperature or as a module in a bedside patient monitor. They may use single or two tubes to the blood pressure cuff, and the extension tubing between the device and the cuff may be manufacturer specific so check closely if problem are present. Some devices will have a transducer in the device that will detect small pulsation in the cuff pressure that corresponds to cardiac contractions. Other devices will use a microphone in the cuff that connects to an amplifier in the device to detect cardiac contractions.

RAPID RETAKING OF BLOOD PRESSURES CAN DAMAGE THE VESSELS AND CAN CAUSE INCONSISTANT READINGS. MANY SUGGEST THAT UNLESS IT IS AN EMERGENCY THAT BLOOD PRESSURE NOT BE REPEATED MORE THAN EVERY 5 MINUTES. If you cannot find a problem with a device that was reported to have questionable readings this may be the reason. You should check with the user to see if rapid retaking of blood pressures occurred leading to the questioning of the equipment.

Invasive Blood Pressure Measurement

A catheter is introduced into a vessel, artery or vein, connected to a transducer via a rigid wall plastic tube filled with a saline solution that may or may not have an anti-coagulant drug added. The output from the transducer is amplified and displayed as numbers, waveform or both. Since the skin has been breached the patients first line of defense for both infection and electrical shock have been bypassed. Extreme care must be taken to assure the safety of the patient.

It is rare for a reusable transducer to be used. The single use disposable transducers are now the standard of care.

Transducer commonly mounted on an IV pole next to the patient's bed. It should be at the same level as the catheter in the patient. There is a 2.5 mmHg error for every inch that the transducer is above or below the level of the catheter in the patient.

During the setup process the transducer is vented to air and using the flush solution filled with fluid, removing all air from the system, the vent is closed and the connecting tubing to the patient is next filled with solution, removing all air from that tube. **NOTE THE PATIENT IS NOT CONNECTED AT THIS TIME.**

The transducer vent is again opened and the amplifier is zeroed. Following the manufacturer's procedures. The vent is now closed and the patient connected. If stopcocks are used in the system they all should be in the correct position to allow the flush solution to move from the transducer to the patient. A waveform should appear on the display screen.

Flush Solution The solution is in an IV bag, which is place in either an inflatable pressure bag, which is pumped up to 300 mmHg pressure, or a spring loaded device that maintains the 300

Biomed Certification Study Guide
By Dave Harrington

mmHg pressure in the bag. The tube from the bag is connected to the flush port of the transducer setup and maintains a constant flow of 2 to 5 ml per hour through the transducer to the patient. The solution generally contains an anti-coagulant, such as Heparin, which prevents the tip of the catheter from becoming clotted off.

From time to time extra flush solution will be administered to the patient by pulling the red pigtail or squeezing the flush control on the transducer assembly. This is done to correct any damping that may be occurring on the waveform because of trapped air or just as a preventative measure to remove and clotting at the catheter tip. **FLUSHING MUST NOT BE DONE BY THE BIOMED, ONLY BY A NURSE OR PHYSICIAN.** The reason for this is it is administering a drug, which we are not licensed to do.

Amplifier	Gain of 100 is most common Frequency response 0 to 12 Hz. If the frequency response is too high there will be ringing on the waveform. You may have to adjust the frequency response to get a stable waveform.
Tachycardia	if a patient has a heart rate above 120 there can be ringing on the waveform and this will give an artificially high systolic pressure. This can also happen if the dP/dt of the waveform is very short. These both can generally be corrected by reducing the frequency response of the amplifier. The frequency response is switch selectable on many amplifiers. The other solution is to introduce a small air bubble into the transducer. Once the patient's heart rate returns to normal ranges the ringing usually disappears.
Pressure ranges	arterial 30 to 250 Venous 2 to 50 Central venous 1 to 20 (CVP) Pulmonary artery 4 to 30 (PAP) Wedge 2 to 15 Intracranial 2 to 15

ON INTRACRANIAL PRESSURE MEASUREMENTS NO FLUSH SYSTEM SHOULD BE CONNECTED TO THE TRANSDUCER. IF CONNECTED IT CAN KILL.

In monitoring intracranial pressures (ICP) slight changes, 2 or 3 mmHg in pressures can lead to permanent brain damage so the mechanical zeroing of the transducer is very important.

Pressure conversions	50 mmHg to 1psig 17 mmH ₂ O to 1 mmHg
----------------------	---

Cardiac Output Measurement

The measurement of cardiac output is done on critically ill patients in an ICU setting. The system used is called thermal dilution. This is an invasive procedure where a long multi lumen catheter that is directed through both right chambers of the heart into the pulmonary artery. One lumen has an opening in the right ventricle and the tip of the catheter has a thermistor in it. The clinician will inject a bolus of saline, 3 to 10 mL into the lumen that empties into the right ventricle, this saline can be either chilled or room temperature on the next cardiac contraction this solution is forced past the thermistor changing its resistance. This resistance change is converted into a flow measurement. This measurement correlates with the output of the heart in volume. If the device is designed for chilled injectate and room temperature is used there will be an error message. If problems occur they generally are a result of wrong temperature injectate, or injecting too slow.

Pulse Oximeter

This is a non-invasive method of measuring the oxygen level in the blood. It uses a specific light spectrum reacts with the dissolved oxygen in the blood in a linear manor give the saturation of the blood with oxygen. The sensor can be placed on a finger, ear lobe, toe or forehead depending upon its design. Some are single use while other are multi-use. Multi-use sensors should be clearly marked so they do not get thrown away after use. Multi-use sensors can cost up to \$200.00.

Pulse oximeter can either be stand along units, part of a patient monitor or combined with non-invasive blood pressure and temperature monitors. When not part of a patient monitoring system the display of data is either on an LCD or digital displays generally with the ability to set alarms for saturation levels and heart rate. Note that the heart rate is not computed from an ECG complex but from the pulsatile blood flow past the sensor.

Some of the common problems

Ambient light	if the sensor is not properly positioned ambient light may interfere with the detection of pulses.
Nail polish	when finger probes are used nail polish will block light transmission.
Cold patient	if the patient is cold the blood vessels may constrict making detection of blood flow a problem

There are no major hazards with this technology; it is non-invasive and low power. Most complaints Involve the adhesive used to hold the probe in place or the pressure on the finger/toe with multi-use sensors.

Pulse Oximeter

Probably no device has had such a wide spread and quick acceptance into clinical instrumentation in the last 20 years than the pulse oximeter. The modern Pulse Oximeter should not be confused with the ear oximeter, which was marketed by Hewlett-Packard in the mid 70's. The technology is quite different the old system which used 8 wavelength detectors could only be used on the ear lobe; required heating of the area and it was not portable. Another early version from Minolta used a fiber optic cable for light transmission and detection as they were too big to be put into a probe that could be, comfortably applied to the patient. Much of the original work on the pulse oximetry was to develop a non-invasive method of determining cardiac output. The side effect of getting a good correlation on blood oxygen levels proved to be the marketable product and research on using the technology for cardiac output basically stopped. An urban legend developed saying that both the pulse oximeter and Viagra were side effects of the prime objective of the engineering work, one measuring cardiac output and the other increasing it.

The "modern" pulse oximeter owes much of its success to Dr. William New who introduced the Nellcor unit in the mid 80's. Ohmeda introduced the Biox II in the mid 80's utilizing microprocessors was another major factor in the utilization of pulse oximetry. Additional credit has to go to the malpractice insurance companies that told anesthesiologists that if they used pulse oximetry that their premiums would be reduced.

The pulse oximeter works on a reasonably simple principle of light absorption, as defined in the Beer-Lambert law or Bouguet's law depending on the textbook used. Basically it states that light is absorbed or passed through a solution based on the concentration of the chemical in the solution for a certain light wavelength. It was found that hemoglobin, (Hb), non-oxygenated blood which is dark red in color, and oxyhemoglobin, (HbO₂), oxygenated blood which is bright red in color, have different light absorption levels. By using 2 detectors one in the 660nm range to measure hemoglobin and the other in the 940nm measuring the oxyhemoglobin along with proprietary algorithms accurate clinical results on blood oxygen could be obtained.

Pulse oximeters have some limitations as ambient light can affect the readings, as can shivering, low flow, very thick skin and poor placement of the sensors. Most of the newer designs, after 1998, have much better rejection systems for motion artifacts. When the finger is used as the location of the probe, it is important

Biomed Certification Study Guide
By Dave Harrington

that the light source be placed on the nail and the detector on the soft tissue of the finger. Needless to say the patient should not have nail polish on. A patient with carbon monoxide exposure will register falsely high on oxyhemoglobin as the blood will be very red. For these patients co-oximetry or end tidal CO₂, (capnometry) will give better clinical results.

The wide spread of pulse oximetry has increased patient comfort in that many fewer blood gas measurements are made now than in the past. If you have ever had an arterial “stick” for a blood gas you know that it is quite painful. The direct monitoring of blood pressure, another source of getting samples for blood gas tests, is also down in many hospitals.

There are some problems that the Biomed still has to respond to with pulse oximeters. Bad sensors and cables are probably the most common. Some shops will “reprocess the sensors and detectors on disposable units, be careful on this as you may become a manufacturer in the eyes of the legal system and be without insurance protection. Other problems include batteries, white tape, (white tape should be a controlled substance), bounce tests, (most units do not bounce well off the floor) and “we cannot find it on the floor so you must have it in the shop”. To name a few of the more common calls we get.

On some monitoring systems the pulse oximeter is used as the secondary alarm if the patient is being paced, either externally or internally. This can present a problem as the patient monitor may not sound an alarm but only have a “screen flash” if the alarm limit on the pulse oximeter is triggered. Take a little time during the next PM cycle on the monitors to confirm how the alarms react when a patient is being paced.

In closing please be aware of where the alarm limits can be set for the low alarms on your units both in the stand-alone devices, in monitoring systems and in multi-purpose standalone units. Most of us just check the default setting and do not try to adjust the limit down below 90. Some manufacturers will allow the user to have alarm limits as low as 50. So take the time to check the limits.

Defibrillators

The defibrillator delivers energy to a patient at a level that will re-polarize the heart, stop uncontrolled beating and return the heart to a normal sinus rhythm. If all activity in the heart has stopped the energy will sometimes restart the heart. The energy delivered is measured in joules, on some older units the energy may be labeled as watts or watt/seconds.

A capacitor is charge and when discharged through a LCR circuit to the patient the pulse can range up to 7,500 volts at 50 to 60 amps, but the pulse width is only a few milliseconds. Once the charge has been transferred to the patient the device will not automatically recharge, it requires a manual action of pushing the charge button. This is for operator safety.

The 3 most common defibrillator waveforms in use are, the Edmark, Lown, and Biphasic.

The current national standards call for all defibrillators to work the same, 1,2,3. Basically 1 is to turn the unit on and select energy to be delivered, 2 is to press the charge button, may be on front panel or paddles, place paddles on patient and discharge, buttons on paddles. Some defibrillators have the option of using defibrillator electrodes that are place on a patient’s chest before a procedure starts, with these units the discharge button is on the front panel or in the cable assembly. The other steps remain the same.

The defibrillator should never be discharge by putting the two paddles or electrodes together and pushing the discharge switch. At a minimum this will damage the paddles and potentially the unit. If the unit is not discharged into a patient use the test load on most defibrillators or let the unit discharge internally. This will occur in 10 to 15 seconds after the unit is charged. It only takes a few seconds for the units to charge so there is no reason to leave them in the charge mode, it is dangerous to the users.

Defibrillator paddles come in 3 types, external adult and pediatric sizes, internal paddles that are various sizes used when the chest is open, (open heart surgery), and electrode. Most defibrillators will accept all types.

Biomed Certification Study Guide
By Dave Harrington

The gel used to assure conduction between the paddles and the chest wall will sometimes build up on the paddles and have to be cleaned. Alcohol will soften the gel and make removal easy. The external paddles should be inspected for pit marks, these could cause high current density and leave burns on the chest. The marks can be removed using emery paper. Internal paddles should be inspected to be sure that there are no breaks in the insulation around the conductive part of the paddle. If breaks are present the paddles should not be used. The electrodes are pre-gelled and are single use. The patient can be burned if the electrodes are reused on another patient. Electrodes are used with the AED biphasic units that are becoming more common in non-medical areas, planes, theaters, sporting events, etc.

Batteries should be replaced every 24 months, or less, to assure proper operation of the defibrillator.

Cardioversion

Cardioversion is the application of the output of the defibrillator to a patient at a specific point in the ECG complex. The power is lower and the patient must have an ECG complex containing an R wave. The patient is connected to an ECG amplifier that has a special circuit that sends a pulse to the defibrillator to discharge at a particular point of the ECG complex. When observing the screen or tracing of the ECG you will notice a "flag" on the waveform indicating the spot where the discharge should occur, a light on the front panel should also be flashing. The clinical person will place the paddles, or defib electrodes, on the patient and push the discharge buttons. The clinical person may have to hold the button in for several beats before the defibrillator will discharge. The patient should be sedated or under anesthesia for this procedure as it is painful.

The energy level used in cardioversion is under 150 joules. The normal starting point is 50 and if the problem is not corrected higher levels will be used until the arrhythmia is corrected. Normally the patient will also be receiving drug therapy for the condition. In severe cases the patient have to have a defibrillator implanted.

There is a safety lock system on the unit so that the defibrillator cannot be left in the cardioversion or sync mode. If it were the unit would not work as a normal defibrillator as it would be looking for an "R" wave to trigger off of generally in 50 milliseconds or less.

Implanted Pacer

The implanted pacer is not generally handled by Biomed but only by the cardiologists. The Biomed may get involved with the pacer programmer or the pacer testing systems but these are very vendor specific. If you do get involved you have to read the manuals of the devices. Generally the programmers and test units are not owned by the hospitals but supplied by the vendor of the implanted pacer.

REVIEW QUESTIONS

- 1 According to the AHA the monitoring frequency response of an ECG amplifier is?
 - A 0.01 to 45 Hz
 - B 0.5 to 35 Hz
 - C 0.05 to 100 Hz
 - D 0.1 to 35 Hz

- 2 What are the 2 most common paper speeds of an ECG recorder?
 - A 12 and 25 mm per second
 - B 25 and 50 cm per second
 - C 50 and 100 mm per second
 - D 25 and 50 mm per second

- 2 What is meant by the term CVP?
 - A Central Venous Pressure
 - B Controlled Venous Pressure

Biomed Certification Study Guide
By Dave Harrington

- C Computed Ventricular Pressure
D Common Venous Pressure
- 3 What is the diastolic pressure?
A The first sound heard when listening to a BP cuff deflate
B The lowest pressure in an intact artery after a cardiac contraction
C The peak pressure in the left ventricle
D The lowest pressure in the right ventricle
- 4 Why is it important for an ECG amplifier to have high input impedance?
A To increase amplifier gain
B To reduce voltage outputs
C To increase frequency response
D To reduce artifacts from being amplified
- 5 What is the “offset error” of a transducer located 2 inches below the level of the catheter?
A +10 mm Hg, usually 2 mm per centimeter from catheter tip level
B -10 mm Hg
C +2 mm Hg, usually 1 mm per inch from catheter tip level
D -2 mm Hg
- 6 What can cause the baseline of an ECG trace to wander?
A Bad electrodes
B Too high of a gain setting
C Patient movement
D Any of the above
- 7 What will cause the heart rate display to show a rate twice the patient’s rate?
A Amplifier gain too high and the P or T waves also being counted
B Electrode placement
C Amplifier saturation
D The electronics is right and the manual pulse determination is wrong
- 8 Are direct and indirect blood pressures always the same?
A Only when the heart rate is below 60
B Only when the indirect pressure is taken from the leg
C Only when an electronic stethoscope is used
D No, systolic pressure increases as you move away from the heart
- 9 Should defibrillators be discharged by putting the paddles together and pressing the discharge button?
A This is a good way to test isolation of the defib
B It may cause damage to the defib
C You might be injured
D B and C
- 10 If no ECG is detected can a patient be cardioverted?
A Only if CPR is being done on the patient
B Only if the amplifier gain is increased
C No, cardioversion requires the presence of an ECG

Biomed Certification Study Guide
By Dave Harrington

D Only if the patient has a flat line not fibrillation

PERINATAL DEVICES

The Perinatal refers to the time around birth, the exact length of time is open for discussion but for the purpose of this course it will be a term of 60 days, the 30 before and 30 after birth. Some devices will only be briefly mentioned, such as ultrasound, as they are covered more in other modules.

Ultrasound

Ultrasound is used to monitor the growth, positioning and general health of the fetus throughout the course of the pregnancy. Generally the sex of the fetus can be determined along with any gross malformations. Just prior to delivery an ultrasound is generally done to document the position of the fetus. The probe used is either 2.5 or 3.5 MHz, with the 2.5 most common

Fetal Doppler

This device is used to detect the fetal heartbeat and is used from about the end of the first trimester to delivery. The probe is 2.5 MHz and the output is sound, no pictures or charts are used with this device.

Common Problems

Bad probe		no output is heard even when a common stethoscope or fetal scope indicates that a fetal heartbeat exists. <ul style="list-style-type: none">• Check probe by gently tapping on the surface• Check the sound level by moving the volume control to max• Check the connection of the probe to the instrument
No power	*	Check battery if present <ul style="list-style-type: none">• Check line power• Check fuse
Other	*	check speaker for gel <ul style="list-style-type: none">• if the speaker has gel in it generally cannot be cleaned but has to be replaced.• Check ear phones for broken connections, most common at connector

Fetal Monitor

Fetal monitoring was developed in the early 1970's and has been controversial from the beginning. Some blame the technology for the big increases in C-section deliveries; other say it is unneeded technology. It is most used with high-risk patients, either the mother or fetus.

A fetal monitor documents two major functions the heart rate of the fetus and the contractions, both length of time and strength of the mother's contraction. These are presented both in digital form and graphically on a recording.

HEART RATE there are 3 methods of heart rate detection used, surface electrode, Doppler or scalp electrode. Each system has advantages and problems.

Surface electrode	*	not invasive <ul style="list-style-type: none">• can be used any time during pregnancy• low cost• subject to detecting mother's heart beat<ul style="list-style-type: none">• uses phase-lock-loop to reject mother's heart beat• has problems with certain fetal positions• has problems with multi-fetus pregnancies
Doppler	*	not invasive <ul style="list-style-type: none">• high cost

Biomed Certification Study Guide
By Dave Harrington

- requires repositioning during labor
 - has problems with multi-fetus pregnancies
- Scalp electrode
- * invasive
 - potential for infection
 - potential to attach to other parts of the body
 - not useable on multi-fetus deliveries
 - extra wires
 - moderate cost

Depending upon the manufacturer, the contractions are measured either with a strain gage transducer mounted externally or with a belt containing a strain gage, both called a Toco. Repositioning is required as labor progresses to assure accurate data.

Presentation

The fetal heart rate is displayed digitally on many units and in graphic form on a chart. Typical fetal heart rates are in the range of 130 to 150 beats per minute. During contractions the heart rate will decrease and revert to previous levels after the end of the contraction. If there is a delay in the heart rate returning to its previous level it can indicate that there is fetal distress. If this occurs regularly it is an indication that a C-section may be required. If the heart rate decreases before the contraction, call early deceleration; it is also an indication of fetal distress.

While the chart paper for various manufacturers may be the same width, the graduations on the paper may be different. The operator should be able to identify the wrong paper when the graphic display and the digital display do not agree as to the heart rate. During the PM process the paper should always be checked. Also the type of paper should be verified, wax or thermal.

The chart speed should be checked, as should the proper paper loading.

In some hospitals the recording are saved as part of the medical record while in other hospitals the data is electronically archived and the paper is not saved.

NOTE ALWAYS CHECK WITH THE CHARGE NURSE BEFORE MAKING ANY ADJUSTMENTS TO A FETAL MONITOR OR REMOVING IT FROM OPERATION WHEN ANY PATIENT RECORDS ARE PRESENT.

Common Problems

The most common problems with fetal monitors are with the cables and transducers. The users will lose them, chargeable item, or bend pins in the connector.

Other common problems include paper in wrong, wrong paper, (key is the digital and graphic heart rates do not agree), positioning of electrodes or transducers. During the PM process the gear drives for the chart paper should be inspected, cleaned and lubricated.

Fetal Monitoring Systems

In hospitals where the fetal monitoring data is electronically archived there can be several problems with the system and its connections. The main unit is a computer and associated software. This software is generally for only one type and generation of the bedside fetal monitor. In some cases the hospitals have purchased additional software to handle new generations or other manufacturers. If new equipment is introduced and the archive system rejects the data it is a SOFTWARE PROBLEM, not an equipment problem. There is very little a Biomed can do to repair this device as it is software driven and has not adjustments. It should be on a dedicated power line and have a power conditioner on it to assure that line variations do not affect its operation.

BIRTH

For a normal birth a birthing bed is used, in most hospitals. These are specially designed beds that the lower part drops down allowing for easy access. These beds are electric and have numerous adjustments, the common problems are

- * hand controls
- jammed up/down mechanism
- spills

In most hospitals, the birthing bed is repaired by the maintenance department and only electrical safety testing is done by a Biomed.

If a delivery table is used refer to OR module for common problems.

Some hospitals will use vacuum assisted deliveries. This can either be a manual or electric device. Basically a cup is placed on the back/top of the head of the fetus. It sometimes is used in place of forceps to deliver the infant. With electric units **NEVER** adjust the suction above the recommended limits set by the manufacturer. Always document what the limits are and what the setting on the unit is. If the vacuum is left on too long or is placed over the face of the fetus damage can occur.

For devices used in C-section deliveries refer to the OR module.

Once birth occurs the baby is kept warm until it is able to stabilize its temperature on its own, this can take from 2 to 30 hours for a normal baby and longer for low birth weight babies. Most babies are tightly wrapped in blankets while others require additional heat sources.

Infant Incubator

This is sometimes called an isolette, which is a trademarked name for infant incubators manufactured by Air Shields.

An infant incubator can be described as a see through container with access doors and a heater that keeps the internal space at a selected temperature between 34 to 37 degrees C. In some cases the heater is controlled via an air probe while in others a thermistor is attached to the baby. The air temperature and surfaces of the internal space should never exceed 39 degrees C, (102 F). In some older units the temperature is controlled by a rheostat and must be manually adjusted as conditions change. The temperature is displayed via panel displays, digitally in newer units, with an analog meter in older units and with a thermometer in real old units. In units that use a thermometer, mercury thermometers should be avoided. (If the line on the thermometer is silver in color it uses mercury, spirit thermometers generally have a red line). All but the oldest of the units will have alarm settings for over and under temperatures in the incubator, there also is a default high temperature cutoff that prevents the incubator from heating above 40 degrees C. If a unit is set in the MANUAL mode of operation, often used to pre-heat the unit, there is not feedback system so the unit warms up to the selected set point.

Heat is generated via a resistance coil that is below the baby; the heated air rises through vents in the bottom of the infant chamber. Most units have a small fan to move the air past the heater and into the infant chamber. This fan can get noisy; it requires lubrication on a regular basis and may have to be replaced. If the fan is noisy it can affect the long term hearing of the infant. The noise level in the infant chamber should be below 65db, with the heater and fan running. The path for the movement of air must be kept clear to assure that the temperature is stable and even across the infant in all positions. In some units there is an inner wall in the infant chamber that directs the flow of the heated air around the infant. These inner walls are held in place with plastic standoff posts and may loosen up with use. These should be inspected to assure that they are properly fastened in place. Literature indicates that the use of an inner wall reduces the metabolic heat production of the infant. If external heat sources are present, sunlight or photo therapy (billi) lights, they can affect the warming characteristics of the incubator. The infant chamber and heater areas should be closely inspected for the presence of mercury. If a mercury thermometer was broken in the chamber all traces of mercury must be clean up. The mercury vapors are

Biomed Certification Study Guide
By Dave Harrington

toxic to developing nervous systems and mercury exposure can have lasting impact on a neonate. If mercury is found follow the hazardous material guidelines of the hospital.

The fan also draws in room air, through a filter, which has to be cleaned or replaced on a regular basis. The need for replacement is affected by the environment and hours used. The fan also assists in the removal of carbon dioxide from the chamber, which should be kept below 500 PPM. This is not a bacterial filter but just removes larger dust particles from the air. Another department, such as Respiratory or Nursing, may do the replacement of these filters.

In some units there is a reservoir of water that the air moves over to increase the humidity in the infant chamber. This is often supplemented by other sources of humidity. To reduce the water loss of an infant in an incubator literature suggests that the relative humidity in the incubator be between 60 and 90%. The reservoir should never be left with water in it during storage, as it is a potential source of bacterial growth. If water is found during the PM process it should be emptied and the reservoir cleaned before returning the unit to service.

The access doors, (porthole), in the hood may have vinyl or latex sleeves that can close around the clinicians arms as they work on the infant. By moving the cuff slider on the access door the opening in the sleeve should increase or decrease. All the access doors, (portholes), should have positive latches on them so the stay closed. The hoods will have one or more cable/tubing entry ports that allow for monitoring cables, IV lines, suction tubing, etc. to enter the infant chamber without going through an access door, (port hole). All access doors and entry ports should have protective covers that act as gaskets around them. They should be replaced when the material starts to crack or flake off.

Heater Controls

The heater controls are either digi-switches or a rheostat with markings as to approximate temperatures.

If digi-switches are used the “tens” digit should be fixed on 3, the unit switch should only allow selection of 6 to 9, while the decimal switch should be 0 to 9. This means that the unit cannot go below 36.0 degrees C or above 39.9 degrees C.

If the heater control is a rheostat the knob should be checked to make sure that it is not loose and turning on the shaft. The markings on the control are only approximate and must be verified via other means. There could be ‘dead’ spots in the rheostat where a slight movement could make major changes in the temperature. This must be check on each PM cycle to assure repeatable performance of the incubator.

Common problems

- air probe
- skin probe
- door latches
- fan motor
- casters
- port covers
- power cord/caps
- fuses

Infant Warmer

True infant warmers use resistance or radiant, (infrared energy), heating elements, not heat lamps. Warmers can dehydrate the infant, fluid replacement is critical; also the infant’s eyes are covered to prevent damage. Warmers are often used for the patients that require the most care, as it is easier to work on the infant on a warmer instead of an incubator. Warmers do not offer the environmental protection of an incubator from air borne particles, pathogens or humidity. Higher electrical leakage readings are common as the heater approaches its failure point.

Biomed Certification Study Guide
By Dave Harrington

In the resistance element unit's long rods are placed approximately 1 meter above the level of the infant, reflecting heat downwards. There is an open grille that covers the rods. When energized the rods glow red. Some old versions may use open coils, which can give inconsistent heat distribution over the infant.

With radiant warmers the heating elements are not visible as they are imbedded in the cover material or behind the cover. The elements are focused over the infant providing for a consistent distribution of heat. It is difficult to judge if the unit is working by sight, but if it is working you can feel the heat.

A thermistor is placed over the liver of the infant, (the largest internal organ, closest to the skin, with good blood flow), and is connected to the control module. The output of the heaters varies around the set point, similar to an incubator, as the infant's temperature varies. While units can be used without the thermistor, manual mode, but it is not recommended. Most units have a probe failure alarm, which will shut down the heater. When doing PM inspections the heat should be measured in various locations on the mattress to assure that even levels of heat are being delivered.

Many infant warmers will have exam lights and billi lights built into the warming hoods. These exam lights can vary from simple incandescent light bulbs, to mini-spot lights to reflector type (Halogen) lamps. Billi lights can range from Florissant tubes to reflector type lamps with special filters to get the proper wavelength of light to the infant.

Common problems

- missing side panels on patient table
- missing or wrong probes
- burned out exam light
- burned out billi light
- alarm lights burned out
- caster locks
- power cord/cap
- uneven heating

Billi Lights (also known as Phototherapy Unit)

The buildup of bilirubin in an infant's blood, caused by decreased liver functions, can cause long-term damage to the child. Bilirubin buildup causes the patients' coloring to range from yellow to orange to red depending upon the level of bilirubin in the system. By exposing the patient to certain wavelengths of light, 425 to 475 nano meter range, the bilirubin is broken down and excreted from the body.

The use of Florissant tubes is quite common. The "Gro-Lux" light, also used by indoor gardeners was the most common form of treatment. Unfortunately these tubes degrade and have to be replaced after about 200 hours of use to keep the proper light spectrum. The reflector type lights have a more consistent output of light at the desired spectrum. Generally they are good until failure and don't have to be replaced based on hours of use. The same light spectrum is used, in a PUMA unit, to treat certain skin disorders in adults and for tanning units.

The patients' eyes must be protected when these lights are being used.

The light should be consistent over the surface of the patient and is measured with a light meter designed for the spectrum shown above. A photographer's light meter can be used to get the overall strength of the light but may not accurately indicate the spectrum of the light.

A third type of phototherapy unit is the "billi blanket". In this method a light source with special bulbs and filters is connected via a fiber optic cable to a blanket where the individual strands of fibers are imbedded into the blanket providing an even distribution of light.

Biomed Certification Study Guide
By Dave Harrington

Common problems

- missing lenses
- poor output
- not focused properly towards patient
- attachment hardware to the warmer missing or loose.

Transilluminator

This device is basically a light source connected to a fiber optic cable with a smooth fitting on the patient end. The light is used to “see through” the limbs of a neonate showing blood vessels, clots or fluid buildups.

It is important that the heat generated in the light source is not transmitted to the end of the cable that touches the patient as it could leave burns.

Apnea Monitor

It is not uncommon for a neonate to have its respiration rate monitored using impedance pneumonography. This is sometimes called an apnea monitor. In this process electrodes are placed in the 5th intercostal space on each side of the neonate. A signal of 55 kHz at 2 to 3 mV is injected into the electrodes and the impedance of the chest is measured as the size changes with each breath. These same electrodes are used to monitor the ECG. There is a potential for errors with this monitoring setup in that the electrodes may miss the chest expansion and pick up muscle movement or bowel gas. This appears as erratic respiration rates or a low rate. The ECG waveform may exhibit low amplitude R waves because of the electrode positioning. This unit passes electrical safety measurements because of its high frequency and the voltage does not affect the ECG signal as it also is above the frequency cutoff of the amplifier.

The unit generally has alarm limits, both high and low respiration rates along with a selectable delay of up to 15 seconds. This delay is used to cut down on false alarms during the normal apnea periods that a neonate has. The staff should be instructed to use the shortest delay setting possible for the neonate.

Common problems

- bad patient cable, cables with resistors or coils in series with the lead wires should not be used.
- Poor ECG trace
- False alarms, either rate or apnea
- The babies electrical heart activity is very high and blocks out the small chest movement during respiration

REVIEW QUESTIONS

- 1 What is perinatal?
Generally consider 30 days either side of the birth date
- 2 What is the common frequency of for a fetal Doppler?
2.5 MHz
- 3 Can an infant warmer dehydrate a neonate?
It is a common side effect and requires monitoring
- 4 What is an indication that the wrong paper is being used in a fetal monitor?
The digital heart rate is different than the recording heart rate
- 4a How should patient information found on a fetal monitor be handled?
This is a HIPAA problem see SOP 006

Biomed Certification Study Guide
By Dave Harrington

- 5 Should a mercury thermometer be used in an infant incubator?
 Never
- 6 When Billi lights are being used should the patient's eyes be covered?
 Yes, billi lights can cause damage to both the retina and corneas
- 7 Why doesn't impedance pneumograph affect the ECG trace of the patient since the same
 electrodes are being used?
The cut of frequency of an ECG amplifier is 100 Hz max, impedance pneumograph operates at 55 kHz
- 8 What physiological effect does the Billi light correct?
 A buildup of bilirubin in the liver
- 9 Should a Biomed check the casters on an infant incubator?
 a good idea
- 10 The noise level inside of an infant incubator, when running should not exceed?
65db

OPERATING ROOM EQUIPMENT

Surgery is one of the heaviest users of instrumentation in modern hospitals, ranging from simple mechanical devices to very complex laser and optical systems. It is a dangerous area with a wide range of hazards, bacterial, blood borne, gases, electrical, mechanical and physical. As a Biomed working in this area and on the equipment you need to understand the hazards of individual devices and the interaction between devices. You also need a good working knowledge of sterile techniques plus where and when you can enter the suites or rooms. This module is broken down into groupings of equipment that you will come in contact with, some will be present in all rooms and others will be only in a few or brought into the room for a particular case. Some of the devices may also be used in other areas of the hospital.

Anesthesia

Anesthesia is defined as the loss of feeling or sensation. The common terms that you will encounter are defined below.

General anesthesia, a state of unconsciousness, with an absence of pain sensation over the entire body, produced by anesthetic agent(s) and muscle relaxants administered by inhalation, intravenously, intramuscularly, rectally or via the stomach. A common relaxant is curare, which relaxes the muscles to the point of parallelization. There are many reported cases where the anesthetic agent was never administered and the patient felt all the pain of the operations without being able to do anything about it.

Local where a specific area is “numbed” such as in a dentist’s office; the patient is awake and may feel some limited pain. In an operating room muscle relaxants are generally administered with the local agent.

Saddle block where the patient is conscious and the area of the body that would touch a saddle is affected. This is accomplished by injecting an anesthetic agent low in the dural sac. This is commonly used for childbirth.

Spinal an anesthetic agent is injected beneath the membrane of the spinal cord. There is no sensation below that point until the agent wears off.

General Anesthesia unit, inhalation

These are generally large, on wheels, that contain one or more vaporizers, flow tubes, attachments for compressed gas cylinders, ventilator, ports for obtaining compressed gases from wall connections, carbon dioxide absorber with various monitoring devices either built in or attached to the unit. These units can cost over \$60,000.00 to purchase and require regular maintenance. Some of the maintenance requires specialized testing equipment that may not be available in all hospitals. This test equipment includes devices for the measurement of the concentration of anesthetic gases, flow rates and pressures. Additional training is required before any calibration to or repair of the gas delivery system should be attempted.

Vaporizer

Vaporizers are used to convert a liquid anesthetic agent into a vapor. A vaporizer is a multi-chambered container where the liquid agent is poured into the lower part of the unit, as compressed gases move across the top of the vaporizer the agent vaporizes and is entrained into the flow of gas moving towards the patient. The amount of the anesthetic agent getting to the patient is regulated by the gas flow across the vaporizer; a valve in the incoming gas line regulates the flow. The incoming gas can be oxygen or air and possibly combined with nitrous oxide. The amount of each gas is regulated via needle valves and shown on a flow tube. All the gases going to the patient are controlled via another needle valve/flow tube labeled “Patient”. Vaporizers are generally calibrated once a year.

Flow tube

Flow tubes are made from either glass or plastic tubes with a metal float that moves up the tube as flow increases. The tubes are calibrated in cc or ml of flow per minute. Needle valves at the bottom of the tubes control the flow rates. Sometimes when the pressure in the tanks drops as the tank empties the flow rates

Biomed Certification Study Guide
By Dave Harrington

can fall and need to be adjusted to maintain the proper mixtures of gases getting to the patient. Flow tubes are cleaned and calibrated once a year.

Purge button

The purge button allows for 100% oxygen to flow to the patient connection, this bypasses all other flow tubes. This button is used before a case starts to clear any residual gases from the patient connection and as the case ends to start to reduce the level of anesthesia the patient is under.

Pin index

Every compressed gas tank used on an anesthesia machine has what is called a pin index connection. This is a safety control that allows tanks to be placed on specific yokes on the machine. The yoke where the tank is attached has pins sticking out that match the holes in the neck of the tank. During every inspection of the anesthesia unit the pins on each yoke should be checked to verify that they are present and in the correct positions for the designated tank. A backup to the pin index is the color-coding of the paint on the tanks. Oxygen tanks are painted green while Nitrous oxide tanks are blue and air tanks are yellow.

Gases are also obtained from a central source in many hospitals. The fittings at the ends of the hoses have specific thread diameters and pitches, which prevents gases from being miss-connected. The connection hoses should also be color coded with the same colors as the tanks.

Absorber

Some of the patients expired gases are returned to the patient in some situations. When the re-breathing of gases is being done excess carbon dioxide has to be removed from those gases. Passing the expired gases through a soda-ash canister, which absorbs the carbon dioxide and allows the oxygen and anesthetic agents to be returned to the patient, does this. The soda ash is generally replaced once a year in most cases.

Scavenger

The expired gases of the patient contain anesthetic agents they must not be allowed to just “dump” into the atmosphere of the operating room. In addition to possibly placing the staff under its effects certain agents can be toxic to those in the room. This is especially true of Halothane. It can cause high fevers and severe liver damage. The federal limits for exposure is 1.0 parts per million per hour. To reach this level expired gases must be “scavenged” at the exhalation port of the anesthesia circuit and vented outside of the operating room. This is commonly done by connections to a suction line, where the gases are vented outside of the hospital or to the air handling system, if vented to the outside.

Residual gases should be tested once a year in all areas of the hospital where inhalation anesthetic agents are used or patients are recovering from their use.

Anesthesia circuit

The anesthesia circuit consists of disposable tubing that transport gas to and from the patient. It includes the connection to the patient, mask, endo-trach tube, etc. There may be connections to and from the absorber that while part of the circuit are not replaced with each used. As with all tubing leaks can occur potentially exposing personnel to higher levels of anesthetic agents.

Bellows

Some units will have a bellows that indicates the tidal volume of each breath by its movement in a calibrated chamber. The bellows is generally connected to a ventilator that controls the patient’s respiration, both the rate and volume of gases delivered.

Reservoir bag

The reservoir bag is in line with the patient and the anesthesia machine. If there is no automatic ventilator present and the patient cannot breath on their own the anesthesiologist would squeeze the bag to deliver gas to the patient 15 to 20 times per minute. The compliance, resistance, of the lungs can be felt through the bag and may indicate that more anesthetic agents are required or that the physiology of the lungs is changing.

Capnograph

Some units may have a capnograph that measures the expired levels of an anesthetic agent. The connections are made either as “main stream” meaning that the full expired flow passes through the sensor, or “side stream” meaning that only a partial amount of the expired gas passes through the sensor, the most common type of unit. Side stream units often have a small pump in them that draws the gas through the sensor. In either case the sensor is affected by the water content of the expired gases and if that content is too high erroneous readings will occur. Also the buildup of water may trigger alarms. A moisture trap is generally in line with the sensor to prevent the buildup.

Anesthesia depth monitor

Some anesthesia units may have a monitor attached that is used to measure the depth of anesthesia that a patient is experiencing. This is a simplified version of an EEG monitor that selects certain brain waves as an indication of how deep the patient is under anesthesia. It is used with both inhaled and injected anesthetic agents. While the unit is called depth of anesthesia it actually is an indication of the hypnotic state of the patient that closely parallels the depth of anesthesia.

Other monitoring

The anesthesia machine may also have a multi-parameter monitor mounted on it with ECG, invasive pressures, non-invasive blood pressure and pulse oximetry. These units should be tested as any other monitor, even if built in to the machine.

Injectable anesthetic agents

These agents, which are either injected as a shot or as part of an IV, are combined with muscle relaxants and are used for short-term procedures.

Explosive agents

Agents, such as ether or cyclopropane are rarely used in a modern hospital.

Tables

The tables used in the operating room have a top surface that is separated into 3 sections, head, body and leg. Each section can work separate from the other in up/down functions. Whether the table is electrically or mechanically operated the functions are the same. A common problem is that once a position is selected it will slowly change over the period of the operation. The hydraulics/pneumatics leaking causes this. Most hydraulic fluid is red in color so look for puddles of oil, on the floor and in the pan section of the table base. Low fluid levels can contribute to the problem; they should be checked before doing more extensive testing and inspection. Refill as needed. Very heavy patients, over 400 pounds can cause the tables to sink during procedures.

On manual tables the up movement is created via pumping a foot pedal. If not movement occurs check the following points,

- 1 is the bleed valve closed
- 2 is the pedal connection to the hydraulic cylinder broken
- 3 is there a fluid leak
- 4 is the correct pedal being activated

The down movement is controlled via the bleed valves releasing pressure from the cylinders. Bleed valves also control the table tilt. The bleed valve actuation can be handles that turn, slide knobs or lifting the foot pedal up past its resting position.

On electric table's motors and lead screws replace the pedals and valves but the functions remain the same. The hand control is often damaged and requires frequent repairs due to user abuse.

Biomed Certification Study Guide
By Dave Harrington

All tables have a locking system that prevents them from lateral movement when a patient is in place. The brake pads that engage the floor have to be changed over the years as they wear and lose their gripping power. The locks will need adjustment from time to time as they wear.

Major problems occur when the accessories, such as arm boards get broken or lost. These units are difficult to repair as most of the metal parts are cast and cannot be welded; replacement is usually the only option.

A fracture table is a specialty OR table designed for orthopedic use. Instead of the standard 3 sections it has a fourth section. This section is used to position and align the broken limb so internal fixation hardware can be easily done. This fourth section can be attached to either side of both the head and foot section so that all limbs can be worked on.

Lighting

Operating rooms have three very separate lighting sources. The first is the general room lighting found in the ceiling. This is used during the setup of the rooms, cleaning and as background lighting for the staff that is not working in the sterile field. This lighting is not generally checked by a Biomed but by the maintenance department.

The second source of light is the overhead OR lights. These can be large reflectors with one or more bulbs in them, mounted on a counter balanced arm that can be positioned over the site of the operation. These units have a sterile positioning handle that is often adjusted over the period of the operation. Many of the problems associated with these lights are mechanical in that they do not stay in the position selected and the counter weights have to be adjusted. A secondary problem is that one or more of the lights will burn out giving dark spots in the surgical field. The replacement of these lights is generally done by maintenance but if the Biomed does the replacement all bulbs should be changed at the same time so the light field and color is consistent. All the bulbs should be the same type so that the color is the same over the surgical field. These lights have control boxes on or in the wall where the intensity control is along with the on/off controls. This box usually contains an SCR control board, or transformer that powers the lights at some voltage under 115 volts. This can be a failure point and may or may not fall under the responsibilities of the Biomed.

In some rooms there may be a portable OR light. These are large reflector lights that roll from room to room. They simply plug in to a 115 volt outlet and are positioned as needed by the surgeons. The most common use for these lamps is when a secondary procedure is being done at the same time as the prime procedure, such as harvesting a leg vein for transplant.

The third source of light is the “personal head light” that a surgeon will wear. This is a lens that focuses light transmitted to it by a fiber optic cable from a remote light source. This light source may have a multitude of bulbs in it that can be switched into use via a knob on the top of the unit, or by moving the fiber optic cable from one side to another and turning on that light. These bulbs have a life expectancy of about 250 hours and need to be monitored for replacement. Always replace with the same bulb, as any variations in color or brightness will get a “call back” from the user. The lamps can be xenon, quartz-halogen, mercury-vapor or metal halide so replacing the bulb with the correct bulb is very important. Also there can be differences in heat that will affect the life of the bulb. When replacing bulbs care must be taken to avoid touching the reflector part of the bulb as that can affect the brightness at the surgical site. These units are often the personal property of the surgeon and they are very possessive of them. It is a good idea to have a small label on the light source showing the bulb number and type. Who supplies the replacement bulbs is always a question, the OR, stores or Biomed are the common sources, and this varies from hospital to hospital.

Electrosurgery

Electrosurgery, like pacemakers, defibrillators and patient monitors was invented in the Boston area. In the late 20's Dr. Cushing introduced the concept of “bloodless surgery”. By using the output of a radio frequency generator Dr. Cushing was able to destroy cells in a controlled fashion making a clean incision through the skin. By using the same device he could coagulate blood in small vessels so the surgical field

Biomed Certification Study Guide
By Dave Harrington

was dry, or bloodless. This allowed the surgeons to work faster as they did not have to hand tie off every vessel they cut. The patient did better as there was less blood loss and the healing was faster plus the scarring was much less than cuts made with a scalpel. The effect is accomplished by converting the high frequency electrical current into heat, caused by the tissue resistance to the passage of electrical current. The power generated was up to 400 watts. If the waveform is damped it will destroy and coagulate tissue and stop bleeding, (coag setting). If the waveform is undamped there is minimal tissue destruction and it incises tissue, (cut setting). There are four common techniques used in electrosurgery.

Electrodesiccation

A highly or moderately damped waveform is supplied to the contact point, active electrode, a ball, needle or blade that is placed on the tissue before energizing and produces coagulation around the site.

Electrofulguration

The same waveform is used but the active electrode is held 1 to 2 mm from the tissue and when energized sparks spray the area drying it out and leaving some burning of cell edges.

Electrosection

An undamped modulated or slightly damped waveform is applied to the active electrode, which is placed on the tissue surface creating an incision.

The above techniques require that a dispersive or ground electrode be placed on the patient to complete the circuit. These are commonly called mono-polar techniques. The activation of the electrosurgical waveforms is done by the surgeon using either a hand switch on the electrode handle or by stepping on a foot switch. Both have two contacts one labeled CUT for *electrosection* and the other COAG for *electrodesiccation* or *electrofulguration*.

In all these procedures there is the smell of burning flesh and smoke. It is common for a suction tube to be placed near the site to remove the smoke and smell from the room. There is no literature on viruses being contained in the smoke from electrosurgery.

Electrocoagulation

A moderately damped or modulated undamped waveform is used. The active and dispersive electrodes are contained in the uninsulated tips of a forceps or tweezers. The tips are brought in contact with the blood vessel or tissue and squeezed until energy is delivered and coagulation is accomplished. This is used with small vessels and for precise tissue destruction. It is also called BI-POLAR. The bi-polar function may not be on all electrosurgical generators, if part of the generator it will have separate connections and possibly separate controls from the mono-polar functions. It also can be a separate device sometimes called a Malis box.

Until the 70's all electrosurgical generators were based on spark-gap technology. As the gaps aged they had to be adjusted to assure that the waveforms generated were consistent. The operating frequency was in the 1 to 1.7 mega Hertz spectrum, with output power of several hundred watts. Also during that period the dispersive electrodes were metal plates covered with a conductive gel or saline soaked cloths that were placed under the patient. Burns to the skin where the dispersive electrode was placed was common. The trade name Bovie was and still is associated with electrosurgical generators.

In the 70's solid-state circuitry started to replace the spark gap technology in all but the bipolar applications. The operating frequencies dropped to 450 to 950 kilo Hertz range with much lower power outputs. The other major advance was the single use dispersive electrode. Both of these techniques reduce the number of burns that the patients and staff received from the generators. It became possible to use lower power and more precise waveforms prevented many unwanted effects of electrosurgery common with spark gap generators.

Further advances in the dispersive electrodes followed including pregelled pads, conductive adhesive pads that required no gel and capacitance coupled pads. All reduced burns to the patients. As these pads were

Biomed Certification Study Guide
By Dave Harrington

being developed thermal imaging showed that the majority of energy on a dispersive electrode was on the edge closest to the site of the incision, called “leading edge effect”. This knowledge caused changes in the placement of dispersive electrodes on the patients and their orientation to the operation site. The dispersive electrode should also be placed on an area of the body that has good blood flow and not subject to high weight concentration. The side of the thigh is a very common location; under the buttocks is not a good location as it generally is a high weight bearing point. Alarm systems were developed that monitored the contact of the dispersive electrode to the patient; first it was the dispersive electrode in place progressing to the quality of the contact, which is now most common.

Current division is a potential problem when electrosurgery is in use. This occurs when a secondary ground is created by another device or a conductive path between the patient and the table is created. The alarms might not detect this happening and burns could occur.

Electrosurgical Burns

Electrosurgical burns may not be evident when the patient is on the table or just moved into the recovery area. In many ways it is similar to a bee sting. The burn is usually raised and round with either a white or black dot in its center. Electrosurgical burns are inverted cone shaped where the deeper the burn the wider it becomes. The center dot is where the burn started on the skin and the edge of the raised area roughly equals its diameter at its deepest point. It is extremely rare that more than one burn site will be found on a patient. The “leading edge effect” contributes to a burn in that if a point is a better contact then the total area current will concentrate there causing the burn. It is like two active electrodes are in use when there is a point contact on the dispersive electrode, the intentional one in the surgeon’s hand and the secondary one on the dispersive electrode. If a burn occurs in an area other than where the dispersive electrode was located there was current division happening. This can be very difficult to determine the causes as fluid spills or other equipment get cleaned up or moved. Chemical burns and decubitus ulcers are sometimes mistaken for electrosurgical burns. RF burns are round, raised and with a white or black center dot anything else is not an RF burn.

Fires

Unfortunately too many people do not understand that sparks are a common occurrence when electrosurgery is in use. This combined with the administration of oxygen that creates an atmosphere where fires can quickly ignite. The drapes covering the patients are flame retardant but will burn under the right conditions. Occasionally both the surgeon and anesthesiologist will forget about sparks and when doing neck or mouth surgery and will get a flash fire. These fires have been known to kill or seriously injure patients. While they will be blamed on the equipment the root cause is the sparking of electrosurgical procedure in an oxygen-enriched atmosphere. When used for abdominal surgery there is a possibility that bowel gas could be ignited.

In physician’s offices and clinics another type of an electrosurgery generator is used called a Hyfrecator. This is a low energy unit used to remove skin tags and warts. It is based on spark-gap technology and is mono-polar. The patient will hold or sit on the dispersive electrode.

Cryosurgery

Cryosurgery, the freezing of an area, is used for certain dermatology, gynecology and proctology procedures. Some newer applications for treating tumors on the liver and prostate conditions are being investigated. These newer procedures use ultrasound imaging to guide the cryosurgical probe(s) to the location affected. Unlike surgery with a scalpel or electrosurgery tissue affected by cryosurgery may stay in place up to several days after the treatment before falling off. There are two basic types of cryosurgery procedures open and closed. In an open procedure the cryogen is placed on the tissue with a Q-tip, if liquid (nitrogen) or sprayed on as an aerosol if carbon dioxide or nitrous oxide. Like a Hyfrecator this method is generally used for skin tags, warts and moles. There is no instrumentation involved with open cryosurgical procedures.

In the closed system the cryogen, either carbon dioxide or nitrous oxide gas, is used to cool the tip of a probe that is placed against the tissue. This cooling freezes the tissue to –20 to –40 degrees C. The freezing creates ice crystals in the tissue cells, which cause them to rupture and dehydrate. Electrosurgery

Biomed Certification Study Guide
By Dave Harrington

uses heat to do this function. The depth and temperature of the “ice ball” is directly related to the contact time of the tissue and probe. In order for the probe to be moved without tearing tissue it first must be warmed, this is done by stopping the flow of cryogen to the probe tip or in some cases heating the tip.

Except for the newer techniques that are combined with ultrasound imaging cryosurgical units are mostly mechanical. The control panels contain pressure gages and possibly temperature readout. But the units have to be mechanically inspected on a regular basis. Hoses have to be checked for dry rot and cuts. The gas tanks also need inspection to assure that the correct gases are being used. There ***never*** should be adapters used between the tanks and the hoses. That is an indication that the wrong gas is being used. The tips need to be inspected for cracks and bends. Because the tip is under a high pressure, from the cryogen, they can explode if weakened. Field repair of the probes is not recommended.

Lasers

Cost considerations have prevented lasers from replacing either electrosurgical generators in general surgery. There are over 12 types of lasers in use, some only have a few applications, such as ophthalmic or a particular function in the ophthalmic group. Most will use fiber optic probes to bring the beam close to (non-contact or free beam) or touching the tissue (tip contact). These fiber optic probes are easily broken and can have heat build-ups if too many fibers are broken to the point that secondary burns can occur.

Some carbon dioxide lasers have an “open beam” in that the beam is transmitted via aliened mirrors in an articulating arm to near the tissue. In these units keeping them aliened is a major problem as movements from room to room can cause miss alignment. The complaint is that the laser beam does not the same as the target beam. The target beam is a non-laser light indicates where the laser beam will contact the tissue. It can take several hours to get the actual beam and target beam properly aliened.

All laser systems generate large amounts of heat and require cooling systems. Some have built in heat exchangers or radiators while other require outside cooling or connecting to a source of water. The cooling systems require service at least once a year. This generally is cleaning and flushing the system, checking for leaks and refilling. If the cooling system is not properly functioning it causes premature failure of the laser tube. The fluid levels should be checked every month or more often if problems are present. Working around lasers can cause eye damage and the proper safety goggles must be worn. This does not have to be direct contact with the primary beam but can occur from reflections of the beam off of shiny surfaces.

Another danger from laser surgery is the smoke (laser plume). This has been shown to be able to carry viruses, including the HIV virus. The smoke evacuator should always be used when laser surgery is taking place. An open suction point as described in the electrosurgery section or scavenger system as described in the anesthesia machine section can also be used. When a smoke evacuator is used the filter will require changing as it takes on particles from the smoke. In most cases this is a yearly change. The used filter should be handled as a hazardous waste and properly disposed of. Follow the guidelines of the hospital for its disposal.

Suction

In an operating room suction is very important. There can be multiple suction connections in use at the same time, scavenger for the anesthesia unit, smoke evacuation, tracheal suction plus suction for blood and other fluids at the operating site. In most cases these are all connected to the central suction system of the hospital. These outlets can become restricted with dried body fluids over time cutting down on the flow rates. Unfortunately the vacuum levels may stay close to normal, -18 to -23 inches of mercury but the flow rates will drop so low that evacuation of fluids is slow. The minimum acceptable flow rate flow a wall outlet is 3.0 SCFM. For effective suction performance flow rates are much more important than the pressure levels.

Under normal conditions the maintenance department will clean the suction lines once a year. Operator errors contribute to the buildup of material in the lines and can be easily prevented. What will happen is that someone on the OR will remove the shutoff float from the suction canisters. These floats shut down

Biomed Certification Study Guide
By Dave Harrington

the suction before the canister overflows. If a multi canister setup is used the last canister before the connection to the wall suction port must have the cut off float in it. The other canisters, closer to the patient will have the floats removed. Fluids getting into the suction regulator will cause it to fail and require cleaning and rebuilding.

Line operated suction units in the OR are sometimes used in place of the wall suction. These are usually for a specific case where the motor only runs for a short period of time. The canister on this type of a unit is bigger and has larger port to accept tissue and fluids. Its most common use is the termination of a pregnancy.

When working on any suction device it is important to observe both the universal precaution and hazardous materials procedures.

Autotransfusion

In cases where large blood losses are expected an autotransfusion, also called a cell saver, unit may be setup. Instead of blood from the surgical site going into a suction canister it goes to a collection reservoir on the unit. Here the blood is prefiltered and treated with heparin to prevent clotting. The blood is next pumped into a centrifuge bowl where it is washed with normal saline to remove fats, contaminants, less dense cells leaving packed red blood cells (RBC), the wash solution and debris go into a discard bag and the cells are reinfused, through another filter into the patient. This can be either an automatic or manual cycle. To assure that the suction process the vacuum level does not damage the cells should not be above 200 mm Hg, ideally 150 mm Hg.

As with suction devices observe both universal precautions and hazardous material procedures when working on or with this unit.

Fluid warmers

Infusing cold or even room temperature fluids into a patient can cause problems during and after surgery. Blood and other fluids are warmed by immersion, conduction or radiantly. The immersion method is no longer widely used, as it is slow and not well controlled. In this method the bag of fluid is placed into a heated chamber with water transferring the heat from the water to the fluid in the bag. This can take upwards of 15 minutes to raise the temperature of refrigerated blood to body temperature. Also the heaters are heavy and sit on the floor, people tripping over them is not uncommon. The main advantage to this system is cost, as not additional disposable items are required.

In the conduction method the fluid is connected to a disposable chamber that has an effective fluid path of about a meter. As the fluid moves through the chamber, which contacts a heated surface the fluid in the chambers is warmed. Newer units are capable of warming several fluids at the same time.

The radiant method is basically the same configuration except a radiant heater is used in place of the heated surface.

The major problem with all three methods is the thermal link or fuse. Leakage currents should be monitored on these devices to detect if the heaters are degrading.

Cardiac Bypass Pump

Also called heart-lung bypass pump. This unit takes over the function of both the heart and lungs during cardiac surgery. It is also used for ECMO (extracorporeal membrane oxygenation) procedures to treat respiratory distress and smoke inhalation. In this application the heart remains beating and the unit only takes over the function of the lungs. The unit consists of 2 to 7 roller pumps, typically 5, mounted on a cart along with a cooling/heating unit, temperature monitoring, detectors for air bubbles and other smaller pumps for cardioplegic solutions and anesthetic agents. In most cases all the pumps and support devices are powered from the cart so only one power cord is in use. The blood pumps are roller type as they damage blood cells the least and the perfusionist can adjust the speed, (flow rate) and pressure as clinical condition change. All the blood pumps can be hand cranked if there is a power failure and a failure to the emergency power system.

The pumps require very little maintenance, the bearings need yearly cleaning and lubrication and all power cords checked.

Hypo/Hyperthermia

During operations patients may require supplemental external heat to maintain their core temperature. A blanket with tubing channels is placed under the patient and warm water is pumped through it to maintain the patient's temperature. This is a very simple device where a reservoir of water is heated, electrically and pumped through the tubing channels in the blanket. The fluid level needs to be monitored so the heater element is not exposed, especially when disposable blankets are used. The heating element should be inspected for cracking or metal flaking off of it. If either is observed the heater element should be replaced. The filter needs to be cleaned at least once per year and from time to time it is a good idea to add a bottle of hydrogen peroxide to the reservoir to retard bacterial or fungi growth. An indication of a clogged filter is reduced flow to the blanket.

One danger to the patient is chemical burns from this application. If the batadine solution used to "prep" the patient is allowed to pool under the patient it can react with the heat causing a chemical burn. This burn will take the shape of the tubing in the blanket so it is easy to distinguish from an electrosurgical burn.

Hypothermia is used to lower a patient core temperature. This is a common practice in cardiac and neurosurgery cases where the lower body temperatures are beneficial. Patients with fevers can also benefit from this device. The same blanket as used to heat a patient is used. As the compressor cools the fluid it is pumped through the blanket and back to the reservoir. Pressure point from the patient can affect the flow of the fluid through the blanket and may cause uneven cooling (or heating)

There are primary and fail safe thermostats in the unit. The primary thermostat will have an upper limit of 105 to 107 degrees F. The fail-safe point is 110 degrees F. The lower primary limit ranges from 37 to 40 degrees with a fail-safe limit of 35.

The units can work in manual mode setting, automatically with a thermistor placed on the patient. It is advisable to monitor the electrical leakage readings over several inspections/PM cycles for sharp increases in the leakage in both in the heating or cooling modes. Increases indicate that a failure point is being reached. In the heating mode the heater may have to be replaced while in the cooling mode the compressor may require service.

Power Tools

The cutting or shaping of bone cannot be done with scalpels or electrosurgical devices and lasers are slow and expensive when working on bone. Pneumatic and electric saws, drills, shapers (Dremal), shavers and dermatomes for skin are in general use.

Compressed gas, normally dry nitrogen or dry air drives pneumatic tools. The moisture content in these gases has to be very low so not to contaminate the surgical site or to corrode the pneumatically driven rotary –vane motor. A foot control regulates the speed of the motor by increasing or decreasing the gas flow. When a bone is being cut a gear head is installed on the hand piece that converts the rotary motion of the motor to oscillating or reciprocating motions. This protects surrounding tissue from damage. Since the tissue is not rigid it will vibrate harmlessly. The rotation speed of a pneumatic motor is generally much higher than the rotation speed of an electric motor.

Electrically power tools will either have a small motor in the hand piece or a flexible cable drive from a remote motor to the hand piece. If the remote motor is used the speed is controlled with a foot switch/rheostat. If the motor is in the hand piece a slide pot on the hand piece is the speed control. A major problem with the motor in the hand piece is the lack of power.

Most units have a resistance sensing system in them so that when the bone cut is complete the blade/drill stop automatically, this is a further protection of surrounding tissue.

Biomed Certification Study Guide
By Dave Harrington

Some reciprocating blades used in neurosurgery have a dura guard attached. This guard prevents the saw blade from touching the dura protecting the brain.

Several dangers have been identified with these devices. Gas being vented from the hand piece should not be vented towards the patient as it could cause a venous air embolism. The sound level generated by the devices can damage hearing and blood borne pathogens made be part of the aerosol produced by the drills and saws.

A dermatome handle may be powered by the same remote electric motor as previously described. An oscillating smooth blade is passed over the skin shaving off several layers of cells. This strip of skin is then used for grafting onto other parts of the body.

When working on any of these devices follow the universal precautions and hazardous material procedures of the hospital.

Tourniquets

Powered tourniquets are used in limb surgery to impede blood flow to the operating site. These can be kept inflated for up to 90 minutes without damage to tissue. Rotating tourniquets are used on long procedures where significant blood loss can occur. Blood flow to alternate limbs is restricted on a rotating basis to keep more blood in the truck of the body.

Both tourniquets are powered by compressed gas, electric pumps or tetrafluoroethane, which vaporizes into a gas and is toxic, so be careful. The unit has controls to regulate the pressure in the tourniquet(s), a gauge, 0-550 mmHg or display indicating the pressure and a dump valve that rapidly deflates the cuff. The rotating tourniquet will have a timer system for the automatic inflation and deflation of the tourniquets in a preset sequence.

Other than abuse very little goes wrong with these units. The common failure points with the cuffs and tubing are the connectors. Also the tubing is subject to ozone damage, cracking and leaks. Replacement tubing should be rigid enough so it does not deform when under pressure. On rotating tourniquets the timing system may require recalibration on a yearly basis especially if it is mechanical system.

Scopes

There are two types of scopes commonly used in hospitals rigid and flexible. Rigid scopes Arthroscopes for joint surgery and Laparoscopes for surgery in the peritoneal cavity are the most widely used. There may be some older rigid Bronchoscopes and Cystoscopes in use but these have been mostly replaced with flexible versions. All scopes have a minimum of two internal channels, one for the transmitting of light and the other for viewing. Some heat is passed from the light source through the fiber optic cable and the fibers in the scope to the surrounding tissue, which can cause minor problems. The viewing of the tissue is done through the eyepiece on the end of the scope or with a video camera, (usually a CCD which produce a digital signal).

Additional channels are added to the scope for infusing flush solutions, suction and surgical instruments. With a laparoscope there is an additional channel that allows for the infusion of a compressed gas to move organs to create a better field of view. The surgical instruments can be scissors, tissue grabbers, laser or electrosurgical probes and other devices.

To keep the size of the incision to a minimum with Arthroscopic and Laparoscopic procedures it is common to create additional entry sites where instruments are brought to the desired location via triangulation. The benefit is that the viewing is constant and not moving as instruments are brought into the area, to tissue cut or to coagulated or removed tissue. Both Laparoscopic and Arthroscopic procedures require that the skin be punctured, with a trocar. This is a spring-loaded device the punctures the skin and when the center is removed provides a sleeve in which the scope or instruments are passed.

Biomed Certification Study Guide
By Dave Harrington

Very little goes wrong with rigid scopes that can be repaired in the field. Blockages in the instrument or suction/irrigation channels can be cleared with compressed air, after removal from the patient. Everything else is a factory repair.

Flexible scopes, Endo, Gastro, Procto, Duodeno, Broncho and Cysto are all basically the same except for their diameter and length. They enter the body via a natural orifice, mouth, nose, rectum or urethra instead of through a puncture of the skin. The scopes contain one or more instrument/suction channels, a channel for air or water to wash the viewing lens, tissue or to move tissue out of the viewing field along with 2 light channels and a view channel. The viewing channel is generally a CCD video system with wires. The end of the scope can be bent up/down/right/left by moving the control knob of the junction block. This movement should be smooth and easy. The wires attached to the control knob can break or stretch which effects the movement. Wires should not be tightened too much during a repair as it can affect the ease of movement of the tip.

The users should do leak testing of the scopes before reprocessing. If any of the channels is leaking fluids during the reprocessing can damage the camera or other internal parts.

Fibers in both the viewing a light and viewing channels will break. These breaks are seen as dots on the field. These breaks are generally not repairable in the field but must be sent to a refurbisher or to the manufacturer for repairs.

The light sources used for flexible scopes can be similar to those used for headlamps or higher power units using Xenon bulbs. The light source may have an air compressor built in along with a pump for washing fluids. Some will also have a cooling fan.

The video control unit is also part of the system and is in the same instrument rack. Also in the rack are a video recorder and a video printer. It is a good idea to mark all the interconnecting cables so when someone makes an equipment change things get reconnect correctly.

Scope disinfecting and sterilizing units

Flexible scopes cannot withstand steam sterilization without deterioration. Ethylene oxide and glutaraldehyde (Cidex) take 36 and 10 hours respectively to sterilize a scope. Since scopes may be used many times during the course of a day many backups would be need. Most hospitals, to reduce costs chose to use a high level disinfection using an activated 2% glutaraldehyde, 6% hydrogen peroxide of peracetic acid in an automatic reprocessor.

The operator connects the reprocessor to open channels of the scope using adapters. The disinfectant is pumped through the channels and over the outside of the scope, but not the junction blocks our electrical connections. The units are then flushed, air dried and ready for use in minutes. The reprocessor documents on its PC or a printout indicating time, parameters and if the cycle was aborted.

The filters on the water inlet for the rinse cycle need to be changed on a regular basis, this may or may not be a Biomed responsibility. The need for a filter change will be indicated by pressure readings. Most filters only last between 30 and 45 days. Another problem is sticking valves these cannot be repaired but have to be replaced. Some hospitals replace all the valves every year.

Insufflator

An insufflator is a pressure-limited gas-flow regulator used during Laparoscopic or endoscopic procedures to create a gas filled space, (pneumoperitoneum), or to move tissue so the physician has a better field of vision and room for instruments. A needle is inserted into the abdomen and gas, usually carbon dioxide, is injected. Once pneumoperitoneum is reached a trocar is used to enlarge the needle hole allowing the laparoscope to be inserted. The trocar has an attachment to allow the insufflator to be connected to maintain the pressure as gas escapes from the laparoscope or other incisions. The pressure is maintained at between 10 and 50 mmHg and flows of 1 to 15 liters per minute. The pressures and flows vary with the procedures.

Biomed Certification Study Guide
By Dave Harrington

The control units are either pneumatic or electric with the lower flows and pressures being usually from pneumatic units. These are simple units with regulators, needle valves to control the flow rates and readouts to show the pressure of the pneumoperitoneum.

If nitrous oxide is used as the inflating gas a scavenger must be used to collect the leaking gas for the abdomen so it does not affect the staff. Nitrous oxide should not be used if electrosurgical or laser energy will be introduced to the site.

With procedures where a pneumoperitoneum is not required the insufflator is used to move tissue away from the viewing lens.

Very little goes wrong with insufflators except user abuse. Broken gages and bent cases are common problems and loose fittings. Connectors for the gas both into and out of the machine need to have regular checks to assure safety.

Surgical microscope

Surgical microscopes vary in complexity from the simple to the very complex. About the only thing they have in common are the optics and a light source to illuminate the field. The complex units will have automatic focus, positioning and zoom controls, video capability and motion stabilizers.

The most common problems with the microscopes are the control switches or foot pedals. Fluid spills or just abuse are the main reasons for problems. Sometimes the motion stabilizers will leak causing them to slowly move during the procedure; generally they cannot be repaired but must be replaced. Bulbs in the light source are another problem; replacing one during a procedure is not uncommon. Some cases requiring a microscope can last for up to 24 hours.

Operating room environment

Most repairs to operating room equipment are done outside of the rooms or in a shop area. The Biomed will be called into an active room from time to time to do a quick repair or adjustment so you will need to know what procedures to follow. Procedures will vary from hospital to hospital but the core requirements are all the same. Most suites are setup with 3 distinct areas, clean, dirty and sterile. In the hallways there will be a red line on the floor or wall and a door, which indicates the start of the sterile area. To enter this area you need the proper clothing, head and shoe covers and a mask. In the clean area proper clothing, head and shoe covers is needed. In the dirty area street clothes may be permitted but it is a good idea to be properly clothed, as you may have to cross into other areas.

Clothing

Clothing for short-term jobs in the OR jump suits is generally available. These are Tyvek, like what is used as a vapor barrier on new house construction, which is put on over street clothes. These are hot and uncomfortable after about 30 minutes. Right in the same area will be boxes of masks, head and shoe covers. The cone mask is easier to use over short periods but with either type of mask the nose stay needs to be bent over the bridge of your nose to get a good fit. This is very important if you wear glasses, as a bad fit on the mask will cause your glasses to fog over as you breathe. For longer-term stays in the operating room you should change into "scrubs" along with the mask, head and shoe covers. If you are assigned to the operating room you may want to have a special pair of shoes that is only worn in the OR, if you do that no shoe covers are required. If you go out of the OR to another area the "scrubs" need to be covered with a lab coat or gown or wrap and shoe covers put on.

Hands

You don't have to wear gloves when you enter an operating room but you should touch nothing. A good procedure to follow is to cross your arms across your chest as you move about the room. Someone in the room will direct you to the problem and tell you if it is OK to touch the device or if it has to be removed to be serviced. Never assume that you can touch anything in an active OR room. If the room is not active, after a case there generally is no problem in touching equipment. If the room is being setup for a case you should consider the room active and act accordingly.

Tools and test equipment

If you have to work on a device during a case you may have to wipe down the tools and test equipment with alcohol before proceeding. Try to avoid working on active equipment; spare equipment is probably available outside the room.

Movement

Move slowly and watch where you step. Watch out for power cords on the floor and fluid spills. Stay away from the sterile field unless specifically directed to it by the staff.

Speaking

Talk softly and directly to the person who asked you into the room, don't use terms like opps, oh oh or similar terms.

You should also be aware of smells in the OR suite. These could mean that the scavenger system on the anesthesia machines is not properly working, or the smoke evacuator filter needs changing or there have been fluid spills or leaks in other gas systems. Since the air in the operating room is changed 10 to 15 times per hour if smells persist there is a problem that needs to be corrected. It may not be a problem for the Biomed but you should be aware of it.

Hazards

All body fluids and tissue is considered hazardous material. In addition some of the prep solutions, items used during the operation, such as glues and sealant could be hazardous. More than one fire has been started by chemical reactions in the waste buckets in the operating rooms.

Trips and falls are also common in the operating room, as floors can get wet in addition to the power cords and gas hoses on the floor, so be careful walking. If someone does trip on a power cord the device and power plug should be inspected to assure that no damage was done to either. Electric shocks are not common but do happen, they can generally be traced to a fluid spill over a defective power cord or plug.

Radiation exposure is possible from all the x-rays that are taken in the OR and from radioactive implants that are put into a patient. Most x-ray devices are well collimated and there is very little scatter or x-ray but it is still a good idea to be a minimum of 12 feet away for both the generator and the target, (patient). The last hazard to be aware of is physician or nursing egos. The staff can be under great stress and become abrasive and obnoxious to the "lesser" staff. In their minds they can do no wrong and everyone else just contributes to their problems. When this starts it is time to leave the area until they cool down.

Isolated power system

Although no longer required by code, many hospitals have isolated power systems in operating rooms and occasionally in an ICU. The intent of isolated power systems was to prevent a single fault from shutting down an essential electrical circuit, to reduce the potential of leakage currents effecting a patient and to prevent sparks that could cause anesthetic agents to explode. Most if not all hospitals have banned the use of explosive anesthetic agents. Modern device designs have reduced the problems associated with electrical leakage currents and the potential for single faults shutting down an essential circuit. Basically the need for isolated power systems is no longer present but they remain in place. Newer construction and renovations to operating rooms generally do not contain isolated power systems.

In an isolated power system there is no true ground. There is a reference ground relating to the hot and neutral. Since there is no true ground leakage current measurements cannot be made on devices powered from isolated power systems. They must be tested at a non-isolated power connection. This often means that the testing has to be done outside of the operating room, possibly in the corridor or in a workroom.

The isolated system will monitor the total leakage current between the legs and the reference ground and will sound an alarm when that current exceeds 5.0 milliamps, a red light will also illuminate. When the

Biomed Certification Study Guide
By Dave Harrington

leakage current drops below 5 the isolated system will automatically reset. In some older installation the alarm level may be 3.0 milliamps. This is called a line isolation monitor. If a fault occurs the accepted troubleshoot technique is to start unplugging devices from the circuit. Devices with motors, compressors or heaters are the most likely source of the extra leakage currents. Ask the staff which devices can be unplugged before doing so.

Becoming more common in operating rooms are ground fault indicator outlets, GFI. They do shut down the device if the fault leakage level is exceeded and there is no alarm tone. Isolated power systems and the line isolation monitors are the responsibility of the electricians and should not be worked on by Biomed.

Laminar Flow

In some hospitals the operating room(s), designated for orthopedic cases. In this type of an installation filtered air is blown from the ceiling downward around the patient and operating room team. This increases the positive pressure in the room preventing microorganisms from getting into the room. This is a noisy system and may not be used on all cases in the room. These are not generally covered by Biomed, as they are part of the facility equipment.

Germicidal lights

Some hospitals place germicidal lights over the doors leading into operating rooms, central supply and processing areas and other areas. While the effectiveness of these lights in killing bacteria is open for discussion they present a danger to the staff. Looking directly into the lights, even up to 10 feet away can cause burns to the cornea. The proper protective eyewear must be worn if servicing these units.

REVIEW QUESTIONS

- 1 What is the upper fail-safe limit of a hyperthermia unit?
 109° F, upper test limit is 105° F
- 2 General anesthesia is defined as?
 No sights, sounds, memory or pain
- 3 A vaporizer on an anesthesia machine is used to?
 Converts a liquid agent to a gas
- 3a Who can calibrate or repair a vaporizer used on an anesthesia machine?
 Only people specifically trained and with the correct equipment
- 4 What is the “pin index” system?
 Prevents mistakes in using “E” gas cylinders
- 5 What is the leading edge effect in electrosurgery?
 The majority of the heat at the dispersive electrode is at the edge of the pad closest to the operating site.
- 5a Is smoke generated during laser surgery dangerous?
 Yes, it can contain both bacteria and viruses
- 6 Can a leakage test be performed on a device if it is plugged into an isolated power system?
 No because there is no ground reference
- 7 What indicates the start of the sterile area in an operating room suite?
 In most hospitals a red line on the floor or wall
- 8 What is an indication that the filters on a scope washer need to be changed?
 Getting low pressure alarms

Biomed Certification Study Guide
By Dave Harrington

- 9 What is the frequency range of solid-state electrosurgical devices?
 They range from 350 to 700 kHz depending upon manufacturer
- 9a Can an electrosurgical device ignite drapes used to cover patients during surgery?
 Yes and often
- 10 What is a capnograph used for?
It measures expired carbon dioxide, which indicates how the lungs are working

CRITICAL CARE/INTENSIVE CARE UNITS

As technology advanced in healthcare, in the 1950's, decisions were made to put the technology into confined areas instead of dispersing it throughout the hospital. This led to the creation of the first intensive care unit, with patient monitors at Bethany Hospital in Missouri in 1959. Certain patients had a much better outcome in intensive care than those that were left on the general floor. Remember that this occurred 4 years before the DC defibrillator became available.

Over the next few years, as additional units were installed in other hospitals the separation of patients started to take place. It was found that cardiac patients did better in units that were quiet with low lighting and a slower pace. Surgical and trauma patients did better in areas with brighter lights, more noise and a faster pace of activities, it was thought that this stimulated the patient and help them regain a sense of normalcy, if possible, in an ICU setting. In smaller hospitals the units may still be combined, with cardiac patients on one-side and surgical/trauma patients on the other. Many of the surgical/trauma patients are transferred to larger hospitals, as are the very critical cardiac patients.

In larger hospital there maybe a number of intensive care areas, cardiac (CCU), surgical (SICU), cardio/thoracic (CTU), medical (MICU), Neuro (NCU), neonatal (NICU), respiratory (RICU) and while not officially an ICU, for reasons of reimbursements, areas where bone marrow and gene therapy patients are treated. In some very large hospitals there may be an area just for patients with infectious diseases where they are quarantined from the general hospital population. In smaller hospitals these patients are often put into isolation rooms that are part of an existing ICU.

IN ALL INTENSIVE CARE UNITS IT IS VERY IMPORTANT TO FOLLOW THE UNIVERAL PRECAUTION PROCEDURES THAT THE HOSPITAL HAS IN PLACE. THIS IS FOR BOTH YOUR AND THE PATIENT'S PROTECTION.

In the typical ICU setting the nurse to patient ratio varies with the acuteness level of the patient. It can range from multi-nurse to a patient to 2 or 3 patients per nurse. Many states have set minimum staffing levels for the ICU. The nurses and other staff in these settings are under considerable stress and may not always be friendly to the Biomed. They need and expect their equipment to work and work the same way every time they use it. This can contribute to stress levels of the nurse, which is not good. Our job is to assure that the equipment is properly working and that it does not make their functions more difficult. The patient is their first concern as is ours. It is sometimes difficult to get to the equipment in the ICU areas as the beds are occupied almost all the time.

In the mid 1990's a study was done that showed that an occupied ICU bed generates billing of between \$7,500 and \$9,500 per day for the hospital. Keeping those beds full and the equipment working is a major source of revenue for hospitals. This also contributes to pressure on Biomed to get the PM's done without effecting patient care in the ICU.

Physical requirements

Electrical

Most states have set minimum requirements for an ICU. Typically the room size per bed is 100 to 120 square feet. Most are separate rooms with glass walls so patients can be observed from other rooms or common areas. Drapes are installed for patient privacy especially during procedures or the time around death. If TV cameras are used to monitor patients, not visible from a central point, it can present a privacy problem that has to be resolved at the administrative levels not at the technical level.

Electrical outlets commonly number in the 20's and they are divided into several circuits. Most outlets will be connected to emergency power sources, designated by their color, generally red but could be white. All outlets should have the circuit number on them which so resetting the breaker is easy. The Biomed should make it a point to know where the breaker panels are in all ICU areas.

Biomed Certification Study Guide
By Dave Harrington

Some outlets in the ICU are “dedicated lines” in that no other equipment can be plugged into that circuit, these are generally for monitors and computers. Unfortunately it is not unusual for other outlets to be connected to the circuit making it non-dedicated. As part of the PM process in an ICU it is a good idea to be sure what is plugged into what circuit. Making sure that the monitors and computers are on dedicated lines, if present, is also a good idea. Circuit overloading is not uncommon so be aware of it and work with the staff on what can be plugged into what outlet. Occasionally a problem of a noisy ground will affect a monitor or other device, a wide baseline is a common indicator of the problem on a monitor and error messages on a computer. This can be corrected generally by using another outlet. The offending device should be located and corrected. It also could be a defective outlet or aluminum wiring.

In areas that have isolated power systems or equipotential grounding their maintenance should fall under the electrical shop. The Biomed may have to diagnose the problem but if it relates to the AC wiring, a licensed electrician must do the corrections.

Emergency power

As previously discussed some or all outlets in the ICU will be on emergency power. This means that if there is an incoming power failure, the electric company, that the hospital’s generator(s) will provide power to those outlets within 10 seconds of the disruption of the incoming power. Unfortunately some users will confuse a blown circuit breaker with the loss of power and will not respond assuming that the power will be back in 10 seconds. This is an education issue that should be covered in the nursing orientation and in the yearly safety fairs.

Gas and Suction

There will be a number of compressed gas outlets on the headwall in each ICU bed area. There will be one or more air outlets, one or more oxygen outlets, possible a nitrogen and a nitrous oxide outlet, which is not very common. The pressure at these outlets should be 50PSIG +/- 2. The fittings to connect the hoses from the gases to the devices are specific to the gas so cross connections are not possible, exterior to the wall. If work is performed on the central piping system the outlets should be tested for the correct gas, water content, (dry), and particulate matter. If either the air or oxygen has water or particulate matter in them it will affect the filters on the ventilators and can cause failures.

If the failure rate on ventilators is high it often is an indication that the gases are not clean. They should be tested and any problems found corrected. Another indication of particulate matter in the gas is discolored flow tubes for oxygen and air.

If the ventilator being used requires compressed air and it is not present on the wall a compressor has to be used. Some ventilators have a built in compressor but most do not. The external compressor needs to be plugged into AC and may have a large enough current draw to limit what else can be on that circuit, a common source of an open circuit breaker. If no central oxygen source is available tanks must be brought to the ventilator. These tanks, generally 2, take up considerable floor space near the patient’s bed.

Nitrous oxide, if present on the wall outlets, is used in place of or in addition to painkillers on critical patients. This is not a common practice and if used a scavenging system is needed to remove the expired gas from the room so it does not affect the staff.

Nitrogen, if present, is used to power tourniquets or similar devices.

Suction outlets

The number of suction outlets on the headwall varies with the type of intensive care unit. In a surgical or cardio-thoracic unit suction is needed for airway, gastric and possibly wound and chest tube suction. In a coronary care unit possibly on airway and gastric suction would be used. The vacuum and flow requirements are the same as in the operating room.

Biomed Certification Study Guide
By Dave Harrington

Suction regulators are generally installed on each active outlet. The regulators may have a selector for either constant or intermittent suction function and an off position. The constant setting is used for airway, gastric and chest tube applications. The intermittent selection is used for wound suction.

The suction level can either be totally adjustable or low, medium and high settings. The high settings are used for airway and gastric suctioning. The medium setting for chest tubes and low setting for wound suction. If proper techniques are not used the material from the suction canister can migrate back to the regulator. When this happens the regulator needs to be cleaned and possibly rebuilt.

When intermittent suction is used a timing device in the regulator turns on and off allowing airflow for 15 seconds and turning it off for 45 seconds. This may be a standalone device called a Gomco 765 suction unit. This unit can easily be identified, as it has no motor as other suction pumps have. There is a red light in the center of the panel and a high low switch to one side. This is sometimes called a Thermotic unit. It operates on the principle of air movement caused by heating and cooling. A coil in the unit heats up for approximately 45 seconds at which point the power to the coil is shut off and it cools rapidly. This cooling creates a suction airflow and pulls fluid from the wound site. These devices cannot be used for airway, gastric or chest suctioning. Blood buildup, post-surgery, is common and if the body cannot absorb the blood around the site this type of suction is needed. With the advent of microsurgery, especially on hand injuries this type of suction is too strong and the tubing too large so especially breed of leaches are used to remove the blood buildup.

Chest tube suction requires a water seal so that air does not enter the chest cavity. There are two reasons for chest tubes, one is open heart surgery where a catheter is placed inside the pericardium to remove blood that may leak from the surgery site, this is normally removed after 48 hours or less depending upon the level of bleeding. The second reason is to reinflate a collapsed lung. Here a catheter is placed in the chest cavity to remove air. This allows the lung to reinflate; it may take several days for the lung to heal enough to allow for the removal of the chest suction. Instead of a suction canister a device with built-in water seal is used. It is called a Pleurovac. It is plastic and hangs on the side of the bed.

WHEN WORKING ON ANY SUCTION DEVICE FOLLOW THE UNIVERSAL PRECAUTIONS PROCEDURES OF THE HOSPITAL.

Lighting

The lighting in an intensive care unit varies with the type of unit. Cardiac care units usually have lower levels of lighting background but stronger lights can be turned on at any bed location. Surgical intensive care units have higher background lighting in addition to the selectable brighter lights at bedsides. In a neonatal unit there may be a device called a transluminator. This is basically a light source with a fiber optic probe. When the probe is brought in contact or close proximity to the skin it is possible to see through the skin locating blood vessels and bones. This tool is used to locate vessels so IV catheters can be inserted. In the adult units there may be a device called a cold light. This is a light bulb in housing, generally with a fan for cooling, and a long Plexiglas rod that directs the light to a very confined area, less than 10cm in diameter. Its major use is to light an area of the body where a catheter is being introduced. Some models do not have the rod but use shutters to focus the light. On adults the light does not penetrate the skin. The housings of both units can become hot and have to be considered as a potential source of injury to the user.

Air handling and filters

Most intensive care areas are positive pressure environments. That is the air pressure inside the unit is higher than the pressure outside of the unit, which helps prevent microorganisms from entering the ICU area. This is accomplished with the air handling system of the hospital that also filters the incoming air. The air handling system can either use outside air or recirculate some or all of the air through a set of filters also called hepa filters. There are regulations on the number of air changes per hour in an intensive care unit but the physical facilities personnel handle those details. Some intensive care units may have isolation rooms. In this room the air pressure is negative to the adjacent area, which prevents anything from the inside of the room to get outside of the room. There is a second set of doors that separate the rooms with the outside room being positive pressure. Isolation rooms are used when patients are infectious to others.

Biomed Certification Study Guide
By Dave Harrington

If you have to enter such a room you must follow the posted signs for gowns, gloves and masks for your own protection. The sign may say “**reverse precautions**” which means you can become infected by the patient. “**Precautions**” means you can infect the patient.

If equipment is in the “reverse precautions” area **it must be cleaned and disinfected before being moved**. This cleaning is done by specially trained personnel and not by the Biomed. The Biomed can watch and direct the cleaning but should not do the cleaning unless specifically trained to do so.

Noise levels

It is not unusual for patients to complain about the noise levels in an ICU setting. Noise is generated by the monitor alarms and “QRS” beeping, plus other alarms and equipment running. Combined with the voice and phones it can get very noisy. Unfortunately the alarm volumes will get turned down or off. This generally is not a major problem if the nurse only is taking care of that one patient. But if 2 or more patients are under the care of a single nurse the alarms need to be audible. Some hospitals have gone to lights instead of sound for alarms but this often requires modifications to instruments and is not always possible. Alarms should never be disabled by the Biomed. Recent changes in HIPAA and JCAHO requirements limit the use of intercoms from rooms to a central location, which has led to the use of “enunciator panels” in halls that show a room number and any monitored parameter that is in alarm.

Monitoring Systems

In most intensive care units the monitors are connected via cables to a central monitor. This monitor displays physiological waveforms from each patient, usually just the ECG waveform but others may be selected, on most systems. The central monitor also displays the computed heart rate of the patient and may also display the heart rate alarm limits. On some systems if a patient has an alarm condition, all the traces for that patient, will appear on the central screen.

The central monitors also include an alarm recorder that will print out the waveform of the ECG and in some cases the parameter that is in alarm. This print out generally contains information from up to 8 seconds before the alarm event and 8 to 10 seconds after the alarm event. Most printouts also have alpha/numeric data such as patient’s name, time and date, what the alarm condition is and possibly other information. The alphanumeric information may now be limited due to HIPAA requirements.

Some central monitors have the ability to classify cardiac arrhythmia and alarm when certain events occur or when a certain number of those events occur. These may not be primary alarms but secondary ones. In some systems the arrhythmia detection is done in the bedside module. This type of a system requires extensive user training to be totally effective. It is not unusual for the staff to turn off some of the arrhythmia detection software. When responding to a trouble call on arrhythmia detection be sure that the alarms are on before doing any troubleshooting. Also be very careful on how you report any event where alarms were either turned off or had very wide limits set. This could become a legal case if there was a bad patient outcome.

On all systems there generally is a junction or interface device that the bedside units are wired to. This device needs to be on emergency backup power so the system will not fail when there is a power outage. The problem will surface during emergency power tests and must be corrected by plugging the unit into an emergency power outlet. These units are located in storerooms, under the desk or in the ceiling and may be difficult to locate. Their location should be documented in the unit and in the Biomed records.

Many ICU’s will have “slave scopes” located in various positions around the unit and in the nurses’ lounge. These are passive monitors that, generally, only display the ECG waveforms for the patients and indicate which patient has an alarm condition.

Some ICU’s may have interfaces between the monitoring systems and other systems in the hospital, such as medical records or billing. These interfaces are not generally part of the Biomed responsibility but you should know about them especially how and where they are connected to the monitoring systems.

Biomed Certification Study Guide
By Dave Harrington

Some monitoring systems provide for the connection of other devices via a modem/interconnect so that data from that device is included in data presented by the monitoring system. This is sometimes called a MIB or medical information bus. This is another area where responsibilities for service have not been clearly established. Because of the physical layout of some ICU units not all beds can be view from the central desk area. The line of sight viewing may be required in some states. To get around this problem closed circuit TV cameras are used. The positioning of the TV monitor is important so that the patient's privacy is protected. The position of the cameras and monitors may have to be approved by the Risk Manager. Who maintains the video system is often not clear.

When using closed circuit TV or slave scopes the hospital needs to be aware of HIPAA requirements.

Ventilators

Many patients in an ICU require the mechanical ventilation of their lungs. Some have a physical malady that prevents them from breathing on their own while others have had their ability to breathe effected by drugs that are injected. In either case ventilators take over the major effort of respiration for the patient. Ventilators fall into some general categories based on how the cycle between inspiration and expiration of gasses.

Some people use the term ventilator and respirator interchangeable. They are not the same. A respirator is a device that supplies or filters air in a harsh environment, such as the apparatus used by fire fighters where air is supplied from a tank. Another version of a respirator is the masks, with filters, used around chemicals or heavy dust.

Volume limited

In this mode a preset volume of gas is delivered to the patient regardless of the pressure reached in the lungs or the time required to complete the inflation. This is a simple system where a gas is drawn into a cylinder and then forced out of the cylinder and into the lungs. The cylinder is adjusted for the volume of gas desired. The motor is rate adjustable, generally between 5 and 50 breaths per minute. The drive mechanism is a cam that creates a rapid inflation of the lungs and allows for a longer period of time for the deflation of the lungs. In some cases the ventilator contains a "non-rebreathing" valve that opens to allow fresh gas into the cylinder, closes during inflation and opens to allow expiration of the gases from the lungs. One in the tubing set, which is disposable, has generally replaced this valve.

Pressure limited

In this mode a pressure limit is set where gas will flow into the lungs until that pressure is reached, regardless of the volume of gas delivered. In respiratory work the pressure measurement is in centimeters of water, see a conversion chart for PSI and mmHg. The timing system can be adjusted to provide a wide range of respiratory rates but with pressure limited systems it can be difficult to get the needed volume into the lungs as their physiology changes.

Time cycled

This is the most common mode as it combines both the volume and pressure limited methods of operation. In this mode the respiration rate is set, along with the tidal volume to be delivered, the upper pressure limit and the inspiratory/expiratory ratio. At a rate of 20 breaths per minute at a 1 to 2 inspiratory/expiratory ratio gas would flow into the patient for 1 second and 2 seconds would be allowed for the patient to exhale. It is assumed that the preset volume is inspired and that the upper pressure limit has not been violated. If the pressure limit was exceeded an alarm will flash but the flow continues into the patient for the prescribed time. A pressure alarm also generally means that the volume set was also not delivered. The non-rebreathing valve can be either active or passive in this type of a unit. With an active valve a small amount of gas is diverted from the inspiratory flow to a chamber that blocks off the expiratory path of the gases. When the inspiratory flow stops the chamber deflates allowing for the free passage of the expired gases. In the passive system a one-way valve, like a duckbill, is used. As the inspiratory flow passed through the valve it expands to block the path of the expiratory gasses. When the flow stops the duckbill returns to its resting size allowing the easy passage of the expiratory gasses from the patient.

Jet-High Frequency-Ultrasonic

This is the latest method and is used mostly on neonates but is starting to have some application in adults. It is very different from the others in that there is no inspiratory/expiratory ratio and no pressure limits to be set. The basic principle is a constant series of small volume pulses of gas is supplied to the patient. A CPAP unit, used by patients with sleep apnea provides a non-pulsed stream of air to the patient. This is not the same as Jet or High Frequency systems.

Controlled ventilation

This is a common mode of operation with a volume-cycled ventilator where the patient makes no effort to initiate respiratory effort. The ventilator delivers a set volume of gas at a set rate for as long as needed. Some units have a “sigh” level where every so many breaths or minutes the machine automatically provides the patient with a greater volume of gas. This feature was originally put onto machines to fully expand the lungs and prevent pneumonia or other pulmonary problems. It was also common on older anesthesia machines.

Assisted ventilation

This is most common with pressure-cycled ventilators. The patient will trigger the flow of gas by starting to inhale, at a preset withdrawn volume or negative pressure the ventilator will start the flow of gas to the lungs. The therapist as needed adjusts the trigger levels. These units are not generally used long term.

Assister/Controller

This is presently the most common type of ventilator used in an ICU setting. As the patient starts to recover they will make efforts to breathe on their own. This is called fighting the ventilator and is a clinical milestone in the recovery of a patient. Once that starts the staff will start to wean the patient from the ventilator. This is done by slowly increasing the amount of negative pressure or withdrawn volume required to trigger the flow of gas, (assisted ventilation). This weaning process can take from hours to months depending upon the patient’s condition. If the patient fails to initiate a respiratory effort in a certain number of seconds the machine will breath for them and continue to do so, (controlled ventilation), until another respiratory effort is made by the patient. A version of these units is common in home healthcare and rehab hospital settings.

Humidification

The gases delivered by the ventilator are too dry for the human body to moisturize on its own so humidity must be added between the ventilator and patient. In most cases sterile water is heated and the vapor drawn into the gas flow to the patient. Ultrasonic nebulizers are sometimes used instead of the heated system. Some ventilators have the ability to heat the tubing so that the temperature does not change causing “rain-out” of the vapor in the gases being delivered to the patient. On some older systems you still may find water traps where the “rain-out” collects in the tubing.

General information on ventilators

Ventilators are one of a small group of life support devices that if it fails death will occur unless there is intervention by staff and a replacement device available. With that knowledge it is paramount that the ventilators are kept in top working condition and manufacturers recommendations on PM’s be adhered to. Unless you have specific technical training on the ventilator you should only do electrical safety and visual inspections.

Most ventilators will be connected to both air and oxygen wall outlets at a pressure of 50 PSIG +/- 2 via color-coded hoses. These hoses have specific fittings on both ends to prevent cross connections. If wall outlets are not available for one or more of the gases tanks are used for the oxygen and a compressor for the air. Some ventilators have a built in air compressor. At the machines there generally are moisture traps and particulate filters in line with the incoming gases. The therapist will monitor the moisture level in the traps, emptying as needed, and the particulate filters are cleaned or replaced during the normal PM cycle. If there is a high moisture content or high particulate matter content it should be reported to the physical facility department because either the gases are not dry enough, there is a large temperature difference

Biomed Certification Study Guide
By Dave Harrington

along the piping runs or the compressors have not been properly serviced. Too much moisture or particulate matter in the gases will cause failures in the ventilator.

All ventilators have an arm that the patient circuit tubing is attached to. This takes the weight off of the tubing where it connects to the patient. Most of the tubing fittings are also specific sizes to make misconnection harder. On adult machines the patient connector at the machine is 22 mm and the patient end of the tubing has a 15 mm connector. These are slip fit connectors and are standard on all machines.

As part of the PM process the caster locks on the ventilator should be checked to assure that they are properly working.

Intra-Aortic Balloon Pump

The IABP is not found in all hospitals. This device does not assist the heart in pumping blood to the body but forces blood into the arteries that supply the heart muscle, which in turn increases the cardiac output of each contraction. The balloon catheter is positioned in the aortic arch. It is inflated, with Helium, by triggering off of the QRS complex or blood pressure waveform of the patient. Unless the patient is being transported the trigger signals are obtained from the bedside monitor. Cables are connected to the ECG and Pressure waveform out connectors and run to the inputs of the IABP. In some cases the ECG signal has to be reduced from the 1 volt out to the 1mmV input for the IABP, each monitoring system is different and the Biomed has to make up the correct cable. The clinician will adjust the delay time between the QRS complex and the inflation of the balloon. The Biomed **should not** do any of the timing adjustment.

It is a good idea to check the IABP during rounds to be sure that it is plugged in and charging when not in use. Batteries are a major fault point on this type of device. The helium tank is another problem area in that spare tanks are often not ordered. The Biomed may be asked to change tanks while the device is being used. Only do so if there is a clinician with you how can readjust the timing after you have completed the tank change over.

Left Ventricular Assist Device

The LVAD is a specialty device that assists the left ventricle in pumping blood to the body. This is sometimes used as a bridge to a heart transplant or to an artificial heart. These are not generally serviced by hospital based Biomedics other than electrical safety and visual inspections. Care needs to be taken to be sure that the electrical circuit that this unit is plugged into is not overloaded. Also the outlet must be on emergency power.

Extra Corporeal Membrane Oxygenation

ECMO units are basically cardiac by-pass pumps, see module on operating room equipment, that are used in an ICU setting to oxygenate the blood of a patient. The major difference between cardiac by-pass and ECMO is that in ECMO the heart is beating. Care needs to be taken to be sure that the circuit that the unit is plugged into is not overloaded. Also the outlet must be on emergency power.

Leg Compression units

After surgery or cardiac events it is not uncommon for a patient to have impaired venous return in the legs. The legs can be positioned so that they are higher than the rest of the body will help with the venous return; elastic stockings are also used. When the patient does not respond to those methods compression boots are used. The boot can be place on one or both legs. There are two basic systems in use, passive and active. In passive units the boots are slowly inflated to a selected pressure, held at that pressure for a number of seconds, then slowly deflated. This acts as a “milking” mechanism for moving blood from the legs. The boots can be hot and uncomfortable for the patient.

The active units, not in wide use, the legs are placed in a chamber where a bladder inflates based on the triggering of a detected QRS complex. These units do not sustain pressure on the legs or provide much of a “milking” mechanism.

Biomed Certification Study Guide
By Dave Harrington

In both systems the patient should be screened for blood clots in the legs before the unit is applied. Also leg hair can be painful if the boots are to be used for a long period of time.

When calibrating these devices a good pressure gage is needed with a “snubber” on it. A “snubber” smoothes out the rapid pressure changes so a more accurate reading can be made. The gage on the machine should read within 5 mmHg of the test gage.

Pulse Doppler

Pulse Doppler units are widely used in the ICU. Some of their uses include blood pressure measurement where it is difficult to use a stethoscope, detecting blood flow in the extremities and locating blood clots. Most of the units have 2 frequencies that are used, 9.2MHz for most applications and 7.2MHz for vessels that are deeper under the skin then can be detected with the 9.2 MHz probe. The units may have a speaker or headphones, some can use both. Some have battery chargers; some battery eliminators and others operate only on batteries. Some have adjustments that the user can make while others only have a volume control. These are durable units that take a lot of abuse without failure. But it is not uncommon for the probes to fail, or get lost. Gel has been known to get on the speaker causing strange sounds, with cracked cases also very common.

The simple way to test a unit is to place the 9.2 MHz probe on your wrist, where you feel your own pulse, and listen for the output. You should use gel to assure a good acoustic coupling and clear sound. You may have to move the probe around a little to pick up the pulsed flow of blood. The 7.2 MHz probe can be tested on the neck, where you feel your pulse, remember to use the gel for coupling.

The most common problems are batteries and broken probes. Unless there is a broken wire close to a connector probes are not repairable in the field. Connector wear also needs to be checked on each PM inspection.

ICU beds

Patient beds in the ICU can range from the very simple to very elaborate. Some hospitals ban electric beds from the ICU while others allow them. There is no national policy or guidelines about what beds can or should be used in an ICU. Any bed can be used in an ICU as long as the headboard can be quickly removed to give clinicians clear access to the patients head area and the bed can be placed in the Trendelenburg, head lower than the feet, and reverse Trendelenburg, head higher than the feet, positions. There are several types of specialty beds that are used in the ICU, which may or may not fall under the Biomed repair responsibilities.

Stryker Bed, (Frame)

This bed is used for people with spinal cord injuries. It is canvas straps and webbing on a metal frame that rotates. The patient is immobilized and strapped to the frame. When the patient is rotated another frame is secured over the patient at which time the patient is turned over and the original frame removed. The patient either looks at the ceiling or the floor and nothing else. This is a purely mechanical bed.

Circoelectric bed

This bed is similar to the Stryker bed in that it is used for spinal cord patients and the patient is sandwiched between frames when moved. The major difference is that the frame can rotate 270 degrees so the patient can be placed in many positions. The hoop that the patient frame is attached to is positioned using electric motors and a hand control that only the clinical staff use. A common problem with this bed is linen getting caught in the drive mechanism. When the patient is still on the bed the best way to get the linen out of the drive system is to cut it so as little fabric as possible is in the mechanism and then slowly move the mechanism to remove the rest of the fabric.

Century Bed

This type of bed has a built in scale for patient weight. These beds can go out of calibration with movement and require close monitoring of the scale accuracy. These may or may not fall under the Biomed repair responsibilities.

Sand bed or Air bed

In most hospitals these are rented for a specific patient. These are large and heavy with air being blown through ceramic pellets. This action reduces pressure points between the patient and the bed surface preventing or promoting the healing of decubitus ulcers on the patient. These beds have a heavy current draw and care must be taken not to overload the circuit that they are plugged into.

In addition to the specialized beds that may be in an ICU there are “add on” to the regular beds and stretchers used in the unit.

Water mattress

This is a heavy-duty vinyl bag into which water is poured. This bag is then placed over the existing mattress on the bed. The purpose is to reduce the pressure points between the patient and the bed to prevent ulcers and for increased patient comfort. One problem with water mattress is that they are not heated and can cause the patient to cool. When that happens the patient may require a hyperthermia unit or Bair Hugger to maintain their body temperature. A water mattress under a 200 plus pound patient will probably exceed the safe weight limit on the bed.

Air mattress

There are 2 types of air mattresses in general use. The most simple is similar to what would be used at a beach or camping. It is inflated with a pump and reinflated as needed. The second type has an external pump that cycles air into chambers in the mattress. There are some publications that suggest that this type of an air mattress helps the venous return of the patient. Some patients become motion sick on this type of a mattress. These units are generally rentals and are not repaired in house. Both types of units are placed over the existing mattress on the bed. They also have a low current draw.

Fluid pumps

It is not unusual for a patient in an ICU setting to have 6 or more fluid pumps connected. These pumps can supply basic fluids and electrolytes, nutritional support, antibiotics and pain medications. Some pumps can have up to 4 separate channels infusing fluid at the same time. All fluid pumps work on one of three principles, volume displacement, and roller peristaltic or linear peristaltic. The positive pressure generated by the various manufacturers' pumps can widely vary. All pumps should be able to overcome arterial pressures of a patient; most have a pressure limit of 500 mmHg (10 psig). Users can lower the pressure limits. Once the unit is turned off and on the pressure limit goes back to the default pressure that was set either at the factory or by the Biomed during an incoming, or PM inspections, pumps with lowered pressure limits are often labeled as “pedi”. On many pumps the output pressure also has a low limit and if that is passed an alarm sounds. This is commonly used as an infiltration alarm. An infiltration is when the catheter is no longer in the blood vessel but infusing fluid into the surrounding tissue. The clinical result of an infiltration is a restart of the IV, a lump where the infiltration took place plus a black and blue mark on the patient.

Some pumps require that the IV bag or bottle be a specified height above the pump. This is to assure that the volume chamber properly fills so delivered accuracy of the pump is maintained. The common complaint for improper height above the pump is that the pump is under infusing. All modern pumps have a method of detecting air bubbles in the fluid line and stopping the pumping action if they become a certain size. That size varies from manufacturer to manufacturer and the manual has to be checked for the limits on air bubbles. Most pumps will have an adjustment, not available to the user that the Biomed can change to increase or decrease the detection levels. On some units this circuit is also used to detect an empty bottle/bag.

Most pumps no longer have drop detectors that are clamped over the drip chamber of the IV set. These detectors can be an error point if the drip chamber is too full of fluid or the photoelectric cell is damaged or covered with crud.

Biomed Certification Study Guide
By Dave Harrington

IV pumps should not permit “free flow” when the administration set is out of the pump or when the pump door is opened without human actions, such as opening the clamp. This is a safety consideration.

Volume displacement

This type of an infusion pump requires a dedicated IV administration set, available only from the manufacturer. The administration set is placed in the device, often behind a door panel, and only can be installed in one direction. The displacement chamber may actually contain up to 3 chambers, 1 large and 2 smaller ones. The first small chamber traps air bubbles as it passes fluid to the center or largest chamber. As the main chamber empties it passes through the second smaller chamber, which acts as a capacitor to smooth out any fluctuations on the volume or pressure transmitted to the patient. The fluctuations occur when the main chamber is filling with fluid as it prepares to deliver another stream of fluid. The principle of operation is simple. The rate of delivery and the volume to be delivered is set via the control panel. This rate is, in cc or mL per hour, is converted into a pulse rate, which is the rate that the stepping motor runs. Each step of the motor will deliver a set amount of fluid by compressing the center chamber. When the chamber empties, the motor reverses and rapidly draws fluid into the chamber, (fill cycle), reverses direction again and starts to pump fluid to the patient again. This fill cycle is very short so the amount of fluid in the third chamber, still moving to the patient, smooth's out the very brief time it takes for the chamber to fill keeping the flow to the patient very steady.

Some units are able to handle a “secondary medication”, also called “piggy back”. These medications are administered via the same line to the patient but only for a short period of time, several times a day. The rates are set via the digital switches after the “secondary” option is selected along with the volume to be infused, some units will also allow for setting how many hours to the next infusion. The clinician will clamp off the main line and open the secondary line; alarms will sound when the infusion is completed so the care provider reopens the main line.

All pumps have what is called a “keep open rate”. This is a slow infusion of solutions, generally 2 to 3 ml per hour, after the volume to be infused setting has been reached, to keep a clot from forming around the catheter. When the pumps are in this mode there usually is a flashing indicator indicating KVO, (keep vein open). This will continue until the bottle is empty or the clinician makes changes on the pump's control panel.

Some volume displacement pumps are not suited for the administration of whole blood. Check the operator's manual for compatibility with the administration of whole blood.

Most volume displacement pumps will run for 45 minutes on battery power, be sure to check manual for how the flow rates effect the battery life.

Linear peristaltic pump

Instead of a cassette containing the pumping chamber this type of a pump uses straight tubing that on some manufacturers devices may have a special section of tubing, usually silastic, which the linear peristaltic mechanism “milks” the fluid through. Since this tubing is a known diameter the volume infused can be calculated by the number of times the lowest “finger” opens and closes. This is the same basic calculation that is used with a volume displacement unit. A major difference with this type of pump is that it has a “free flow prevention device”. This is a mechanical system to clamp off the tubing when the door is opened so the patient does not get a bolus infusion. New requirements indicate that there needs to be an automatic clamp to prevent free low when the set is removed from the pump. The rate of infusion and infused volumes are set the same as on the volume displacement pumps, as is the secondary infusions where present. The battery life is about the same as are the infused pressures that can be generated.

As the peristaltic mechanism wears it can affect the accuracy of the delivered volume, it is important that the delivered volume be part of the PM testing. With normal use these pumps will last for 5 to 7 years before major rebuilding has to take place on the pumping mechanism. The most common indication that the mechanism needs rebuilding is the infused volume delivered during testing is greater than the tolerance allows.

Biomed Certification Study Guide
By Dave Harrington

Most of the manufacturers of these pumps indicate that the infusion of whole blood should not be one of the fluids pumped, but check the manuals to be sure for each model.

Roller peristaltic

In this type of a pump a special silastic tube is stretched around a series of rollers. The volume of fluid in the tube is known between the rollers so the machine can calculate infused volumes. The infusion rate is selected via digital switches, which sets the frequency of the pulses to the stepping motor that drives the rollers. The pressure adjustments are minimal as the occlusion pressures of the rollers are mechanically set. Very few of this type of a pump are used for the administration of IV fluids; most are used as feeding pumps.

Feeding Pumps

There can be some confusion as to what constitutes a feeding pump. Some patients are fed using a TPN solution, which means "Total Prenatal Nutrition". TPN is a mixture of a high concentration of dextrose, over 30%, amino acids, multi-vitamins and lipids that are administered via a major vein, using an IV pump, directly into the blood stream. A central line, a catheter feed into the vena cava, is commonly used with TPN. Patients can be fed via this method for years as long as the catheter does not become clogged or infected.

The "gastric" feeding pump is not an IV fluid pump, but a specially designed device for "tube" feedings. The pump handles a high viscosity fluid and air bubbles are not a concern nor is long-term accuracy. The term "tube feeding" originally meant a tube was inserted via the mouth or nose into the stomach and fluid, similar to baby formula, was poured down this tube to provide nutrition to a patient that was either unable or unwilling to eat.

It is more common now for a catheter to be surgically placed directly into the stomach or other part of the intestinal tract that a feeding pump is connected to. This is less traumatic for the patient and those that visit them. Several times a day the nutritional formula is pumped into the patient and when completed the pump is disconnected. But before being disconnected a flush of water should be used to clear the catheter so the formula does not solidify in the catheter causing high backpressure that the pump may not be able to overcome. A commonly reported problem with feeding pumps is that the occlusion alarms are constant. In most cases when you test the pump it works properly. This is an indication of an occluded catheter that was not properly flushed after the completion of a feeding. The medical staff will insist that the pump is not working correctly, as they do not want to place another catheter. With proper care these catheters will last for years.

PCA Pump

Patient Controlled Analgesia, PCA, is administered via a specially designed pump that provides a continuous flow of an analgesia drug to a patient, but the patient may trigger a larger dose if they are in pain. These pumps have a mechanical lock over the drug chamber, to prevent theft, and a code required to change flow rates, to prevent overdosing of the patient. Most Biomed shops will have a key to open the lock and a default code to set the pump up for testing. The key must be closely controlled so that it does not get lost.

The process varies from hospital to hospital but it is most common for the pharmacy to install the agent into the pump and set the prescribed flow rate before being delivered to the patient. Once connected the patient can increase their dose by pressing the delivery button. There is a system that allows only for one or two "booster doses" per hour, regardless of the number of times the delivery button is pressed. Most pumps will have a "data dump" port where a printout can be obtained on the number of times the patient called for extra drug.

Syringe Pump

A syringe pump is used when fluid to the patient has to be limited or a very precise amount of a drug is to be administered. One of the most common uses is for the administration of epidural anesthesia. These

Biomed Certification Study Guide
By Dave Harrington

pumps can be battery or line operated. Units may take standard lead acid C or D cells while others have rechargeable battery packs, while others may use “battery eliminators” for long term cases.

Most units will require the programming of the pump, via the control panel keypad, for syringe size, (10 to 60 cc), flow rate and delivered volumes. The clinical staff only does the programming of the pump, but the Biomed must know the programming procedure so they can troubleshoot or calibrate the units.

Some of the most common problems with syringe pumps are the clutch slipping which causes the under infusion of the drug, broken latches so the syringe does not fit securely onto the pump and bad batteries. User abuse is very common as the pumps are dropped on a regular basis.

Dialysis

Dialysis is defined as the diffusion of solute molecules through a semi permeable membrane, passing from the side of higher concentration to that of the lower. Most membranes of the body’s cells are semi permeable allowing the passage of smaller molecules such as crystalloids of glucose and urea. Many bodily processes such as digestion, urine formation, respiration and the distribution of nutrients depend in part on dialysis. If the kidneys fail or become inefficient the result is a buildup in the blood of potentially toxic bi-products of the cellular dialysis process. Those bi-products can be removed via hemodialysis or in some cases peritoneal dialysis.

Hemodialysis

In most ICU’s one or more beds are setup to allow for the use of a hemodialyzer. This includes connection to water, both hot and cold so the correct temperature can be obtained and a drain for the wastewater. Because the dialysis unit will have a reverse osmosis water treatment system attached it should not be plugged into an outlet that has other equipment on that same circuit, as the current flow can be high.

The patient circuit is installed into the machine and connected to the patient, blood comes from an artery is pumped through the dialyzer membrane; heparin is added to the blood to prevent clotting and back into a vein. The other side of the membrane has dialysate that has been diluted by mixing the concentrate with treated water in a proportioning pump, which is heated to body temperature and checked for conductivity before moving through the membrane. The crystalloids pass from the blood to the dialysate and down the drain. It takes several hours for the process to be completed. The length of time is determined by blood chemistry and weight reduction. During this entire process the patient remains either in bed or in a recliner chair. Once connected to the machine they cannot walk around.

Most membranes are reprocessed and can be used up to 20 times on the same patient. Other patients should not use them, after reprocessing. This work is done outside of the ICU and not by Biomed.

Peritoneal Dialysis

Peritoneal dialysis can be administered in any clean location; it does not require water or drains. It is possible to perform without any electronic devices. A cyclor is commonly used for peritoneal dialysis. This device heats the dialysate solution and controls the flow into the peritoneal cavity, via a catheter, where the peritoneum acts as the membrane for dialysis. After a period of time, 2 to 12 hours, the flow is reversed and the fluid comes back to bags on the cyclor where it is weighed. The weight of the used dialysate indicates how efficient the treatment has been. The weight is entered into an “exchange record” for that patient. Since no membrane is required this method is less expensive than hemodialysis but is not always as efficient in getting toxic material out of the body.

A variation that is becoming more common is the closed peritoneal dialysis procedure. This is basically a self-administered treatment. The dialysate is infused into the peritoneal cavity; the catheter has a two-way valve on it so that the solution can be drained back into the same bag after the necessary hours in the peritoneal cavity. The patient weighs the filled bag, records the results and starts another cycle. This is sometimes referred to as CPD, (constant peritoneal dialysis) or CCPD; (constant closed peritoneal dialysis). This is an ambulatory procedure not requiring hospital or clinic visits once the patient is trained.

Refractometer

A refractometer is a simple device that is present in most ICU's and on many general patient floors. At first glance it may appear to be a microscope to many people, and in some ways it is. It is used to measure the specific gravity and check for solids in body fluids, mostly urine. A drop of fluid is placed on the viewing lens and the cover placed over that. The clinical person looks through the eyepiece and gets the specific gravity from calibrations on the lens and views any solids in the fluid. The common problems with this unit are that the bulb burns out or the cover gets broken. If the unit is dropped the lens may crack or an air bubble may develop behind the lens. These are not repairable in the field and the unit will have to be returned to the manufacturer for repairs.

You will encounter other devices in an ICU setting that are not covered in this or other modules. When that occurs you need to ask questions of the personnel using the devices, review the manuals and if the devices are common in your facility request that a test procedure be prepared for PM's on those devices.

It is also a good idea to visit the ICU on "rounds" every day or every time you are at that hospital, to pick up simple problems before they become major problems. Rounds are an effective method of getting known by the staff which will greatly help when you have to get the PM's done in the unit.

REVIEW QUESTIONS

- 1 After the loss of electrical power from the outside source how long before the emergency generators should start?
 10 seconds or less
- 2 Should a Biomed adjust the timing of an IABP?
 Never
- 3 What is the most common type of a ventilator used in an ICU regardless of manufacturer?
 Time cycled/volume limited
- 3a At TiM who is allowed to perform repairs on ventilators?
 Only those who have completed factory training
- 4 What is a clinical danger with the use of leg compression units?
 Moving blood clots from the legs to the lungs
- 5 Can the dialysis membrane be reused?
 Yes, but only on the same patient after "reprocessing"
- 6 What is the most common upper pressure limit of an IV pump?
 500 mmHg
- 7 What is the frequency of a pulse Doppler used for blood flow detection in an ICU?
 9.1 MHz
- 8 What is the pulse Doppler used for?
 To detect blood flow, to locate venous clots near the surface, to detect blood pressures when a stethoscope cannot be used
- 8a Are feeding pumps and infusion pumps the same?
 No

Biomed Certification Study Guide
By Dave Harrington

9 Why are humidifiers used on ventilators?
Compressed gases are very dry and if no humidification is supplied the lungs would dry out.

10 Why is there a “keep open rate” on an IV pump and what is that rate?
This allows some time from the completion of an infused volume for the nurse to change solutions containers without the catheter becoming clotted.

LABORATORY EQUIPMENT

Laboratory equipment in hospitals falls into two main groupings, clinical and research. This section concentrates on the clinical laboratory equipment but the same principles of operation are applicable to many research devices.

In the simplest terms laboratory equipment perform one or more of the following functions

Measure	using light, ions, conductivity, weight, and color
Separate	using electrical or rotational force
Count	cells, particles, and events
Change temperature	heat or cool
Display the results	on CRT, digital display or paper
Communicate	with other devices or computer systems

How the samples are prepared, delivered and measured is covered in the various equipment descriptions of this module.

Because of high capital costs and changing technology many of the larger devices are not owned by the hospitals but leased or obtained on “reagent rental” basis. Reagent rental is also called per test rental/lease. On non-hospital owned equipment service support is generally part of the lease/rental agreement so we only do incoming and visual inspections. In some cases we may provide a “first look” before calling the outside repair service. First look is limited to verifying error codes that are displayed and clearing any external problem that we are trained to perform. Unless you are specifically trained on the device and authorized by the manufacturer do not try to perform the repairs.

ALL LABORATORY EQUIPMENT SHOULD BE CONSIDERED, AS HAZARDOUS AND PROPER PRECAUTIONS MUST BE OBSERVED WHEN WORKING ON THESE DEVICES.

Clinical analyzers, discrete, continuous flow, automatic, semi-automatic or manual all contain 6 basic functions that can and do cause problems. Some units may have 2 extra parts that do not generally cause problems, for Biomed. Those are a system port and a self-check/calibration function.

The Basic Functions

Sample prep

The sample may be diluted or mixed with a reagent, or filtered. This may be an automatic process where the samples are placed into special trays or racks and loaded into the analyzer.

Sample introduction and transport

The prepared sample is aspirated or injected into the analyzer where it may be further diluted or additional reagents added and moved to the detector chamber. In discrete systems this is done with an internal pipetter and with a continuous flow system the samples are separated by air bubbles or water.

Detector

This can be ion specific electrodes, photometer, counters, conductance measurements or any combination of these detectors.

Processor

A microprocessor where information from the detectors is compared, processed and calculations made automatically.

Flush

This automatically cleans the transport system and detector so the next sample is not contaminated by the sample just processed. On continuous flow systems the flush is part of the sample separation system. On some units there is an additional flush that occurs after a set number of samples processed or time.

Display/printer

The results of each test on a sample are displayed on a CRT or printed onto a paper format. Some devices may have both. If the printer is external to the device it may be part of the Biomed service responsibilities. Each hospital is different so check first before working on them.

Some devices may have the following parts.

System Connector

This communication port allows for information to be directly sent to medical records, billing and to other systems in the hospital. Information Systems personnel generally handle this interface. You should keep up with HIMSS changes and interconnections.

Self-check/calibration

Automated systems have this function built in and they are run one or more times per day/shift. When present this is a valuable source of information and needs to be checked before any troubleshoot is started.

External power conditioner or UPS

While major units are on dedicated power circuits some do require power conditioners to assure stability of the power. In some hospitals a UPS may also be installed if the device cannot handle the power drop of 10 seconds or less between loss of power and the startup of the emergency generators.

You should take the time to list those laboratory devices that are on the emergency power system of the hospital. When doing so also be sure that peripheral devices used with a major device are also on emergency power, if not the analyzer may not work.

Blood Gas/pH Analyzer

With the wide spread use of pulse oximeter Blood Gas/pH Analyzers are not as common now as in the past in intensive care units and operating rooms. Even with a pulse oximeter blood gases are done on patients but less often. Blood gas samples are arterial blood so the patient either has an arterial blood pressure line in, (see Module 2) or the clinician has to perform an arterial “stick”. Because of the depth of an artery in the body this is a painful procedure and the “stick” may not clot off quickly leaving with patient with a hematoma and associated bruising.

The arterial blood is drawn into a heparin-coated syringe that is placed in ice if it is not to be analyzed in 2 to 3 minutes.

The sample is injected into the analyzer where it enters a constant temperature chamber (37 C) and is diluted. After temperature stabilization it then goes to the detectors, which have been previously calibrated with buffer solutions, where it passes 3 electrodes. These ion specific electrodes, one measures dissolved oxygen concentration in the blood, the second measures the carbon dioxide level and the third measures the blood pH. Once the readings are obtained the system flushes itself and injects a buffer to recalibrate the pH electrode and prepare for the next sample. Calibration gases may also be injected at this time to verify the accuracy of the other electrodes.

The results of the tests are displayed, either on a CRT or as numbers on a digital display and in most instruments on a printed record. On some units the results could be electronically transferred to the patient's medical record.

Biomed Certification Study Guide
By Dave Harrington

It is not unusual for Blood Gas analyzers to be located outside of the clinical laboratory area. They could be in Respiratory Therapy, ICU, OR/Anesthesia, in a Cath lab or EP lab. In these areas more problems will be encountered, as the users may not be well trained on the devices and rarely use them.

Common Problems

- Out of date buffer solutions
- No cal gases
- Poor flushing
- Paper jams
- Not taking the time to properly warm up the analyzer
- Bad electrodes

You should always do a self-test or auto calibration procedure before doing any troubleshooting on the device. These steps will generally indicate where the first problem is. After correcting the indicated problem keep doing the self-test and auto cal steps until all the problems have been cleared.

BE SURE TO WASH YOUR HANDS AFTER WORKING ON THE BLOOD GAS ANALYZER.

Bilirubinometer

In Module 3 there is a section on Photo therapy. In that section we talk about using light to break down the high levels of bilirubin present in some neonates.

Bilirubin occurs naturally as hemoglobin in worn out red blood cells break down and the liver is slow in processing these cells for disposal. The buildup of bilirubin causes jaundice, the yellow discoloration of skin, eyes and mucous membranes. Shortly after birth there is a high level of bilirubin until the immature liver can catch up. Most newborns will exhibit some level of jaundice in the first few days after birth. Most do not require treatment but the problem corrects itself. In adults jaundice is generally not self-correcting and interventions is required.

Because the blood sample used to detect bilirubin has to be processed in less than 10 minutes from being drawn Bilirubinometers are generally located in clinical areas not in laboratories. The Bilirubinometers used for testing neonates will no work on blood samples from older children or adults. Keep this in mind when you get trouble calls on Bilirubinometers from other then neonate areas.

For neonates a whole blood sample is placed into the detection chamber were light in 2 wavelengths is used to do the measurement. The absorbance of light at 455 nanometers is proportional to the concentration of both bilirubin and hemoglobin while the absorbance only measured at the 575 nanometer wavelength. When these numbers are compared and the bilirubin level displayed.

In older patients, from about 3 weeks up, whole blood cannot be used as the natural pigmentation of blood changes with age. In older patients blood is diluted with a diazo reagent before being tested. It should also be pointed out the light does affect the samples so they must be protected from light during transport from the patient to the machine.

Common problems

- Light burned out
- Dirt or spills on mirror
- Old samples
- Wrong patient age for machine
- Users not properly trained on the specific device.

BE SURE TO WASH YOUR HANDS AFTER WORKING ON A BILLIRUBINOMETER.

DO NOT LOOK DIRECTLY AT THE LAMP AS IT CAN CAUSE EYE INJURY.

Clinical Chemistry Analyzer

Clinical Chemistry Analyzers determine the concentrations of electrolytes, proteins, metabolites and drugs in samples of serum, plasma, urine or other body fluids. Depending upon the make and model of the device it will have between 3 and 255 preprogrammed tests that it will perform.

In automated discrete systems the fluid sample is placed into a rack or cassette where it may be diluted or have reagents added and mixed with the sample. During this process the samples could be warmed to match the temperature that is in the detection chamber, on some devices. The samples are identified and the record started. Bar Codes are generally used to identify the sample and patient that the sample came from. The sample is moved to the detection chamber. On some units only one sample is tested at a time while on others multi sample are tested at the same time. Where the sample is carried in a cassette it is moved past the detectors in a sequence that allows for the treated sample to be tested by the various detectors and with varying reagents. With this system scratching on the cassettes can cause problems on certain tests and the mechanical positioning is critical.

More common is for the treated sample to be aspirated into the detection chamber, where the ion specific electrodes and spectrophotometry is performed. It may take several samples to complete all the tests as different reagents could be used. After each sample is tested the detection chamber is flushed before the next sample is aspirated. If the flush is not total there can be "carry over" from the previous sample that could affect the results. In some units the samples are divided and separated by water so the flow is continuous into the detection chamber. The water used to separate the samples also serves as a flush. As the tests are performed the results computed and compared with normal limits before the results are printed/displayed. On some units any result outside of a normal limit is printed/displayed in a different color. Units can be connected to the hospital information system to send results back to the clinical floors/offices, to medical records and to billing.

If the report printer is not built into the device it may become a service issue in some hospitals, who takes care of the printer, is it part of the contract on the device, a separate Biomed device or part of information services is the question that will come up.

On many of the Clinical Chemistry Analyzers power conditioners/UPS and water treatment/filters may also be connected to the unit. Again there is a question of "ownership" when it comes to servicing these external devices.

Common Problems

- Mechanical positioning of cassettes
- Loss of aspiration pump
- Inadequate flushing between samples
- Dirty detection chambers
- Paper jams

BE SURE TO WASH YOUR HANDS AFTER WORKING ON A CLINICAL CHEMISTRY ANALYZER.

DO NOT TRY ANY REPAIRS WITHOUT PROPER MANUALS AND SPECIFIC TRAINING ON THE DEVICE.

The same principles and problems are present in all clinical analyzers if they only do a few tests per sample or many. By following the same troubleshooting procedures most problems can be corrected without a service call to the vendor. Lastly be sure to use the self-test/calibration features on most devices before starting any additional troubleshooting, the problem is usually defined and the remedy outlined in the service manual.

Centrifuge

A centrifuge is a simple device based on the principle that rotating a liquid at an angle will separate particles and liquids of various densities. From this simple principle a multitude of devices have been designed. They vary in size, in speed of the rotation, how long they will run, temperature and angles of rotation that the samples are subjected to.

The simplest centrifuges have a single speed motor, a mechanical timer and a rotor that holds the samples at a preset angle of between 20 and 40 degrees. The lid of the centrifuge should have an interlock on it so that the unit will not spin with the lid in the up position. This is for user safety.

A simple rotor is made from metal with 4, 6 or 8 holes drilled into it at an angle where the samples are placed. Balancing the rotor is very important, if the user has only a few samples to be spun down they may have to use “dummy tubes” to properly balance the load. Since the motor shaft is what the rotor attached to any unbalanced load can cause motor damage and uneven speeds.

Another type of rotor has sample carriers that are vertical at rest but when spun move to the 20 to 40 degree angle as set by mechanical stops on the carrier.

Another type of rotor has arms to which baskets are mounted, these baskets have space for a number of sample tubes and during rotation the baskets move to a preset angle.

Rotors need to be inspected on a regular basis looking for cracks in the metal as a rotor break can cause injury to those working in the area. Particular attention has to be paid to centrifuges that have rotors that can be changed out. The users have been known to not fully tighten down the knob securing the rotor to the motor shaft causing severe damage to the device and lab when the rotor broke loose while spinning.

Rotation Speed

The simplest centrifuges have a single speed ranging from 2,500 to 10,000 RPM. Unfortunately many are not clearly labeled as to what their speed is so the users can make mistakes. When a centrifuge receives its incoming inspection a tag should be placed on the unit indicating what its set speed is. This speed should be verified at every PM inspection and after brushes are changed. Some units may have two speeds that are switch selectable, in this case both speeds need to be verified and marked on the tag.

The simplest variable speed centrifuges will have a rheostat speed control, which may be non-linear. A common practice with variable speed units is to mark one or more points on the speed indicator with a measured speed. Most of the newer variable speed centrifuges do have built in tachometers that provide the users with a speed indication. Where there is a built in tachometer it should be checked for accuracy at incoming and at each PM inspection, the measured speed should be +/- 5% of the indicated speed.

Other speed control systems can involve SCR's, stepper motors and servo systems. Again they must be verified on a regular basis to assure quality results. On larger units and ultra-high speed centrifuges drive belts between the motor and rotor are not uncommon. Drive belts have to be inspected on a regular basis to assure both accuracy and user safety.

Low speed centrifuges have RPM rates up to 12,000 RPM, high-speed units go up to 35,000 RPM and the ultrahigh speed can reach 125,000 RPM.

Most high speed and all ultrahigh speed units are refrigerated because the friction caused by the air on the samples will dry them out and change results. As part of the normal PM inspections the accuracy of the

Biomed Certification Study Guide
By Dave Harrington

temperature indicator is checked. The refrigeration personnel at the hospital can do repairs to the refrigeration system on a centrifuge; it should not be done by the Biomed. Temperature measured should be +/- 5° C.

Timer

Centrifuges have a timer that is either electronic or mechanical built into the controls. Depending upon the centrifuge the time can be set from seconds to days. If no time is selected generally the centrifuge will not run. Also the centrifuge may have a time delay on the start where it will not start to spin for several seconds after the RPM rate and timer are set and the start button pushed.

Mechanical times do break and do need lubrication from time to time. It is suggested that lubrication of the timer be done during a PM inspection. The accuracy of the time should also be checked and anything more than +/- 5 seconds, at 60 second setting needs to be corrected. For times between 1 and 59 minutes use +/- 10 seconds.

Electronic timers are more accurate and also need to be checked during the PM inspection. For times less than 60 seconds use +/- 3seconds, from 1 to 59 minutes uses +/- 10 seconds and for those times over 60 minutes uses +/- 30 seconds.

Brushes

Most centrifuges use carbon brushes to make electrical contact with the rotating part of the motor. These brushes wear down over time and need to be replaced. They should only be replaced with brushes of the same size, do not use undersize brushes as they may wear unevenly and score the shaft of the motor. Brushes are held against the shaft via spring pressure, if the spring weakens, breaks or is missing the motor may not spin. If the caps holding the brushes in place become loose or cracked that can also cause the brushes lose contact and the motor will not run at all or will not run consistently.

Brushes that are installed properly and with the correct tension make the brushes wear evenly and have a bright almost shiny look on the contact end. If the brushes are defective or not making good contact the contact face of the brush will be dull and not smooth. **Both** brushes should be removed from the unit and **compared** when troubleshooting. Dust from brushes should be clean out of the centrifuge during the PM inspection process.

Braking system

If the rotor was left to stop on its own, it could take a long period of time for the rotor to drop from 100,000 RPM to stop. To cut the time most units have a brake designed in. This is not a mechanical device, as on your car, but a switch that reverses the electrical field in the motor to get the motor spinning in the opposite direction. The operator has to energize the switch and should only hold the switch in the "reverse" or "stop" position for a few seconds at a time. In some very old and low speed centrifuges there may be a mechanical brake that is applied by pushing a lever, these are rare.

Cover interlock

All centrifuges produced after 1990 are required to have an interlock system that does not allow the rotor to spin unless the cover is closed. Some of these interlock systems are very simple; a solenoid that pushes a rod through a hole in the cover latch is common. Other are more complicated and may involve several solenoids, flexible cables and a clock. The clock can be tied to the RPM indicator and will not release the solenoids until a set time has elapsed after the speed drops to zero. These "timed" units may give the appearance of failure because the operator cannot immediately open the lid. Check the manual to confirm both the delay and if that delay is adjustable.

Gaskets

Damaged gaskets can affect the centrifuge by altering its speed, changing the balance of the rotor and altering how the interlocking system works. Gaskets should be carefully inspected during each PM cycle

Biomed Certification Study Guide
By Dave Harrington

and replaced as needed. Gaskets will also dry out and particles may flake off affecting the samples being spun.

Feet/casters

On bench top units the feet are often like suction cups as they help anchor the centrifuge to the bench top. They may have to be adjusted so that the centrifuge is level and remains stationary while in use. As they age they become less effective and might have to be replaced. They should be checked on the PM cycle.

Floor units, in most cases will have casters with brakes on at least 2 wheels. They may also have leveling feet that have to be adjusted to assure that the unit is level. This adjustment may lift one or more casters off the floor, which makes movement to work on the unit difficult.

Common problems

- brushes
- not correctly balanced
- interlock jamb on door
- timer out of specification
- speed not calibrated

Cell Washer

In the operating room equipment module there is mention of cell washers as part of an auto transfusion system. In the laboratory there is another type of cell washer that is often confused with a centrifuge. It looks the same, acts the same and has most of the same problems but there are several major differences.

- 1 There should only be samples from one patient at a time
- 2 The whole blood has been previously spun down and the cells decanted to a new tube
- 3 The cells are mixed with 2 to 5 % saline and spun again.
- 4 Three to four times additional normal saline (0.9%) is decanted into the tube containing the cells.
- 5 The tubes overflow and the waste product is collected in an external chamber.

The saline rinses remove serum proteins from the surface of the cells so they do not affect the tests that are performed on the cells when reagents are introduced.

Common Problems

- same as centrifuges
- problems with decanting pump for the saline
- overflowing waste container

BE SURE TO WASH YOUR HANDS AFTER WORKING ON CENTRIFUGES OR CELL WASHERS.

Coagulation Analyzers

Coagulation analyzers range from the very simple, clot timer, to semi and fully automatic devices that test all 12 coagulation factors. The automatic devices generally cover both the hemostasis, arresting of bleeding (clotting), and homeostasis, maintenance of blood fluidity. The machine may use whole blood, plasma or platelets for testing. Some units can test all three while others may be limited so as a Biomed you have to determine what the medium is before doing any testing on the device.

Clot timer

This is a small device often found in cardiac catheterization labs and operating rooms. They may be battery operated. A whole blood sample, in a tube, is placed into the well of the unit, which triggers both a small heater and a timer, (some older units may have a start button that has to be pushed). On one side of the

Biomed Certification Study Guide
By Dave Harrington

tube there is a light and on the other a photo detector. As the blood clots less light passes through the sample, when fully formed no light passes as the timer stops. This time is usually under 60 seconds.

Common problems

- Battery dead
- Dirty light or photo detector
- Defective switch

Automatic Coagulation Analyzers

These are generally large units located in a central laboratory area, sometimes on reagent rental contracts. Be sure that the client owns the device before performing any repair functions on the equipment. These units can use all three types of specimens and batch testing is most common. The integrity of the sample must be assured to have accurate results, if the samples are left unrefrigerated for any length of time they may start to clot before any testing is done. Also if the sample is drawn using too small of a needle cells can be damaged and the sample compromised. (Blood should never be drawn, for testing, with any needle less than 22 gauge in diameter. Note the higher the number the smaller the diameter).

Samples are placed into a rack and introduced into the analyzer, this is a mechanical process and alignment is critical for smooth movement. Once in place various reagents are added to the samples. The tests are done both by electrical conduction and photometric detectors. Generally if there are faults in the measurement system they cannot be corrected by non-specifically trained personnel who have access to the replacement parts.

While sample collection is not part of what we are responsible for improperly obtained samples will affect the results. If the majority of the samples are not getting good results look at the collection process. Samples to be tested in these machines *must* be collected in plastic, silicon zed or nonwetable glass. Ordinary glass allows the sample to coat the surface and will affect test results. Also investigate the size of the needle used to obtain the samples.

Results are displayed in printed form and some units may be directly linked to a computer that distributes result reports.

Common problems

- Mechanical alignment of the sample trays
- Tray transport system in the machine
- Reagent delivery problems
- Wrong paper used in report generator
- Waste product receptacle full.

Wear gloves when working on these units and was your hands afterwards, before leaving the laboratory area.

Hematology analyzer

Like the coagulation analyzers, hematology analyzers range from the very simple to fully automated systems. The acquisition costs can range from several hundred dollars to over a \$100,000.00 with wide variations in what the units do.

Cell counter

This is the simplest hematology analyzer in that a whole blood sample is injected into the unit where it is diluted and divided before being aspirated past optical sensors that count cells. The first sample division the red cells would be counted, the second division would count white cells and the third division platelets would be counted. The results would be displayed as a numbers on a display and printed out on paper. These units are used for quick counts for patients in clinics and physician offices. The ability to accurately

Biomed Certification Study Guide
By Dave Harrington

count platelets is questionable in many units. Also these units do not adequately count immature cells, particles or do any serum testing.

You may encounter a platelet counter, no longer in wide use, in clinics. This works the same as a cell counter but was designed to just count platelets.

Common problems

- Dirty optics
- Low suction levels so samples do not aspirate
- Wrong paper in printer
- Tubing leaks, especially in the suction line
- Incomplete flushing between samples

Automated Systems

Most hospitals have automated hematology analyzers that combine the tests performed by cell counters along with some of the tests done by Coagulation analyzers and may include testing for certain proteins, serum or particles.

Since these systems perform tests on samples from many patients the identification of the samples is critical. The samples from many patients are prepared and placed in racks that are transported automatically into the system. The samples are diluted and aspirated into the system. Samples are separated by air, flush solution or water from each other. As samples pass from detector to detector reagents may be added for specific tests, automatically. Results of the tests are printed out with patient identification. On some units if a fault occurs on a testing step all other tests are stopped and cannot be restarted until the fault is corrected. On other systems the unit will keep running and just not perform the test where the fault has occurred. Once the rack has been completed it will not accept another test rack until the error/fault has been corrected. You will need to know how the system handles faults as it can effect when service can be performed.

On the automated systems suction is generally obtained from the central system of the hospital. If there are problems with the central suction it will affect the operation of the unit as the aspiration of the samples into the detectors. This is often the cause of contaminated readings, as the flush solutions are not correctly drawn through the system.

Water treatment systems should be considered as part of the system when troubleshooting. If water pressure drops due to clogged filters the system may stop until the pressure is returned to the correct levels.

With all automated analyzers problems with the physical facility can and do cause the devices to malfunction so you should be aware and check external of the unit before getting into troubleshooting the units.

Also before doing any troubleshooting, check all the error messages that are contained in the service menu of the device. These messages should point to the problem and give an indication of what has to be adjusted or repaired.

Common problems

- Bad or incomplete flush of detector chambers
- Loss of suction
- Drop in water pressure
- Voltage drops or spikes
- Reagent or mixing pump failure
- Racks not aligned on the transport track

BE SURE TO WASH YOU HANDS AFTER WORKING ON THESE UNITS, EVEN IF YOU WORE GLOVES.

Histology Devices

The Histology section of a clinical lab is the area where tissue is prepared and studied to determine its cell structure. The devices in this area are mostly mechanical or electro-mechanical with very few microprocessor-based devices. The pace of work is slower than in other parts of the laboratory as it can take up to 72 hours to prepare a tissue specimen for study. In this area you will find tissue processors, slide strainer, paraffin heaters, microtomes, microscope and water baths. If the area is not well ventilated the smell of the processing chemicals can be very strong. The smell is also an indication that something is not operating correctly either with the chemical dispensing or draining.

Tissue Processor

Tissue to be studied is first bathed one or more times with a fixative such as Formalin. This preserves the natural state of the cellular components so they can stand the steps of cleaning, dehydration and embedding. The specimen can be either stationary with fixative pumped into and out of the chamber, stationary systems or the specimen is automatically moved from one bath to another, rotating systems. Each bath lasts from 1 to 4 hours. The next step is dehydration in a series of ethanol solutions, up to 6, ranging from 70 to 100% in concentration, lasting up to 1 hour each. Next the specimen is "cleared" twice with Toluene or Chloroform for 30 minutes to 3 hours each. (A major source of odor in the lab). The next step is the immersion in a paraffin bath for up to 4 hours after which time it is removed and placed into a mold where more paraffin is added, from the paraffin dispenser, to make a consistent size and shaped block that can be sliced on the micro tomes.

This is a long process, often done during the off hours when no one is in the lab so the timing system and temperature controls have to be calibrated and properly working to assure good specimens. The ideal temperature for the baths is 60° C. A temperature above 65° C will cause tissue destruction.

If a specimen is being prepared for examination under an electron microscope plastics are substituted for paraffin.

Common problems, rotating systems

- Sticking in the up position as specimens are move from one bath to another
- Temperature variations
- Spills and drips
- Timer, especially if mechanical
- Smells

Common problems, stationary systems

- Pumps not filling or draining properly
- Temperature variations

Both systems are potential fire hazards and the wiring should be carefully inspected at each PM cycle.

Common problems on paraffin dispenser

- Temperature variations
- Paraffin buildup in dispensing valve

Microtomes

Most Histology laboratories will have two basic types of microtomes, rotary units and a cryostat microtome for doing frozen sections. Each operates in the principle of cutting tissue into thin slices, from 0.2 to 50 micron in thickness. The very thin slices are not often used, as they are difficult to perform and have limited clinical value, in most cases.

Once the specimen is clamped in place it is advanced on the feed pawl until its edge is in the cutting zone. The knife is moved on an up-down stroke by turning a flywheel. As the knife descends a specimen slice is made, as the knife ascends the specimen is drawn back so the knife-edge does not touch the specimen. At the top of the ascension stroke the specimen is move forward to be in position for the next descending

Biomed Certification Study Guide
By Dave Harrington

stroke of the knife. This process is repeated a set number of times until there are enough slices for the study to be done. On some units the knife and feed pawl are motor driven, but most are manual and mechanical linkages.

The technologist removes each slice by hand and floats the slice on a heated water bath. The tissue is not handled but paraffin surrounding the specimen is what is grabbed by the tweezers and placed in the bath.

A cryostat microtome is basically a rotary microtome placed in a refrigerated cabinet, typically -30° C that uses frozen tissue specimens instead of prepared specimens from a tissue processor. The slices are generally several microns thicker and have to be quickly viewed. Instead of hours or days frozen sections are done in minutes to get a gross reading. Frozen sections are used when a quick determination has to be made, typically while the patient is still on the operating room table. A portion of the specimen will also be sent through the full process for a definitive diagnosis.

Common problems

- Feed pawl not advancing correctly
- Blade not cutting straight down, concave face on specimen block
- Loose blade
- Bad blade

On cryostat units

- The entire above plus;
- Defogger not working on viewing port
- Temperature variation.
- Low temperature lubricants were not used on mechanisms.

Slide Strainer

The technician will select several of the floating slices from the water bath by slipping a glass slide underneath the specimen. The specimen is allowed to air dry for a short period of time before undergoing the staining process.

The slides are stained with one of more dyes to help define tissue edges, nucleus, collagen or elastin in the tissue cells. Of equal importance is the removal of excess stain from the slides. The staining and removal of excess stain is done automatically linear or rotating units.

The rotating units can look very similar to the rotating tissue processor, as there are a series of “pots” containing stain and solvents that the slides are dipped into. Since the slides are vertical specimens may slide off during the dipping process. There is a linear version of this where individual or small numbers of slides are dipped into stains or solvents, but it is for low volume applications.

The most common unit is a linear system that is like a conveyor belt. Slides are placed on the transport and moved from one station to the next. This allows for greater volume of slides to be processed and slides can be added at any time.

Some units may have a “drying” station where hot air is gently blown over the slides to remove any residual moisture. The key word is gently as too much force will affect the quality of the slides.

Because of the solvents used these devices should either be in a specially vented area, in a fume hood or have an air handling system with a filter to remove the odors.

Common problems

- Rotating unit same as with rotating tissue prep unit

On linear units

- Broken slides in transport gears

Varying belt speed
With all units smell is a major problem.

Microscopes

In Histology, pathology, hematology and other sections of the clinical laboratories the microscope is a critical device. While these units rarely fail they do require cleaning and lubrication on a regular basis. In some hospitals this work may be done by an outside contractor so before doing any work on microscopes makes sure that there is not existing contracts in place for their repair and cleaning. The replacement of bulbs is generally not part of the contract.

Microscopes have a light source, either external or built in that is used to bottom light the slide-mounted specimen. It may be a direct light beam or focused via a mirror, while others may use fiber optics to transmit the light. On some units there is a diaphragm that will control the size of the light beam to the specimen. There may be an intensity control on the light source that can fail. There also may be a filter between the light and the specimen that removes certain wavelengths of light from the spectrum. Bulbs should only be replaced with the same bulb. If the bulb is different it may have differing light output, filament voltages, heat or light spectrums that could affect the reading of the specimen. In other words use only the exact replacement bulbs.

If mechanical positioning adjustments do not operate smoothly it is an indication that either too much or too little lubricant has been used, clean off any excess lubricant, especially if it has dried and is “clumping”, use a soft cloth dampened with alcohol for the cleaning. Do not use any solvents that may leave a residue. Also be careful not to leave lint on any surface.

Optics can be cleaned with an alcohol dampened lint free cloth. It is a good idea to blow off any dust with canned air before cleaning. Be very careful not to scratch the optics.

Common problems

- Light bulb
- Spills
- Scratches

If you wear gloves when working on microscopes, be sure that they are powder free.

WASH YOUR HANDS BOTH BEFORE AND AFTER WORKING ON MICROSCOPES.

Incubators

Laboratory incubators come in various sizes and levels of technology. All are designed to maintain set temperatures and conditions within the chambers. Some may have internal AC outlets so other devices can be used inside of the incubator. Most will have fans to move air from the heating elements around the cultures, (specimens) and out a vent. Much of the air is recirculated within the chamber and not vented. The doors have to seal tightly and should only be opened on a strict as needed basis. Every time the door is opened it will take several minutes for the temperature and humidity to stabilize. A difference of 1° C can cause culture growth to slow or stop, which affects the clinical results.

All modern units will have digital temperature indicators and many will also have digital indicators for the levels of humidity and CO₂. The technologist using this equipment should be the person doing the adjustments not the Biomed. Also the inside of the incubator should be cultured and cleaned on a regular basis, usually monthly, again this is for the technologist to do not the Biomed.

Biomed Certification Study Guide
By Dave Harrington

If there are questions on the CO₂ levels the Biomed may be asked to perform the checks. This has traditionally been done using a device called a Fryrite but it can also be done quicker using a CO₂ level monitor borrowed from the anesthesia department. This can cut the time to make the CO₂ adjustment from several hours to minutes.

There generally are one or more lights in the incubator not only for visibility but to promote the growth in the cultures. If the light needs to be replaced you must use an exact replacement and not just one that fits. The emitted light spectrum is very important for the proper functioning of the incubator.

Filters on the air system have to be cleaned on a regular basis. In most cases the technologist will do the replacement or cleaning during the normal cleaning of the incubator. It is not a good idea to remove and clean the filter while cultures are in the incubator. Also any moisture traps should be cleaned at the same time.

Common problems

- Door gaskets leaking
- Fan not working
- CO₂ level out of specification
- Uneven heating, generally caused by fan failure or blockage

Wear gloves when working on the chamber of an incubator and wash your hands after removing the gloves.

Laboratory Ovens

Ovens used in laboratories are used to dry samples and for evaporating, dehydrating or sterilizing functions. On a limited basis some are used as a dry incubator. The simplest ovens are little more than a chamber heated by a resistance coil with a light to indicate that it is heating and a control for the temperature. Temperature is measured with a simple thermometer with its bulb in the chamber and its scale sticking out of the top of the unit. Some units also have a built in fan to move the air from the coils into the chamber.

Common problems

- Burned out light
- Door gaskets
- Fan not working
- Broken thermometer

The more advanced ovens will have double doors, temperature recorders, and digitally selected temperatures. Their temperature regulation is much better than the simple ovens and they are sometimes used as a dry incubator for doing cultures. The common problems are the same as with the simple ovens.

The measurement of leakage currents on these devices is an indicator of the condition of the heating elements. As the elements age their leakage increases and when they reach the top limit, you can expect a failure on the next inspection for current limits. You may want to purchase a new heater before that next inspection.

Bench Top Devices

In all laboratories you will encounter numerous small devices that will require inspection and testing. Some devices such as Bunsen Burners only need the hose to be inspected for leaks and if there are leaks you will generally smell the gas long before you can see the cracks in the hose. If a leak is discovered in a location other than the hose maintenance need to be informed and gas shut off into that area of the laboratory until the leak is repaired.

. Such devices as *Immersion* and *Mantle Heaters* either work or not. Unless there is a problem with the power cord or connector these are no repairable items. As with any heater electrical safety testing needs to be done and when close to the top of the allowed range they should be scheduled for replacement. There is a combination *Immersion Heater/Circulating Pump* that can be used to turn any watertight vessel into a

Biomed Certification Study Guide
By Dave Harrington

circulating water bath. The temperature control is not precise but it is in general use where temperature control is not critical.

There are numerous types of **Baths/Heating Blocks** used in the laboratory area. The simplest units have a heater pad bonded to the underside of the bath, which conducts heat through thermally conductive beads to test tubes or flasks placed in the baths, called **Dry Bath or Bead Bath**. Another version of this has metal blocks drilled with holes that fit test tubes.

Another version of the bath is filled with water and flasks are placed into the water for heating. A variation of this is the **Shaking Water Bath**. Here a rack that is about $\frac{3}{4}$ of the size of the bath is suspended in the water and moved laterally via a motor driven cam. The rack glides on Teflon bearings or rollers. The movement speed of the rack is adjustable via a motor control. A sub version of this bath is that a heating rod is used instead of the contact heaters.

A **Floatation Bath** is used in Histology and is confused with a water bath. There are several major differences between them. Most noticeable is that the floatation bath has a glass removable liner and is only about 2.5 CM deep. There also, in most cases, is a light that illuminates the bath so the floating specimen section can be easily picked up with a glass slide being passed under it.

Hot Plates and **Hot plate Stirrers** are very common in laboratories. These are simple units with contact heaters under the surface that flasks are placed on. The heater regulation is +/- about 2° C and are limited in their capacity to heat large volumes of material. The **Stirrer** version has a small variable speed motor under the heater with a permanent magnet mounted on the shaft. A “stir bar” is placed in the flask sitting on the heater and as the motor/magnet rotate so does the “stir bar” creating a vortex mixing of the fluids. The “stir bar” can be magnetic or made from material that responds to magnets and must be coated with a material that will not react with the solutions being stirred.

Another bench top stirrer is called a **Vortex Genie**. This is a cube shaped device with a rubber cup on the top. When a test tube is held on the rubber top it energizes a motor, in the cube, that shakes the rubber cup in such a manner that it creates a vortex effect in the fluid thereby mixing the fluid. This is only used for single test tubes.

You will also find **Block Heaters**, which are aluminum blocks with up to 8 holes machined in it to accept test tubes. Under the block or on the side is a contact heater. These units have very little temperature control and many don't even have a fuse but a thermal circuit breaker that will open if the heat is too high.

The **Bacti Incinerator** is found in various parts of the clinical laboratory and is a simple device. It consists of a resistance coil heater with a small opening in the center into which small samples are inserted, generally on the tip of a ceramic spatula. This dehydrates the specimen as part of the preparation for examination under a microscope. There are no controls for heat level, only an on/off switch. Because heat is generated by this device the protective shield should be examined to be sure that it is secure and fully protects the user.

Mixers/Homogenizers also known more widely as a blender. They come in hand held and counter versions the same as the ones in your kitchen. Many are 2 wire devices.

The last of the minor bench devices are the **Tube Rockers** and **Rotators**. A **Tube Rocker** is a device that slowly moves small test tubes, 20 CC and under, over a 45° arc. It has a small clock motor that is connected to a cam that moves the back and forth through the arc. This is often a 2 wire double insulated device. A **Tube Rotator** handles larger test tubes and rotates them 360°. This is also run with a clock motor that is directly coupled to the disc that holds the test tubes. Both of these devices are generally a single speed and not used for long periods of time.

Common Problems, all devices
Spills

Biomed Certification Study Guide
By Dave Harrington

Leaks
Heater failures or high electrical leakage
Missing hardware
Temperature control

Wash your hands after working on any of these devices.

There are many other devices used in laboratories both clinical and research that operate on the principles that are listed at the beginning of this module. Most have the same common problems, of spills, dirty optics and not being properly flushed between samples.

REVIEW QUESTIONS

- 1 How many electrodes are contained in a typical blood gas analyzer?
3
- 2 If a centrifuge does not start what should be checked?
Timer, power, lid, brushes
- 3 Can the same Bilirubinometer be used on neonates and adults?
No, two different light spectrums
- 4 What solution should be used to clean the optics of a microscope?
Alcohol
- 5 What causes a concave cut on a Microtome?
Feed pawl not tracking right on the lead screw
- 5a How does a cryostat differ from a microtome?
A cryostat is a microtome in a refrigerated cabinet, used for frozen sections
- 6 Why are ultra-high-speed centrifuges refrigerated?
Air resistance would heat the specimens
- 7 On an automated device what should be done first before starting any testing?
Check the error log
- 8 What device is used to check the CO₂ level in a laboratory incubator?
A Fri-rite
- 9 What must you do after working on laboratory equipment?
Wash your hands
- 10 What are the 6 basic functions of most laboratory equipment?
Measure, Separate, Count, Change Temperature, Display Results, Communicate

INTRODUCTION TO IMAGING DEVICES

Background Information

Medical Imaging actually predates the recording of an ECG by about 8 years. X-Rays were discovered on November 8, 1895 by Wilhelm Roentgen. In seven weeks Roentgen did additional research and published his findings. He did not apply for any patent protection on his discovery. He was awarded the Nobel Prize for Physics in 1901. Many of the top scientists of the era got involved with X-Ray's including the Currie's and Thomas Edison. Clarence Daley, who worked with Edison, provided the next key date in the development of imaging when he died in 1904 reputedly of radiation poisoning. Progress was slow for many years and other applications of X-Rays were developed, such as treating acne, tonsillitis and viewing feet in shoes to be sure that they fit. After World War II mobile vans were equipped with X-Ray units for screening the population for TB.

In the late 1940's Sonar, used to detect underwater objects, was adapted for use on patients to view internal organs and structures in Japan. It arrived in the US during the early 1950's mostly as a research method and not in wide clinical use until the late 1960's. The 1980's brought color and in the 1990's 3 dimensional images were developed.

In the 1970's CT was introduced and its wide spread use was hindered by costs and reliability. As electronics advanced so did CT until it is now rare that a hospital does not have at least one in the facility. Also size has come down to where portable CT's are now offered. The scanner can be brought to the patient instead of the patient to the scanner.

The 1980's brought the introduction of NMR, (Nuclear Magnetic Resonance), which quickly got changed to MRI, (Magnetic Resonance Imaging) for marketing reasons. Three Mile Island and Chernobyl made anything with the word Nuclear in it of concern to the general population. Problems with motion and long times in the magnet field have been overcome and MRI is now one of the primary diagnostic tools used by physicians.

The 1990's brought PET and SPET imaging that are just starting to become available in more than just a few hospitals. As with CT and MRI before costs, reliability and reimbursements have limited the wide spread use of PET and SPET technology

Now we are seeing the combining of several imaging technologies to diagnose and treat patients.

X-Ray Generation

Trying to learn about x-ray is like reading a Russian novel in that the same person, (function), can have 2 or more names. In addition there are various formulas and physics terms that are widely quoted but never used except in the design of the tube? In these next few paragraphs we will cover the basic physics of x-ray and then get back to plain English for the remaining information.

X-rays are electromagnetic waves, like a radio, that are very short, generally 0.1 to 1 angstrom, (an angstrom is 10 to the minus 10 meter). Because the wavelengths are so short they behave more like particles than waves so the names photon or quantum are used to indicate small quantities of energy. Now add to the mix that if the frequency of the wave doubles so does the energy. Which means that for the same voltage and current settings by increasing the frequency, (reducing the angstrom) you double the energy, (radiation). This is confusing but unless you go into design you will never have to use this information except on a test.

Photon, (quantum), energy is measured in electron volts (eV). An electron volt is the amount of energy an electron gains when it is accelerated by a voltage difference of 1 volt. To get clinically useful x-ray you need a minimum of 60,000 electron volts. As electrons from a source, (filament), are accelerated and strike the target, (anode), 2 types of x-rays are produced along with heat.

General Radiation

Also known, as *breaking radiation* or *bremstrahlung* is the x-ray generated when the accelerated electron passes near the nucleus of an atom in the target where it is deflected and decelerated. When this happens a small amount of x-ray is emitted, generally 1% is x-ray 99% is heat.

Characteristic Radiation

The accelerated electron passing near the nucleus of an atom in the target collides with and ejects an electron from one of the inner rings of the atom. An electron from one of the outer rings will move to replace the ejected electron and as it moves it emits an x-ray.

The intensity of the x-ray beam is the number of photons in the beam multiplied by the energy of each photon, (both general and characteristic) and is measured in Roentgens per minute, R/min.

X-Ray Tube and Housing

Working in the field you should never replace an x-ray tube as it takes considerable skill and specialized equipment. What we do replace in the field is the tube housing which contains a new tube that has been aligned and the housing filled with oil. But to understand x-ray we need to go over what a tube is and some of its typical problems.

All tubes contain three basic parts, enclosure, (generally made from Borosilicate glass but some high power tubes may have metallic or ceramic enclosures). A filament made from a tungsten alloy and the anode or target that is made with tungsten or other metals and backed with copper. Most tubes will have more than one filament, one for each focal track on the anode, a focusing cup or cathode to better direct the electrons moving from the filament to the target, and a target, (anode) with one or more focal tracks machined in it that rotates up to 20,000 rpm. The various parts are assembled in the enclosure, which is sealed and a vacuum drawn on it. The material used to seal the enclosure has to have the same expansion characteristics as the enclosure so the vacuum is not broken when the tube heats up. If the enclosure is not properly evacuated there can be internal arcing and inconsistent output, (gassy tube). Sometimes this can be corrected by a process called "seasoning" which is performed when the tube is installed or reactivated after not being used for a long period of time.

Filament voltages range from 2.5 to 15 volts and each filament in the tube could have a different voltage. The filament current range is generally between 3 and 6 amperes. (Tube current is measured in mA). The filament are constantly on, if the unit is powered up, in a keep warm state. Since the filaments are kept warm it is releasing some electrons, which are kept confined by the focus cup, (cathode). The focus cup also aims the released electrons at the target when the system is generating x-rays.

The anode, (target), of a tube is disc about 10 CM in diameter and 2 CM or less in thickness. The disc is surfaced with a tungsten alloy over a copper base. Copper is used for its heat conduction properties. There will be one or more angled surfaces on the disc, called focal surfaces, or tracks, that are where the electrons accelerated from the filament hit to generate the x-ray. In all but the simplest tubes, (mostly dental x-ray units) the anode is rotated. The rotating anode allows the heat, (only 1% of the energy is in x-ray and 99% is heat), to be distributed over the entire target. This also keeps the focal surfaces from being distorted from the heat, which keeps the focal spot consistent and increases the life of the tube. The bearings on the anode are sealed and self-lubricating and cannot be worked on in the field.

The tube is placed into a Tube Housing where connection are made between the filaments and anode and the exterior connection on the housing. In most cases the housing is then filled with oil that acts as both an electrical isolator and a thermal conductor to move the heat away from the tube. The tube housing is cooled via conduction in low use application, via convection with a fan in higher use settings and with cooling systems in very high use systems. Tubes are rated in Heat Units (HU) and will shut down if the rating is exceeded. Tube housings with fans need to be cleaned on a regular basis to assure good cooling. Fluid levels in the tube housings requiring cooling systems also should be checked on a regular basis. On one side of the tube housing will be a "window" where the x-ray beam exits the tube housing. This can be plastic or glass and may have tape or some protective material over it for shipping. This has to be removed

Biomed Certification Study Guide
By Dave Harrington

before mounting the collimator to the housing. Several recent studies have indicated that the oil loses its ability to conduct heat after prolonged use and may contribute to shortened life of the tube. An indication of the problem is the tube in “sputtering” (non-linear output or radiation), below the HU units that it generally has happened in the past. Heat units problems are rare with film studies but common with fluoroscopic studies so carefully document what procedures were being done when the tube started to “sputter”. When replacing the tube it may be a good idea to get one with a

The focal spot(s) of a tube is a function of geometry of the target, target material, texture of the target material, size of the filament and the focus cup, (cathode), plus any wobble that may occur in the anode as it rotates. Focal spots are stated in mm, typically .3, .5, 1.0 and 1.5. Measurement of focal spots is done using a pinhole camera or a Star Pattern. With a pin hole camera the image is measured and divided by the amplification factor. The Star Pattern requires more math and is sometimes difficult to establish where the line blur. These measurements are done at the factory and by the physicist during validation testing. The focal spot size, as built, is listed on the tube housing and serves as a reference point on future validations.

As the tube ages the focal spot will increase in size. Some of the growth in size can be compensated for by changing “techniques”, (voltage, current and time settings), by the technologists. The smaller the focal spot the better resolution of small objects. While that is the “official” line of thinking the consistency of the x-ray generated also affects the resolution. This is evident when edges of objects are not sharp but blended. The use of filters and grids can increase sharpness, also called clear image or central area, and decrease the blurred/blended area, also called edge gradient or penumbra. The testing of new tube at installation should document not only the size and shape of the focal spot but any tilt, blurred edges or uneven radiation. A hard copy of this information should be kept on file as long as the tube is in service.

The focal spot geometry produces an uneven beam of X-ray called the Heel Effect. This means that there is more energy at one end to the field than the other. Ideally by aligning the tube so that the radiation caused by the Heel Effect is directed towards the thickest part of the object being studied helps maintain the Density (how dark the film is) and Contrast, (darkness relative to surroundings) of the film. If complaints start suddenly about Density and Contrast check to be sure that the tube has not been rotated.

Collimators, Filters and Grids

Up until this point most of this module has been about items that Biomedics cannot or should not touch or was just background information. The remaining information will be dealing with items that Biomedics actually work on.

Collimation of the x-ray beam starts with the tube design, specifically the focal spot track, which focuses the majority of the x-rays generated in one direction. The tube housing further reduces stray radiation and continues the collimation process. Exiting the tube housing through the “top hat”, a lead cone with a rectangular hole in it that sets the maximum film size that can be exposed at a given distance, (also called source-image distance or focal-film distance. This also helps reduce stray radiation and shape the beam. The collimator-mounting block, made from aluminum and the rotation ring secure the collimator to the tube housing. These items should be checked on a regular basis to assure that the hardware is secure. An old trick is to use a dab of nail polish on the screw or bolt head to housing surface and if the polish is cracked the hardware is starting to loosen.

On some collimators there may be a slot in the housing, near the mounting block that allows for the placement of filters in the x-ray beam. These are thin sheets of copper or aluminum, but other material could be used, that are inserted to remove spikes in the radiation intensity that are generated by characteristic radiation and to smooth the remaining radiation so it is consistent. This may also be referred to as “hardening the beam” or removing soft radiation. ***These filters should only be added or removed as directed by the physicist doing the radiation certification on the unit.*** The certification may need to be redone after major repairs to the generator but otherwise is done as required by local and federal regulations, (a maximum length of certification is 3 years). It is not uncommon that when filtration is added or removed the technologist will have to adjust their techniques. It is not uncommon to have an increase in “retake” films right after changes are made in the system based on the requirements of the physicist. You

Biomed Certification Study Guide
By Dave Harrington

need to work closely with the department supervisors and technologists to assure that the “retake” rate returns to the previous level or less.

Below the filters are the upper level shutters. These are flat lead alloy strips of metal with have beveled mating edges so to totally block x-ray passage when closed. The upper level shutters are mechanically linked with the lower level shutters so they work together. On some units there is a feature called automatic collimation. This is when the unit senses the size of the film cassette installed and automatically adjusts the shutters to that size. When a problem occurs with the automatic collimation it is generally traceable to the sensors in the Bucky Tray. With manual collimation problems are generally based in loosing of the adjustment knob or the linkage between the knob and the shutters.

In the space between the upper and lower shutters are a lamp and a radiolucent mirror. This is called the aiming light, centering light, collimation light or field light. The light beam is focused through the protective lens on the bottom of the collimator which has crosshairs used to properly line the tube with the area of the patient to be x-rayed. The alignment of the centering light to the film cassette needs to be checked on each PM inspection to assure proper alignment. The lamp is replace from the side of the collimator, never by removing the lens with the crosshairs and reaching through the shutters. The light should only remain on for less than a minute.

As part of a PM the shutters should be fully closed and a film exposed. There should be no exposure on the film if the collimator is working properly. If the shutters do not fully close the exposure will indicate which shutter is not closing or is damaged. While not a major issue for safety a damaged or malfunctioning shutter can affect the quality of patient films, possibly leading to “retakes”, which are costly.

At the bottom of the collimator on some units are channel slides used to mount cones, cylinders or other shaped metal units to further focus the beam to an even smaller spot on the patient. These are mechanical devices and need only to be checked when purchased and for mounting security at PM's.

As the x-ray beam passes through a body striking cells or bones some of the beams are deflected, some will trigger the release of chrematistic radiation from cells/bones all of which can cause the lack of definition of the object being studied. By placing a grid between the patient and the film, deflected and Compton scatter radiation is reduced giving a sharper image on the film. There are two basic grids used. A parallel grid, and a focused grid Focused grids are limited in that they are designed for a single Source Image Distance (SID) or Focal Film Distance (FFD). Compton scatter is caused by x-ray beams reacting with body parts and creating secondary x-rays, (similar to chrematistic radiation).

Grids come in various ratios, height of the strip versus the space between strips. A common grid is 8:1 or the lead strip is 8 times a high as the space between it and the next strip. The common ratios in use are 5:1 for low voltage work, 8:1 for mid-range voltages, 12:1 general purpose, most common, and 16:1 for high voltage work. Next item to consider is the spacing of the strips. The common choices are 30 strips per CM for general use, 45 strips for skull studies and 60 strips for vascular studies. In most cases the technologists can change grids as needed without Biomed involvement. When the technologist has a problem with a grid it generally shows up as poor films. The common problems are that the grid is not installed flat or the grid is installed upside down, especially with a focused grid. Occasionally they will be off center so the film edges are not clear and the contrast is off on one or more edge.

If the films come out with noticeable grid lines there is a problem with the Bucky. The movement of the grid is the “clunk” that you hear during an x-ray exposure. The grid is moved 2 to 3 CM in one or more directions so the grid lines do not appear. Dr. Hollis Potter and Dr. Gustav Bucky working independently developed this system in the 1920's. The drive mechanism to move the grids can be springs, motor, solenoids or some other simple drive. The film cassette is placed in the Bucky tray, which sets the collimator to that film size. The grid is mounted over the tray and moves during the exposure. It generally takes more time to get to the grid to fix the Bucky mechanism than it does to fix it.

To further confuse you with terms the OFD (Object-Film-Distance) is the amplification factor of the imaging system. The greater the distance the larger the object appears on the film. This is rarely used but is sometimes useful in locating breaks in small bones.

Film and Film Cassettes

For most x-ray examinations dual emulsion films are used. This means that both side of the film take the image. These films are more durable then the single emulsion films used for Mammography studies. Double emulsion films tend to be brighter but give up some detail.

In the film cassette there are 2 intensifying screens that emit light when exposed to x-ray. This light, along with the x-rays is what exposes the film creating an image. This allows for lower dosage to the patient but there is a small loss in clarity of the image on the film. Sometimes the screens become damaged and the resulting images are not high quality. Sometimes problems with the film cassette screens get reported as problems with the x-ray unit. An indication of a screen problem is that only one of a group of films has a problem. Finding the bad cassette can be very time consuming. Cassettes should also be monitored fir light leaks by the users. This is usually evident on the edges of the developed film being clear. When troubleshooting x-ray problems always look at the last films taken before doing anything with the equipment. The films will provide an unbiased report of what is wrong, if anything, with the generator.

More information on film problems is in the section on processors, multiloaders and dry imaging.

Power Supply

Since the maximum voltage coming into a hospital from the power grid is 13,800 volts, well below the voltage needed to create an x-ray transformers have been used for years to obtain the needed voltages. The highest voltages on the floors of a hospital is 480volts in a “y” using 4 wires.

Simple x-ray units, such as a dental unit, may work off of single-phase line voltage, 117VAC, with a step up transformer with the tube acting as a rectifier. This is a single pulse system that is inefficient and the quality of the x-ray is not great. Basically this is a half wave rectifier system where the x-ray is only produced for the short time the half-wave reaches the critical voltage, (65,000 volts). These are reasonably small and inexpensive units with a fixed anode and rarely require service. One thing to remember is that these units are not well collimated and stray radiation is common. Patient and user exposure levels are higher than in most radiographic rooms.

In some very old units the power supply is single-phase line with full wave rectification. The rectifiers are in the same “tank” as the transformer, either solid state or tubes, along with capacitors to smooth the ripple of the full wave rectification. Most of these units have been replaced in modern healthcare facilities but may show up in a physician’s office. Repair parts are hard to find and some tanks may have PCB based oil in them even though all PCB’s were supposed to be replaced in the early 1980’s. These were called 2 pulse systems.

The majority of medium and high power units installed up to the early 1990’s used 480 volt 3 phase power supplies. These were also called 12 pulse systems. With the 3 legs of the output side of the transformer are combined into DC the ripple is so small that 95% of the voltage will produce x-ray versus less than 50% in a single pulse system.

So for a voltage of 150,000, used in angio suites step up transformers were needed. Because of line fluctuation and inefficiencies in transformer designs a turns ratio of about 1:350 would have to be used. The size and weight of these transformers required special floor braces and additional room. There could be several in the same area if more than one tube was to be used. There was also a heat consideration, as these units could get hot, especially if constant use is required. The transformers require regular inspection to check the oil level, is there arcing in the transformer tank, darkened oil is an indicator of arcing or excess heat. The units also need to be examined for leaks, dents or bulges in the sidewall. All can indicate impending failure of the system.

Biomed Certification Study Guide
By Dave Harrington

Most modern x-ray systems use what is called high frequency power supplies. The incoming frequency is amplified to approximately 100 kHz, which allows for smaller transformers to get the voltage gain required and at the high frequency there is not need to rectify the waveform. The x-ray generated is very constant in intensity allowing for lower doses to the patient. Most of all the high frequency power supplies are smaller, lighter, and less prone to failures and can be put in the console freeing up floor space.

It is important to have the manuals available before starting any repairs on the high voltage systems. You should follow the required “lock out – tag out” procedure that is in use at the location for your own protection and that of the staff. More than one incident has occurred when a unit was not properly “locked out –tagged out” and got turned on. Not only is there an electrical shock hazard serious damage can be done to the device. It generally is a good idea to have a second person in the area when working on high voltage systems for everyone’s protection.

It is also important that you communicate what you are doing, when you expect to be done and if the physicists have to be called to validate the system after the repair is completed. This physicist should be notified when any changes are made in the high voltage power supplies or timing circuits and when a tube, I/I or video chain is modified.

Fluoroscope

The original screen fluoroscope was invented in 1895 by Thomas Edison and promptly patented. The basic design remained constant for close to 60 years before being replaced by video systems. Fluoroscopic exams are used to view dynamic events in the body, light movement in the intestinal track or blood flow. It is real time imaging. If a record is needed a “spot film” is taken. Some units may be equipped with a rapid film changer, also called a ‘puck’. This unit allows for the sequencing of film, very quickly, during a procedure. Some units may have a “multi format” camera attached to them when up to 32 images can be placed on one sheet of film. Basically the same information that would be recorded by the puck on many sheets of film is done electronically off to the fluoro image as picked up by the video system and transmitted to the multi-format camera. Since the image is captured by a video camera the image can be digitized and manipulations done to that image, sometimes called “digital subtraction or digital subtraction imaging. The fluoroscope works at a lower power level than for the typical x-ray film requires so if a film is to be taken the system goes into “boost” mode to expose the film then automatically drops back to its previous level of exposure. Generally a patient receives a higher dose of radiation during a fluoro study than they would if just films were taken. While the power is lower the time of exposure is much longer giving the higher dosages of radiation. Hanging off the sides of the I/I are strips of lead shielding, which needs to be inspected on a regular basis for secure mounting and adequate coverage.

With the exception of c-arm units the x-ray tube is located under the table on which the patient is positioned. The tube is in the same type of a housing as previously described. But it does not rotate; the collimator is simpler as it has no targeting light or cross hairs. After the x-ray beam passes through the patient they are detected by the Image Intensifier, commonly called the I/I. At the back end of the I/I is a video camera that amplifies the light generated by the x-rays striking the I/I and displays the light patterns on a CRT. That is the simple explanation of fluoroscope, but life is not always simple.

The I/I comes in various sizes from 3 to 15 inches in diameter, 12 and 15 inch units are not common in newer units as the radiation dose for such units is high and modern techniques allow the radiologist to better target the areas being examined. Some units are multi-sized in that either electronically or mechanically they can be set for 6 or 9 inch diameter receiving areas. The I/I is a vacuum chamber, usually made of glass with a phosphors coating on the inside of the large end. As the x-rays excite the phosphors to emit light that light is focused to the small end of the tube. The light beam can be directly linked to a camera, split with mirrors to 2 cameras or between a camera and direct viewing ports, not common in modern designs. Most common is the direct link to a camera, followed by a beam splitter that links the video camera and a cine camera to the light beam coming from the I/I as in a catherization installation.

The video chain

The camera can be a Vidicon, Plumbicon, CCD or other construction and is generally matched to the rest of the video chain. They also come in a wide variety of sizes and mounting styles so you have to be very careful on selecting replacements. On some systems there may be a photo detector between the I/I and camera that is used to provide the feedback for automatic brightness controls, sometimes called automatic gain control. In other systems the feedback is generated after the camera.

Monitors come in a many sizes, formats and resolutions. On older units 450 to 700 lines are used, most common is the 525 line monitor. Newer units may use 1024 line monitors. Many units use 1024 X 768 interlaced, 1280 X 1024 or 1600 X1280 non-interlaced monitors. The system has to be matched from camera to monitor for best results. Simply don't spend the extra money for a high resolution monitor if the camera is not capable of the higher resolution. Another consideration you have to make when replacing a monitor is the weight if the unit is "hung" on a floating arm. You may have to rebalance the arm to assure that it remains stationary when repositioned and does not float up or down.

As previously mentioned spot film systems, rapid film changers and multi-format cameras are often used for "still" recordings of body structures. For motion studies either videotape or cine film is used. Videotape is cheap requires no film processing but does not have the resolution of smaller objects that film does. Videotapes are often used as backups for cine and are becoming more widely accepted by the medical profession. These tape systems are not off the shelf from the local video supply store but professional grade units with "frame grabber", super slow motion and other features. Cine requires a special developing unit and an editing console to view the films. These are high failure and maintenance devices and good PM procedures should be implemented to reduce costs and down time.

Most Fluoro systems have automatic gain or brightness controls. This allows for the automatic adjustment of KV and mA during the study so the contrast and density of the image remain constant. This system can be a source of problems that are often more user centered than technology centered. Hard failures are not too common with these circuits but they often need adjustments as the tube ages. When a tube is replaced it is a good practice to reset the gain control to the new baseline of tube output. On some units this is done automatically.

The Table

The simplest x-ray table is a horizontal surface that has a top with limited motion. Basically the film cassette tray, (Bucky) is stationary as is the overhead tube and the patient is positioned using the "floating top". The head-foot movement is generally 2 feet or less, with side-to-side motion of about half the head-foot motion. Once the table/patient has been properly aligned the top is locked in place using electrically powered brakes. The tabletop is made from a composite material that allows x-rays to pass through it with little or no loss and no additional scatter. Many of these tops have weight limits of 175 to 200 Kilos. Damaged tops should be replaced when found, as damaged tops could compromise patient safety by contributing to lock failures, poor film quality and infection.

Powered tables have the head/foot and side/side motions along with multi cassette trays, plus the ability to move the patient from a prone (horizontal) position to perpendicular positions. The I/I moves with the angular position so that it is always aligned with the under the table tube. Because there are motor drives used to move the able and patient to selected angles it is not uncommon for linens to catch in the drive mechanisms. These should always be covered but when not can present a major potential for a patient injury. Also it can put an unreasonably heavy demand on the motors and lead to failures. The locking systems in tilting tables are critical and should be a major point on any PM program. As with the simple table the tabletop is subject to damage from heavy patients and should be closely inspected after a heavy patient has been on the table. When doing annual PM inspections on the table the gearing should be checked for missing teeth and a buildup of lint. These two items can contribute to premature failures of the drive motors. **On tables that are used for reflux or voiding studies be sure to follow the Universal Precautions procedures for your protection when working on them.**

The over head tube

When an overhead tube is present, it is mounted on a track system, similar to an OR light, except that the amount of movement is much greater. The overhead tube assembly will move in 4 horizontal directions. There needs to be detents, (locking positions) and stops on the tracks to assure safety and proper alignments, the security of the detents has to be verified on a regular basis along with the stops. A very difficult thing to accomplish is to keep other devices from infringing into the area of movement of the overhead tube. Many devices have been damaged by being hit during the movement of the tube. The end stops on the tracks need to be inspected on a regular basis to be sure that the tube assembly cannot fall off the tracks. In many installations a counter balance system using cables and weights is used to allow easy and smooth movement of the tube. These cables fray over years of use and may need to be replaced, especially with systems that brake/lock by clamping on the cable. This can be very dangerous on the up/down movement of the tube over the patient.

With any locking system locks will stick open making it impossible to lock the tube in position. Troubleshooting lock problems is a 2-person function. One person is observing the locks, often while standing on a ladder and the other energizes the lock from the tube head handle. It is not uncommon to have a broken wire in the locking system. A 10-foot piece of wire with alligator clips on each end can be used to locate a broken wire. Clip one end to the switch and the other to the lock, if the lock energizes when the switch is activated you have a broken wire. Replacing lock wires is not easy as it may be difficult to route the wire properly. Temporary repairs to get through the case or at worst case the day should not be considered permanent repairs.

DO NOT USE RUBBER JACKETED WIRE IN ANY AREA WHERE RADIATION EXPOSURE CAN BE EXPECTED. RADIATION DRIVES THE RUBBER MOLECULES INTO THE METAL CREATING HIGH RESISTANCES OVER YEARS OF EXPOSURE. USE ONLY PLASTIC INSULATED WIRES.

The Console

Located outside of the main room with a lead glass window that gives the technologist a full view of the patient. On the console the technologist selects the KV, milliamps and time for the exposure. Depending upon the age of the unit selections are made via rotary switches, push button switches, paddle switches or up/down rocker switches. On some very old units the exposure time is set with a mechanical (egg) timer. While older units may only have an analog meter displaying KV and mA the modern digital units will have displays of KV, mA, time location buttons, (Skull, Thorax, Abdomen, Pelvis or extremities) that automatically set the KV, mA and time for the technologist. There are override controls that the technologists can set as needed.

Most problems associated with the console are the same as with any control surface on any device, loose knobs, stuck switches and cuts in the membranes protecting panel switches.

The panels may have elapsed time and dose information when in the Fluoro mode, heat units and other information. Many of the newer units will also have an alarm memory system that logs faults in the system. This should always be viewed when any problem is reported. Generally alarm memories are only available when a special sequence is entered when the unit is in the service mode. When "technique" errors are present it is an indication that the technologist is overriding the automatically selected settings and may be not getting proper exposures. This may be a difficult situation to handle as if the technologist is challenged they may become more critical of the equipment.

The junction box where the wiring from the Console to the rest of the room can be a problem point. It is not unusual for coffee to get spilled into it, have paper clips short out connections and heavy dust buildup.

When a radiologist is performing a fluoroscopic study they are in the room with the patient and will use either a hand or foot control to control the unit, make spot films and perform other adjustments. Both are failure points and need constant work. Foot controls are subject to spills, kicks and general abuse while

Biomed Certification Study Guide
By Dave Harrington

hand controls are often dropped, (sudden stop or rapid deceleration). One trick is to put the rubber protector on the hand control like on a pulse oximeter.

On some systems there are up to 5 instrument cabinets, 2 high voltage tanks and various other components all interconnected. It is important to inspect all exposed wiring, at least annually, keep the cabinets well ventilated and dust free. The manuals should be kept in the area and secured. Some organizations keep service records in a binder in the area along with any field notices or updates. In radiology service information is power and you have to protect that source of your power. It is not common that the x-ray systems are connected to the hospital's emergency power system. Most systems can be manually connected to emergency power for short periods of time if there is enough generator capacity. It is not uncommon to have parts of the system connected to power conditioners or even a UPS. It is a good idea to put together a listing of how each device in the room is powered, as some fluoroscopic video monitors could be on the same power system as the table or control panel. And will only work if those systems are powered up. People have gone the extra mile to make x-ray systems more complicated and expensive than with any other medical devices. You have 2 to 3 names for the same functions; you have interconnections for devices 2 feet apart that will travel 20 feet into the floor or ceiling to a junction cabinet and back. In addition costs are high and alternate vendors for many items are not available. In imaging it is almost better to be a good manager of technology instead of being a good repairer of technology.

Processors, Multiloaders and Dry Imaging

In Radiographic systems film is used to document images. The most common films are blue or green based. They can have varying speeds, (light required to expose them), emulsion, (what molecules that accept light), base material, single or dual sided emulsions and sizes. There is day light film, no dark room required, and normal film, dark room required. Combined with daylight or dark room cassettes that have intensifying screens in them that match the film being used the chance of mistakes and mismatches is very high. The film type, (blue or green), the speed, the intensifying screens in the cassettes and the chemicals in the processor all have to be compatible for quality results. Combine these factors with technique variations, (KV, mA and time settings) it is easy to see why the waste film bins are always full.

Dark Room Films

Working in a dark room under a "safe light" the technologist hand loads sheets of film into cassettes by opening the back of the cassette. The cassette is either hand carried out of the dark room or placed into a "pass box" where another technologist would pick up the cassette and do an exam, by placing the cassette into a Bucky tray and exposing the film with a patient between the source, (x-ray tube) and the film. The cassette is brought back to the dark room or pass box, where the cassette is opened and the film manually fed into the film processor.

Common problems

Light leaks around the edges of the film, indicating cassette not close properly or is defective, look for the indications of dropping

Marks on the film caused by dust or dirt on the intensifying screens
Cover latches not closing properly

Day Light Films

Under normal light conditions packs of films in various sizes are placed into a multiloader by a technologist, usually 100 sheets at a time. The cassette is pushed into the "loading slot" where fingers open the end of the cassette at the same time as determining its size. The machine selects the correct size of film and with push rollers forces the film into the cassette. The technologist would then use the cassette for a procedure. After the procedure the cassette is placed into the "unloader's, which is attached to the film processor. The fingers open the cassette and eject the film onto a roller system that transports the film into the processor.

Common problems

Light leaks, generally only of one edge of the film which could be caused by a bad cassette or light exposure to the film as it was loaded into the multiloader.

Biomed Certification Study Guide
By Dave Harrington

Marks on the film caused by the loading or unloading rollers

More than one film loaded into the cassette. This is a common problem is the humidity in the multiloader is allowed to get too high

Film Processor

Auto film processors have changed little since their introduction in the 1960's. The exposed film moves downward into the developer solution then back up to the crossover rack that sends the film downward into the fixer bath then back up to another crosser rack and down through the rinse bath and then into the drying rack before being dropped into the developed film bin on the front of the processor. With each film that passes through the processor additional chemicals are added to keep the system in balance. If the processor sits for long periods without films being processed the chemical balance can also be affected. Most processors have a "stand-by" cycle where developer and fixer are added to the processor every hour replacing the evaporated chemicals. This can cause problems with the quality control on films as the concentrations can get too high and will cause very dark films. It is wise to discourage placing film processors in low usage areas, as they require more care than those in high use areas.

The solutions used have to be compatible with the film emulsions and need to be monitored for quality by doing "densitometry" tests at least every other day, every day is better. A film is exposed with a sensitometer and run through the processor. On the edge of the film is a 21-step exposure ranging in density from 0.05 to 3.05 in steps of 0.15. Using a densitometer 3 points on the exposed film are measured. The first point is the film outside of where the gray scale appears from the sensitometer. This is the base or fog reading, which should remain constant. Next two steps on the gray scale are measured, such as 9 and 13; this can vary from hospital to hospital and even within a single hospital, (the selected steps are part of the QA program for the radiology department). The measurements from these points is plotted and any variations longer than 2 days generally will require either the cleaning of the processor or adjustments to the chemical mix or temperature. If all 21 steps were measured and plotted you would have a characteristic curve of density and exposure. This is also call and H & D curve, which was developed by Hunter and Driffield. The QA chart for each processor shows the 4 key points, the base fog of the film, the readings at each selected step and the temperature of the developer.

The crossover rollers, or rack, should be cleaned every day, first thing in the morning to remove any buildup of dried chemicals on them. They just have to be rinsed under running warm water for a minute or less to remove any build up. If not cleaned the dried chemicals can lead to "pick off" on the film that could indicate the presence of anatomical changes in the patient that are not there. This can be a critical problem with mammo films.

Most hospitals will have a silver recovery system connected to the processors to capture the silver that washes off the films as they are developed. These can cause problems if not changed on a regular basis and they can impede the flow of water from the processor to the drain. Clogged drains, leaking tanks, temperature changes and stuck pumps are common problems with processors. If the processor rollers and racks are cleaned on a regular basis and the rollers replaced as needed they are not major problem areas. If they are not cleaned they become problem areas. ***A good QA program is needed and must be followed to assure few problems with processors and consistent results.***

In most hospitals there is a dedicated film processor for Mammo films. These films are single emulsion and require different temperatures than regular radiographic study films.

When digital systems are in place for either fluoroscopic or radiographic studies the signals are transmitted to a device called a laser camera or laser imager. In this device the images are scanned onto film and transported into the film processor. These systems are prone to failures and require regular servicing, as with any digital system. Be aware of light leaks between the laser camera and the processor can affect the quality of the film.

Biomed Certification Study Guide
By Dave Harrington

A verification of this is called the dry imaging system or dry laser camera. This device takes the digital images and “prints” them onto the acetate base “film”. This is not a true film as it is just clear acetate that has images printed on it. There is no film processor, no cassettes, no film and no chemicals to mix. It is lower in cost to operate, environmentally friendly but only capable of being used with digital imaging systems and some radiologists are not comfortable with it. These units are mostly found in the CT and MRI areas. These systems will become more common as the PAC systems are installed in hospitals. PAC systems are expensive and require major changes in department policies and procedures but pricing is coming down and as more digital systems are installed in procedure rooms the better the return will be on PAC systems.

Specialty units, Mammo, Tomo, Bone Density and Interventional Radiology

Specialty units may not be physically located with the main radiology department but in other areas of the hospital. Mammo and Bone Density are often located in the “Women’s Health Clinic” or in an Out Patient Clinic area. Tomo units could be in the Orthopedics Clinics while the Interventional Radiology areas may be close to the operating rooms. This can put a strain on servicing these devices, as when not in the main areas there is not easy alternate method of doing the tests. These are generally high dollar tests that the hospital does not like to lose. Rescheduling the patients can be a problem so good PM programs are needed to keep the “up time” high on these devices/systems so as not to impact the hospitals finances in a negative direction.

Mammo

Mammograms are part of regular testing for women after age 40. This is a soft tissue radiograph, which has limitations on what equipment can be used along with special accessories attached to the equipment.

Originally when a Mammo was done the collimator was removed from the tube and a cone mounted in its place. The cone was lowered to the body surface and an x-ray taken. The KV used was between 40 and 50 with a long exposure period. It was an uncomfortable procedure and the dose could be as high as 10 rads. Now with specially designed units doing only mammograms while still uncomfortable for the patient the dose levels are very much lower. The use of high frequency generators has further reduced exposures and increased contrasts on the films because the x-ray beam is more consistent.

The breast is compressed between adjustable “paddles” that move tissue to a more consistent thickness and the film is taken. This is a single emulsion film designed for low contrast images. The film is developed in a dedicated processor for that type of film. Digital imaging is slowly becoming more common but its progress has been slowed by reimbursement problems, as many insurance carriers have not approved the use of digital systems in mammographic studies. The FDA was also slow in issuing its approval of the technology.

Common problems include

- Compression paddles that crack or slip
- Mechanical positioning

Replacing the tube is common after 2 to 4 years of use and can be expensive. The physicist should closely monitor the focal spot size on the tube to be sure that it does not exceed its specified size range. This growth will affect the quality of the exams.

You should obtain from the state a copy of the regulations for mammography services and make sure that the installations meet state requirements.

Some radiologist will also have a dedicated viewing panel for the Mammo films. The lights may be brighter and have more output in the blue spectrum of the light. If this is the case it is a good idea to replace all of the light tubes at the same time.

Tomo

This is a procedure that goes by many names, Tomo, tomography, body-section radiography, laminography and planigraphy. The basic principle is to blur unwanted images with maintaining the contrast and density of the desired object. The main use of this technique is examinations of the spine. The operating principle is simple in that the patient remains in a constant while the tube and film move in opposite directions. Only about 1 in 10 units are quipped to do Tomo exams. The most common problems are mechanical and spare parts are often difficult to obtain.

Another version uses the long cassette and film, up to 30 inches long. The film and patient remain stationary while the tube moves.

Other than the movement of the tube and film everything else on this unit is standard, including the development of the film.

Bone Density

The loss of minerals in bones was difficult to diagnose for many years, Tomo exams were used to confirm degenerating vertebrates but were not practical for mass screenings. In the late 1980's new devices came onto the market specifically designed to measure the density of bones. The system is fairly simple and generally reliable.

Under the table is an x-ray tube with dual energy ranges, (70 and 140 KV are typical). By using a high frequency power supply the quality and quantity of the x-rays generated is very consistent. Instead of a collimator that limits the output to a square or rectangular shape a "fan beam" is created, long and narrow. These are rotating anode tubes and some require additional cooling to maintain the ideal operating temperatures of the tube. The beam passes through the patient and is detected by a series of sensors mounted over the patient. The sensors are connected to a computer where the data is reconstructed into a picture. In most cases the image is printed out on a standard computer printer, laser or inkjet, with computed densities printed next to the image. If a dry imager is available the image can be printed on that also.

Scan times can range for seconds a small part up to 20 minutes for a full body scan. The dose levels to the patient are about equal to a chest x-ray even with the long scan time. Because the beam is so confined the walls do not have to have lead lining and the operator needs no shielding.

On most systems the patient is placed on the table and positioned at the point where the scan is to start. The tabletop moves the patient past the x-ray tube and detectors until the scan is complete. The total movement of the table is less than 30 inches so keep other devices away from the ends of the table.

Another version of bone densitometry is the heel ultrasonic unit. This is a small unit that is good for mass screenings but not for definitive diagnosis of patients. The patient places their foot onto the positioning platform of the device and the heel bone is scanned. If the reflected power is below a certain number the patient is advised to get a scan using the x-ray system.

Interventional Radiology or Special Procedures Rooms

This covers a wide range of rooms from cardiac catherization laboratories, to angiographic suites, to electro physiology suites to neuro suites. These are all basically rooms equipped with fluoroscopic capabilities but with better video resolutions, smaller focal spots, higher power and a multitude of support equipment. Many of these units are almost like a separate practice within the hospital and it is difficult to get the devices onto a PM program as the equipment is used for 12 or more hours per day. You have to be flexible and get into the areas when they staff is having patient conferences or on breaks.

The support equipment in these areas ranges from simple defibrillators to multi-channel monitors to lasers, pacer programmers, to electrosurgical devices and now even radioactive sources for angioplasty. You may

have problems in maintaining a good inventory of equipment in this area as some of the devices may be on loan, consignment or simply stolen from other parts of the hospital.

Follow universal precautions when working in these areas

Cysto Room

This room is generally in the OR suite and is specially designed to perform studies or procedures relating to the kidney, urethra, bladder and prostate. It is basically a fluoro room with a special table. Films are not often taken as the surgeon uses the fluoro imaging to guide instruments to remove or crush stones. In other procedures dye is infused into the kidney and the movement down the urinary track is observed. Another common procedure is the TUR (transurethral resection) or prostate surgery.

This is a wet environment and close inspections of grounds and measurement of electrical leakage currents is essential for the protection of the patient and staff.

Generally these rooms are available for inspections and PM's in the mid to late afternoons most days of the week. Probably more than in any other x-ray installation the lubrication of mechanical systems needs to be done on a regular basis. Also you should check for rusting on the machines.

Follow universal precautions when working in this area

Portable C-Arm

This is similar to a portable x-ray except that it is a fluoro system. It uses a high frequency power supply, has an image intensifier and view chain to display images. Most have a storage scope where the first image of that patient is kept to serve as a guide to what needs to be done. The systems come in two basic sizes; the larger size is used in operating rooms often on orthopedic cases, such as hip replacements giving the surgeon an accurate indication on how the joint is line up and seated. They are also used in other cases in the operating room for placement of drains, catheters and other apparatus into the patient. Generally there are 2 components to these C-arms, the "C" which contains the tube and I/I attached via cables to the chassis that contains the generator and the video storage electronics.

The smaller units, often called "mini c-arm" are commonly used to assist physicians resetting broken bones in hands, wrists and feet. The mini c-arm is in one chassis so it is easy to move and takes up much less space.

Common problems

- Interconnection cables are easily damaged, as are the connectors
- Positioning locks not holding during procedures allowing the head to move
- Casters and caster locks
- Mechanical damage from running into walls and other objects

There will be no technical discussion of CT, MRI, Nuclear Medicine Imaging, PET, SPET or Ultrasound in this module but the technical management problems are similar and may be mentioned in the management section.

Management of Imaging Devices

There are several hard and fast rules that apply to managing Imaging Devices these rules do not vary between hospitals and cannot be appealed to the courts.

- 1 No matter how capable you or others are in the hospital you will not be able to repair every item, every time, in a timely fashion. You need access to outside experts, be they in the company, an ISO, or the vendor of the device. Even the field service organizations of a supplier often have to call the factory for guidance on problems. ***NO ONE KNOWS EVERYTHING***

Biomed Certification Study Guide
By Dave Harrington

- 2 You will be overcharged for some repair part, time or travel on a regular basis. Look at all service reports and invoices very closely.
- 3 You will not be able to second source all repair parts, especially tubes on newer units.
- 4 What the physicist reports and the real problem with a device are not always the same.
- 5 Doing good PM's that find and correct minor problems before they become major problems makes the greatest financial savings.

It is very important that the chief technologist be kept informed of all repair and PM work done in the department. While you do not have to give detailed reports it is a good idea to meet with them on a regular basis to go over problems that have occurred. Some problems could be caused by poor techniques being used by technologists or trying to do tests on a unit that is not suited for those tests.

It is also a good idea to work with the department on any quality issues that affect patient care or costs, especially "retakes". When a study or exam has to be repeated extra costs are incurred which may be avoidable. The patient is also exposed to a higher radiation level and if the test is invasive to infection. Retake rates can indicate both equipment and personnel problems, which are sometimes difficult to separate and correct.

You need to be aware of any changes in film, processor or contrast media supplies as they may affect the quality of examinations by requiring changes in equipment settings.

Keeping good records on what is done is not easy as some of the work will be done "off hours" and the service reports may be sent to the clinical engineering department. All service reports should be reviewed for completeness, what was done and the time involved. They should be also checked for "boom-a-rang" which happens to all service organizations. It is not uncommon to have a service call on a device the day after a PM was done. Nor is it uncommon to have the same failure within days of a "repair".

Be careful in record keeping and you can save the hospital major expenses on repairs or PM's that were not done or done properly but billed for.

Lastly when working on imaging equipment think simple and look for the obvious as with other technology it usually solves the problem. Ask questions and take time to understand what the problem really is before starting any repair.

REVIEW QUESTIONS

- 1 Which was invented first the EKG recorder or the x-ray?
X-Rays were discovered in 1894 the first EKG was 1903
- 2 True or false Tomo is used for vascular studies?
False, tomo is used for long bones or spines
- 3 What indicates a light leak on a film after developing?
Fog along the developed film edge
- 4 A grid ratio of 8:1 means that the space between lines is _____ of the height.
1/8 of the height
- 5 Compton scatter is similar to characteristic radiation, True or False.
True
- 6 The filament voltage in an x-ray tube are measured in mA, True or False?
False, mA is a current measurement

Biomed Certification Study Guide
By Dave Harrington

- 7 Focal spots remain constant over the life of the tube, True or False?
False, it increases in size with age
- 8 99% of the energy created by an x-ray tube is heat, True or False?
True, even after 107 plus years of development
- 9 What are the 4 items recorded on the QA program of a film processor?
Base fog, speed, contrast, (sometimes called density readings), and temperature.
- 10 A high frequency power supply provides less consistent x-ray output than a 12 pulse power supply system, True or False?
False, a high frequency power supply provides the most consistent output

TROUBLESHOOTING MEDICAL EQUIPMENT

In this outline various points will be presented as a guide to assist in the troubleshooting and repair of medical equipment. Many techniques and methods have been advanced as the best and quickest by various authors. The intent of this outline is to list the various steps and procedures for troubleshooting medical devices and systems in an easy to use format. Also to give structure to your troubleshooting process before you open the device's service manual.

Before you start.

Safety First know the hazards that are associated with the device be it electrical, mechanical, chemical, gas or bacterial. Take all the precautions needed, including personal protection, gloves, etc. **When in doubt as to a hazard, assume it is present.**

What is the device used for? While no longer a common problem, devices are sometimes used for other than their intended purpose. This can lead to a trouble call, which can be more political than technical. Look at the application before starting any work; if it is not the correct application for the device you have got a problem that might take your manager to solve.

Rules of engagement

There are 9 rules and 3 thought processes that are used to troubleshoot engineered products. Unfortunately these rules and thought processes do not work on people all the time as they do on engineered products.

The rules are as follows

- 1 Look at the device/product/process
- 2 Listen to the user/device/product/process
- 3 Smell
- 4 Is the application correct for the device/product/process
- 5 Is there power
- 6 Is there an input
- 7 Is the processor/amplifier/etc. working
- 8 Is there an output
- 9 Is there a memory/program/system problem

The thought processes are as follows

- 1 Look for the obvious
- 2 Think simple
- 3 Don't overcomplicate the problem.

The thought process is best illustrated by this question. What is the end of time and space and the beginning of eternity? See the last page for the answer.

Rule 1 Look at the device/procedure/process

Don't just look at the device/procedure/process but all the information that may be around them. Are there any notes from the users, is there a description of the problem or is it just labeled "broken". Is there a name of the person who found the problem? Is there an error log on the device? Is there evidence of a drop, spill, smoke, heat or other damage?

If there is evidence of a spill it must be considered hazardous and cleaned by someone trained to handle hazardous spills. Spills, even non-hazardous ones are usually conductive and can cause shorts in the device circuitry. Such solutions as TPN are very thick and can act as glue that will overload motors on a pump.

Always follow the Universal Precaution Procedures that are in use at the hospital.

Biomed Certification Study Guide
By Dave Harrington

Next look at any connectors, power cords, input or output cables to be sure that they are in the correct positions and secure. Check the positions of all switches and controls to be sure that they are correctly positioned and working.

Assuming that there are no signs of mechanical damage to the device do a “self-test” or “calibration” on the device. This may also give you the “error log” on the device, which must be reviewed and problems noted. Unfortunately all too many techs will stop the process if the “self-test” passes. There can be other problems that are present but not part of the “self-test” process so complete the full troubleshooting before returning the device to use.

Next remove the covers of the device and carefully look for dust buildup over fans or vent holes, fluid spills, loose hardware or worse floating hardware cleaning and correcting as you proceed. Make sure all the chassis components are secure. Look for signs of heat, smoke burned components, correct as needed.

Look at any fluids carefully, if they are oil based it may be an indication that a capacitor or transformer is leaking or failed. Generally if this has happened there will also be signs of heat damage around the failed component.

Next move on to the circuit boards, are they properly seated, is there dust or spills on them, is there signs of heat buildup, are the components secure on the boards? Correct problems as you find them. You might look over the solder connections on the boards to be sure that there are no “cold” joints. You might also want to clean the connectors; you can use a white eraser. The pink erasers may leave a film on the contacts.

At some point you should look at the manual and the device history to be sure that you have covered what needs to be done and to determine if the problem has occurred in the past. If it is a repeat problem it may require changes in the PM or in-service training of the users

All these steps should be taken with the three thought processes.

Rule 2 Listen, Listen, Listen

You listen to the device/process/procedure for unusual sounds. These sounds can be electrical arcing, motor/fan sounds, pumps or speakers/alarms that are or are not providing true tones. Does the mechanism require lubrication, if so it should be cleaned first and then lubricated, as a buildup of lubricant can be the cause of the problem.

You listen to the user of the device, find out what they see the problem as, what has changed with the outputs or process, is it still within normal ranges or not. Has the speed of the process changed? Has the use of consumables increased? Don't ask question of the users that they don't know the answers to, keep the questions to the setup, controls and outputs of the device/process. It is not unusual for a user or an operator to not know all the functions of a device/process and to avoid looking foolish they will give bad answers to questions outside of their knowledge.

You listen to others who have worked on the same or similar devices or processes. They may have information that will help you in correcting the problem reported.

Rule 3 Smell

The sense of smell is often overlooked in the troubleshooting process. It is generally more useful in troubleshooting a process than a device. If a strong smell is present it generally indicates that either the venting system is not working correctly or the input is being overloaded with a chemical. Sometimes it is an indication of a spill. Sometimes the users are so used to the smell in their area that they don't realize that the background levels have changed and something is not right. This may happen days before the problem that you are involved with happened. With

processes or procedures if a smell is present look first to the ventilation or scavenge system, pumps and for leaks in the feed or waste lines.

On devices, overheated components, shorts or fans that are blocked can cause smells. General rule “if it smells there is a problem somewhere”.

Remember that in the fall of the year when the building heats comes on you will often get calls about smells. In most cases no devices or processes are involved with these smells just dust on the heaters.

Rule 4 The application of the device/process/procedure

This is generally not a problem in most clinical areas. Using the wrong device/process or procedure does happen in research areas and may happen in some clinical specialty areas. It is common in radiology and ultrasound as operators may be looking for details that are not possible with that particular device. It used to be common in the clinical laboratories when tests were done on a particular device as opposed to now when multi tests are done with one device.

More of a problem than the misapplication of a device or procedure is using the wrong disposables on the device. This is a continuing education problem that all have to be involved with. Some even go so far during PM inspections or rounds any wrong disposables are removed from the device. While this is a good preventative step it requires that the person doing the removal replaces the wrong items with the correct ones.

If the wrong disposables are a constant problem you need to notify the Material and Risk Management departments with your concerns. Documentation is critical to get results so documents all failures, time, and expenses and if patient care was compromised.

If disposables are the cause of the problem it is a good idea to inform the Materials Management Department about the problem and let them notify the supplier of the products. It may also require that a report be sent to the FDA under the requirements of the Safe Medical Device Act, (SMDA).

Using these first 4 rules you probably will solve 75% of all your trouble calls. Medical devices do not have high failure rates and the majority of all problems are of user origin. This user origin includes the application, cleaning, (or lack thereof), poor airflow, poor PM and operators that do not understand how to apply the device properly.

The next 5 steps can be used in just about any order and will vary with the device but be sure to use the three thought processes that are mentioned.

As you progressed through the “LOOK” steps you covered much of these next 5 steps. You’ve checked the power cord, plug, switches, fuses, circuit breakers etc. so if the unit does not “power up” it indicates that there is a problem with the power supply, software or system.

Rule 5 Is there power to the device? The most common problem.

Power is not just electricity; some devices require compressed gases, vacuum, or water to work. Are all of these required elements present and at the correct levels? This is the question that has to be answered. During the “LOOK” step you should have been check for the obvious. Is it plugged in, (both ends of the power cord), is the outlet “live”, is the power cord good, is there a second power switch on the unit, if the fuse good, is the breaker open are the most common questions/tests that you would perform. Other problems can be that the unit has a bad or missing battery that is part of the circuit and needs to be functioning for the device to work. The signs that a device is powered up include indicator lamps, the screen is lit, can you hear a fan or motor running, pressure/flow indicators not on zero. On pneumatic, hydraulic or vacuum powered units do you hear or see leaks?

Biomed Certification Study Guide
By Dave Harrington

On some devices there is a voltage compensation switch, check that to be sure it is in the correct setting, also some devices have a 50/60 Hertz switch that needs to be in the correct setting.

If the outward appearance is that power is present recheck to see if the unit is now working before taking the covers off and testing the power. Be sure to test all function and verify the output is what is expected.

On some networked devices the main unit has to be powered for the “slaves” to work, this is not common but it can happen especially in lab equipment, some ICU settings and some general IT systems.

Once the “covers” are off you need to repeat step one very carefully looking for loose connectors, connectors not in place, signs of heat, damaged components etc. **LOOK FOR THE OBVIOUS AND THINK SIMPLE.**

In most modern equipment there is more than one power supply in an instrument, you need to determine which of the power supplies is defective. They are often ± 5 , ± 12 or 15 volt power supplies for the logic circuits, 60 to 120 volts for motors and certain displays, plus high voltage power supplies up to 150,000 KV. Know what you are looking at before starting as going across the wrong points with your meter could leave ashes in your hand or no indication of a voltage present. Remember when testing voltages in an instrument **ONLY USE ONE HAND.**

It might not be cost effective to repair the sub assembly or replace the defective component, when located, often times it is best to replace the sub assembly or board rather than go to the component level.

Your manager needs to be involved with the call as to replace or repair. Remember that the price of the repair may be only a few dollars, but the cost of the repair can be thousands in lost billings for the hospital.

Rule 6 Is there an input to the device? A common failure point.

Where does the input come from? This is the first question to ask. Is it a cable, electrode, probe, tissue sample, liquid sample? What, if anything, has changed on the input? If the device tests blood or tissue samples are they properly prepared? Are the samples being presented correctly?

For devices that acquire electrical signals from a source as the input of the device there are additional questions that need to be answered. As dumb as it may seem, is the patient alive? Has the patient's condition changes, temperature up or down, is there more movement, (shaking, shivering, thrashing around in the bed), did an electrode or sensor fall off or its contact resistance go up? Are the lead wires and cable good? Did you do a self-test or calibration on the device? Is there an error message on the display? If so correct that error first.

Return to Rule 2 and listen to the user. Sometimes they have the answer but are not sure of it so they called you to confirm what they thought.

Rule 7 Is the processor working? A rare failure point.

This is where you can get into serious expenses if you do not handle this Rule well. There are many options that one can select to determine that the problem with the device is in the processor. The first option, if present, is to do a self-test on the device. If that comes out OK the problem probably is not in the processor. If the self-test comes back with an error code that needs to be corrected before going any further. If the output is not accurate there may be a processor problem but the self-test should have picked up that problem. On some devices you cannot do a reset from the panel but have to do a full shut down to reset the program that controls the processor. Check with the user before shutting down a device. If the output of the device is intermittent check everything connected to the output before replacing the processor.

Rule 8 The output

The output of a device is its final product. In many cases it is a delivered energy, a graph or a set of alpha/numeric. In some cases it may be more than one.

Delivered energy can be light, such as laser, ultrasonic energy such as therapeutic ultrasound, or high frequency energy such as Electrosurgical. Fetal ultrasound may have two outputs, one to gather the data and the other to convert the data into an audio tone. Diagnostic ultrasound also has several outputs, from the transducers energy is delivered to the target; the “bounce” of that energy is processed into visual outputs on videotape or in a picture. Other devices that have more than one output include fluoroscopic x-ray, MRI, and photometers.

The most common devices with graphs are recorders, ECG/EEG/Fetal Heart rate are the most common of those. Problems with graphs often involve the paper in installed correctly, the paper not moving at a constant speed and dirt or wax buildup on the print head or stylus.

The alpha/numeric output can be on a CRT, printed on a sheet of paper, placed on a continuous roll paper or sent via a network to another device. When the output of one device serves as the input of another device there can be problems with the transmission of the data. Be sure to isolate the problem as either an output, an input or communication problem.

Some devices will require specific test instruments to determine the output level of the device.

Rule 9 Memory or Program

This type of a fault generally affects both the processor and the output. Sometimes it can confuse you as to exactly what the problem is.

With straight memory problems the installed parameters may be wrong for the patient, they may be for another application of the device or someone might be playing with the unit and changed the default settings. It is a good idea to keep the default settings on a device on the inside cover of the service manual. If the default settings are changed on a permanent basis that change should be logged into the same place along with being entered into the equipment history.

Other devices may have a set number to procedures that it will perform then automatically shut down until a new “program card” is installed. This can be the case with devices that are rented on a per use term or with reagent rentals.

What can be very dangerous is to have similar devices with different software levels. All devices of the same model number should have the same software level.

The last point that needs to be made is that you should develop a “book” on the devices that you commonly work on. It can be in your head or on paper or in a computer database. Your memory and ability to use previous experience is critical to being a good troubleshooter.

The answer to the thought process question is the letter “E”. If you came up with any other answer you are over thinking the problem and not looking for the obvious.

MEDICAL EQUIPMENT FUNCTION AND OPERATION

1 Test Equipment

Definition The act or result of a quantitative comparison between a predefined standard and an unknown.

No test instrument can measure all parameters of every device.

Use only test instruments that are designed to measure what is present.

2 ECG both monitors and recorders

Gain 1,000 nominal with selection to 250, 500, 3,000 and 5,000
Select to get 1mV per centimeter of deflection

Input impedance -66db or 100 Meg Ohms, nominal

Isolation technique isolation transformer for each input

Frequency Response Monitor 0.5 to 35 Hz (50 is also used)
Diagnostic 0.1 to 100 Hz with notch filters at 50/60 Hz

Defibrillator protection spark gap on each input also may have diodes

Note Some input cables may have 1 or 10k resistors in series with each lead wire and others may have a choke for use where ESU's may be used.

Lead configuration 3 or 5 lead wires (electrodes) is the most common for monitors
5 or 10 lead wires (electrodes) are the most common for diagnostic recorders.

Note A 12 lead EKG requires 10 electrodes.

Common EKG leads Lead I LA +, RA -, RL ref
Lead II RA -, LL +, RL ref
Lead III LL +, LA -, RL ref
AVR RA +, sum of LA and LL -, RL ref
AVL LA +, sum of RA and LL -, RL ref
AVF LL +, sum of RA and LA -, RL ref
C1 to 6 C +, sum of LL, RA, LA -, RL ref

To find a bad electrode, lead wire or input, switch through the leads until the problem disappears and use the above locations or the Einthoven Triangle to determine the faulty electrode, lead wire or input.

Always destroy a bad or questionable lead wire do not put it back into the drawer where it can be used again.

Recording and sweep speeds Standard for both monitoring and diagnostic work 25 mm/sec
Special diagnostic speed 50 mm/sec
Trending 12.5 mm/sec

Recording channel width nominal 50 mm, remember the paper is wider but the gradicules are 50 mm wide. Each square is 1 mm or 0.04 seconds at 25 mm/second speed.

Telemetry ECG telemetry can transmit 1 or more leads of ECG information depending on vendor, but only in variations of leads I, II, or III, augmented or chest leads are not common.

Biomed Certification Study Guide
By Dave Harrington

The lead wires are the transmitting antenna for the system so lead lengths need to be constant to have the best signal to noise ratio

For transmitters that also send NIBP or SPO2 information signal strength is very important as is the signal to noise ratio.

All new purchases of telemetry should be on the new frequency channels not in the TV or 450 to 480 MHz bands.

Receivers must be matched to transmitters, they should be sent out for repair together. Note during repairs it might be wise to have the unit "rechanneled" away from the frequencies being proposed to business use, those frequencies are 462.7625, 462.7875, 462.8125, 462.8375, 462.8625, 462.8875, 462.9125, 467.8625, 467.8875 and 467.9125 MHz

3 EEG

Gain	10,000
Frequency response	0 to 50 Hz
Chart speed	30mm/sec nominal can select up to 16 speeds on some units
Channel width	28 mm

4 Blood Pressure measurement, direct and indirect

	Direct
Gain	5,000
Frequency response	0-15 Hz, above 15 Hz, overshoot, (false high), on systolic pressures can occur if the heart rate is above 100
Chart speed	same as EKG
Channel width	same as EKG

Typical pressures in mmHg

Systemic arterial	
Systolic	90 – 140
Diastolic	60 – 90
Mean	70 – 105
Pulmonary artery	
Systolic	15 – 30
Diastolic	4 – 12
Mean	9 – 16
Pulmonary capillary	
Wedge	1 – 10
Right atrial or central venous	
Mean	0 – 8
Right ventricle	
Systolic	15 – 30
End diastolic	0 – 8
Left ventricle	
Systolic	90 – 140
End diastolic	5 – 12

Points to remember

Level detectors determine systolic and diastolic pressures electronically.

Biomed Certification Study Guide
By Dave Harrington

The mean pressure is calculated, usually as 0.707 of the systolic
As you move distally down the arterial tree the systolic pressure rises, pressures taken in the ankle area will be higher than those taken at the wrist.
The transducer must be level with the catheter tip, every inch above deducts 5 mmHg and below adds 5 mmHg to the systolic pressure measured
Direct and indirect pressure measurements almost never agree.

Indirect, Manual

Cuffs The size of the cuff applied to the patient is of critical importance in the indirect measurement of blood pressures. On some very large adults a thigh cuff has to be used on the arm as the large adult cuff is too small. This thigh cuff may give a low pressure reading. If the large adult cuff is too small it will give a high pressure reading. Some dual tube cuffs are arm specific and will provide inaccurate data if applied to the wrong arm.

Extension tubing Long extension tubing, between the cuff and the gage can give inaccurate readings as the tubing acts as a capacitor smoothing out pressure variations.

Deflation rate on cuff The guideline is 2 to 3 mmHg per heartbeat, most practitioners go much quicker which may give false high diastolic pressures.

Stethoscope Placement, condition, hearing ability and background noise all effect indirect manual measurements.

Mercury manometer These have been banned in some hospitals, cities and states but many are still in use, will be banned by the EPA in 2005. If the mercury, tube or filter is dirty the mercury will react slower giving false pressures. Remember that mercury is a hazardous material.

Aneroid manometer If the needle is not in the oval at the bottom of the gage it is not calibrated and should not be used.

Indirect, Automatic

This has the same problem as the manual method with cuffs, extension tubing and placements.

If the device uses a microphone to pick up sounds, positioning of the mike is critical

If the unit does not use a microphone in the cuff it is difficult to get a good reading on a patient that is shivering or is shaking.

The deflation rate on the cuff can be affected by a dirty air filter or in certain cases a low battery.

When part of a telemetry transmitter readings are questionable when the patient is moving.

5 Pulse Oximeters

Light spectrum	600 to 1,000 nm, most use 660 to 940 nm
Pulse rate of light	480 Hz
Sample rate	30 Hz
Light emitting position	on finger probes the emitter should be over the nail
False positives	carbon monoxide in blood can give false high readings
False negatives	dye used for cardiac studies can give false low readings High ambient light can give false low readings

6 Infusion Devices

All infusion devices should be equipped with a system that prevents “free flow” of the fluids when the door is opened. Also the set used should prevent “free flow” when it is removed from the device.

Controller

Accuracy	±5 to 10% depending on manufacturer
Pressure generated	none, uses only gravity, cannot do arterial infusions
Flow rate	2 to 999 cc per hour

Pump, Syringe

Accuracy	±0.1 to 5% depending upon manufacturer
Pressure generated	from 2 to 10 PSIG, (100 to 2,500 mmHg)
Flow rate	60 cc per hour max

Pump, volume displacement

Accuracy	±1 to 5% depending on manufacture and settings
Pressure generated	from 1 to 20 PSIG, (50 to 1,000 mmHg), can be set by BMET
Flow rate	2 to 999 cc per hour

Some units may damage blood cells, check manufacturers specifications

Pump, linear peristaltic

Accuracy	±2 to 7%
Pressure generated	from 3 to 50 PSIG (150 to 2,500 mmHg), some can be set by BMET An IVAC 530 could reach 120 PSIG
Flow rate	2 to 999 cc per hour

Some units may damage blood cells, check manufacturers specifications

Pump, roller peristaltic

Accuracy	±3 to 7 % depending on manufacturer
Pressure generated	from 1 to 10 PSIG (50 to 500 mmHg)
Flow rate	2 to 999 cc per hour

Very little damage to blood cells

Note The by pass pumps used in cardiac surgery use roller the peristaltic technique, the accuracy and pressure generated are similar but the flow rate is up to 10 liters **per minute**.

7 Defibrillator, external

Most of the current defibrillators use either the Edmark or Biphasic waveforms of outputs

Edmark waveform

Peak voltage	up to 7,000 volts
Peak current	up to 50 amps
Pulse duration	2 to 4 msec
Positive voltage	100%

Biphasic waveform

Peak voltage	up to 5,000 volts
Peak current	up to 15 amps positive, 10 amps negative
Pulse duration	19 to 20 msec
Positive pulse	11 to 12 msec
Negative pulse	12 to 20 msec

Biomed Certification Study Guide
By Dave Harrington

Charge time	10 seconds or under
Automatic recharge	no
“Hands off”	yes
Cardioversion	yes, providing an EKG amplifier is present in the unit
Paddle size	varies with manufacturer Adult 7 CM diameter min Child 3 CM diameter
“Hands off” electrode	contact area typically 7 by 12 CM
Energy range	typically 5 to 320 joules on Edmark units typically 5 to 200 joules on Biphasic units, some to 320

AED units can be either waveform but most are Biphasic; units have built in diagnostics and self-test every 24 hours. Power is 200 joules, some allow or automatically go to higher power. Units are not generally connected to a power source to recharge the battery. Battery life is 300 discharges or 5 years which ever come first.

8 Fetal Monitors

	Heart rate detection
Maternal	ECG Electrodes
Fetal	ultrasound, must be repositioned as labor progresses Surface electrodes, (not common on newer units) Scalp electrode, membranes must have ruptured for this to be used
Chart speed	3 CM/minute, optional on some units 1 CM/minute
Contraction pressure	Toco is most common

9 Hypo-Hyperthermia Units

Fluid used	distilled water; hydrogen peroxide can be added as a fungicide
Temperature range	40° to 105° F, (4.9° to 40.5° C)
Upper safety limit	107° F (41.5°C)
Flow rate	measured in gallons or liters per hour, varies widely by manufacturer

On a hydrocollator the water temperature normally should be 160° to 165° F (71° to 74° C) with a high limit of 170° F (77° C)

10 Infant Incubators, Warmers and Billi lights

Incubator

Temperature range	96.8° to 100.4° F nominal (36° to 38° C)
Nominal high limit	102.2°F (39° C)
High cut off	104° F (40° C)
Noise level	no more then 65db from 50 to 20,000 Hz
Thermometer	spirit or electronic only, <u>no mercury</u>
Warm up time	not to exceed 35 minutes
Temperature control	manual or servo

Warmer

Temperature range	same as incubator
Nominal high limit	same as incubator
High cut off	same as incubator
Temperature control	manual or servo
Heat source	resistance rod Quartz element Infra red

Light bulb

Note that when a warmer is being used the baby is subject to dehydration so fluids should be being administered. Also eye protection is needed for the baby to prevent damage to their retinas.

Billi Light

Wavelength of light	425 to 475 nm
Field strength	varies by manufacturer, check each model for specs

11 Nerve and muscle stimulators

Output voltage	5 to 25 VDC
Output current	0.5 to 10 mA

12 Dialysis

Hemodialysis

Blood is removed from an artery, passed through a membrane where certain toxins and excess fluids are removed, electrolytes replaced and pH adjusted before returning to the venous system. This takes several hours and has to be repeated several times a week. While renal problems are most often treated with hemodialysis there is growing use for detoxification of patients on drugs, sickle cell removal and certain liver problems.

Note Heparin is used, as an anti-coagulant so the patient's clotting time has to be monitored.

Peritoneal dialysis

In this process the dialysate is infused into the peritoneal cavity either by gravity or pumping through a catheter. The peritoneum membranes surrounding the abdominal cavity act as a dialysis membrane allowing toxins, other by products and excess water to pass from tissues into the dialysate. The fluid is allowed to flow out of the cavity, via a catheter, after several hours. As with hemodialysis the procedure has to be repeated several times a week. While renal problems are the most common reason from using this procedure it is also used for detoxification and in some cases congestive heart failure.

CAPD Continuous Ambulatory Peritoneal Dialysis

Basically the same as Peritoneal Dialysis as described above except the dialysate, is removed after 8 or more hours, often used while a person sleeps. This is generally done most every day.

Note for Peritoneal and CAPD the fluid has to be warmed before infusing to keep from altering the patient's temperature. An accurate scale to determine before and after body weight is extremely important for all forms of dialysis.

13 Electrosurgical Generator (ESU)

Mono-polar

Electrodes	2, active and dispersive or ground, or return
Frequency	450 kHz to 2 MHz depending on generator
Power output	20 to 400 watts
Power generator	solid state or spark gap
Waveform	Sinusoidal for cutting
	Damped/modulated for coag
	Mixed both cut and coag functions

Bi-polar

Electrodes	usually tweezers with 2 contacts
Frequency	450 kHz to 1.5 MHz depending on generator
Power output	1 to 20 watts
Power generator	solid state or spark gap
Waveform	damped/modulated

Hyfreator

Electrodes	usually 1
Frequency	1 to 1.5 MHz
Power output	1 to 10 watts
Power generator	spark gap
Waveform	damped/modulated

Safety notes

The leading edge (the edge closest to the surgical site), of a dispersive electrode dissipates 90% of the energy of the ESU event.

Current division occurs when a second ground/return is present

Electrosurgical burns are round, red, raised and with a black or white dot in the center, the burn's diameter increases as it goes deeper into tissue.

Electrosurgical units should not be used with explosive anesthesia agents or in oxygen enriched area.

14 Anesthesia Machines

Gas units

Gases used	Nitrous Oxide, Air, Oxygen, (may also use cyclopropane)
Flow Tubes	One for each gas plus one for delivery to patient
Patient Circuit	Generally non-rebreathing

Gas/Liquid Units

Gasses used	Oxygen, Nitrous Oxide, Air plus gases generated in liquid vaporizers.
Vaporizers	range from one to 4 depending upon model
Flow tubes	one for each gas, one for each vaporizer plus one for patient delivery
Patient circuit	generally rebreathing

All anesthesia units have a purge button that will deliver 100% oxygen to the patient by-passing all the other gas mixtures.

All anesthesia machines should have "scavenger systems" that vent expired gases outside of the operating room.

Anesthesia machines may or may not have automatic ventilators as part of the machine.

All gases from cylinders are "pin indexed"; all gases from the wall have specific threads so cross connections are prevented. **Adapters should not be used on gas lines.**

15 Ventilators

Time cycled, with volume/pressure limits

This is the most widely used technique. The therapist sets the number of breaths per minute, the inspiratory/expiratory ratio, (deliver gas for 1 second allow for exhaling 2 seconds is a 1:2 ratio), also set is the desired delivered volume, (aka tidal volume), and pressure. Alarms will sound if the tidal volume is not delivered before the pressure limit is reached. Typical unit using this technique P-B 7200.

Time cycled, set volume with no pressure limit

This is no longer widely used. A set volume is delivered in a set time period regardless of the pressure in the lungs. Effective for patients with very "stiff" lungs. Used mostly by Emerson Post Op ventilators.

Pressure cycled

No longer in wide use. Gas would be delivered to a set pressure without regard to time or volume. Generally the patient starting to inhale triggers gas flow. Sometimes call an assist device. Most common were the Bird Mark series.

Assist/Control Units

Generally time cycled units that will assist the breathing of a patient if they have a respiratory effort, sometimes called fighting the ventilator, or will breath for the patient if no respiratory effort is present.

Jet/High Frequency/Ultrasonic Ventilator

Often used on neonates where very small volumes of gas is delivered at a high rate, generally above 160 breaths per minute.

Respiratory pressures are measured in CM H₂O.

Tidal Volume is the volume delivered by the machine.

Residual volume is what is left in the lungs after the patient exhales.

PEEP is positive end expiratory pressure, (increases residual volume)

16 Intra-Aortic Balloon Pump

A balloon is introduced via the Femoral artery and position at the descending Aortic arch as it inflates, triggered by either the ECG or blood pressure waveform of the patient, it forces blood into the cardiac arteries overcoming blockages. This unit is used to support a patient waiting for cardiac by-pass surgery or post by-pass to increase the perfusion of the cardiac muscle for a period of time. The inflation/deflation cycle of the balloon is adjusted by physicians or trained nurses or in some cases perfusionists. Major problems with the device are battery life, diaphragms and gas leaks. Most units use Helium for the gas.

17 Centrifuge

Fixed Speed

Generally used for small samples of blood or urine. Rotation speed ranges from 2,500 to 3,500 RPM depending on model and manufacturer. Most have brushes and all are required to have positive lid locks so the lid cannot be opened while the rotor is spinning. Often uses a mechanical timer. Braking of the rotor is done by reversing the motor field.

Variable Speed

Used for general purposes on blood and urine, or spinning down various suspensions in fluids. Speeds range from 500 to 10,000 RPM generally using servo speed control systems, some low costs units may use a variac or pot for speed control. All will have RPM readout either an analog meter or a digital display. Many of the motors are brushless. There is also a positive lid lock. Braking is the same as on a fixed speed unit. Timing is either mechanical or electronic

High and Ultra High Speed

These units have speeds up to 60,000 RPM and will run for many hours for certain studies. All units are refrigerated which prevents the rotation speed from heating the samples and dehydrating them. Timing is electronic, speed indicators are digital and the speed control is either servo or stepping motor. There is a positive lid latch and the braking is done both with field reversal and mechanical brakes.

18 Sterilizers

Steam, gravity

As steam condenses on the surface of the items in the chamber more steam has to be added to the chamber, which forces air out of the chamber.

Normal operating range	121° to 123° C, (250° to 254° F)
Pressure in chamber	
Cycle time, (sterilize and cool)	60 minutes typical

Biomed Certification Study Guide
By Dave Harrington

Steam, Vacuum

A vacuum pulls air out of the chamber as steam enters the chamber.

Normal operating range	132° to 135° C, (270° to 275° F)
Pressure in Chamber	
Cycle time, (sterilize and cool)	20 minutes

Flash unit

This is common in operating rooms; instruments are not wrapped but put into containers. Gravity units cannot be used to flash instruments.

Normal operating range	132° to 135° C, (270° to 275° F)
Pressure in chamber	
Cycle time, (sterilize and cool)	under 10 minutes

Steam is delivered from a central source to the sterilizer. If the steam source is self contained the sterilizer is sometimes called an autoclave. A lawyer must have gotten involved with the naming rights.

Tabletop unit

Basically a small capacity gravity unit, with the same specifications. Generally the steam is generated by the unit with an internal electric heater.

Ethylene Oxide

Ethylene Oxide is a flammable gas, above a 3% concentration, that also can cause cancer. The TWA for ETO exposure is 1 ppm for an 8-hour shift.

Pressure in chamber	8 to 12 PSIG
Normal mixture	12% ETO/88% Freon
Humidity in chamber	30% minimum
Cold cycle temperature	27° to 55° C (80° to 131° F)
Warm cycle temperature	49° to 63° C (120° to 145° F)
Sterilize time cold cycle	5 to 6 hours
Sterilize time warm cycle	1 to 2 hours
Air purge	12 to 24 hours

Other methods, may not be approved by the FDA

Hydrogen Peroxide	4° to 80° C (39° to 176° F)
Ionized gas or plasma	requires high vacuum
Ozone oxidation	limited penetration of material

19 Lasers

Lasers are used in various departments within hospitals and now in physician offices for many purposes. Most lasers are specialty specific and are used only for very specific procedures. The use of lasers in cosmetic surgery is growing rapidly.

Ophthalmic use

- Argon
- Argon/Krypton
- Diode
- Dye, tunable and set spectrum
- Excimer
- Krypton
- Nd:YAG

Surgical Use

- Argon

Biomed Certification Study Guide
By Dave Harrington

Carbon Dioxide
Erbium
Holmium/YAG
Nd:YAG
Nd:YAG, frequency doubled

Smoke evacuators should be used on all procedures.
Laser smoke can contain HIV
Protective eyewear must be worn.
Baseline eye exams are required for all who work with, around or on lasers.

20 Ultrasound

Diagnostic

Ultrasound is used to locate, map and determine movements of soft tissue structures in the body. Most common uses are cardiac and OB. Can be used for locating growths in or on organs in some cases.

Frequency range	2 to 10 MHz
Low frequency	more penetration/less resolution
High frequency	less penetration/more resolution
2D	vertical and horizontal plains
3D	adds depth
Sample rate	Usually 60Hz
A Mode	Amplitude modulated, surface mapping
B Mode	Brightness modulated, depth/structure
M Mode	Moving object, heart valve
Doppler	Used to locate structures, can be continuous wave, pulsed wave or low frequency
Color Doppler	Used to show fluid movement/flow
Special probes	Transesophageal (TEE) Transvaginal

Therapeutic

Sound waves used to stimulate or relax muscles	
Frequency	5,000 Hz
Output power	1 to 20 Watts

21 Capnograph

The continuous measurement of carbon dioxide (CO₂) in expired respiratory gases using spectrophotometry. There are 3 techniques in use.

Mainstream	measures gases via an adapter in the patient's breathing circuit. Problems include weight of adapter and moisture buildup in the sensor
Sidestream	measures gas samples in a separate chamber drawn from the expired gas stream. Problems include pump failure, (needed to draw sample into the chamber), moisture and calibration of detector.
Microstream	measures a small gas sample at the patient connection with a disposable chamber.

Biomed Certification Study Guide
By Dave Harrington

Problems have not been identified, as the technique is new.

The information in the guideline may not apply to all manufacturers and models of devices; this should be used as a guideline only.

Always refer to the specific manual of each device when doing repairs or calibrations; do not rely on this guideline.

BMET TEST

CODES. STANDARDS AND SAFETY

- 1 The two basic electrical safety tests that should be performed on line powered equipment before installation or after repairs are
 - a input isolation and defibrillation protection
 - b ground wire integrity and ground wire leakage current
 - c exposed metal leakage and leakage current between leads
 - d proper polarity and contact tension

- 2 The standard color coding of 115 vac calls for the ground, neutral and hot wires to be colored as
 - a green, white, black
 - b white, green, black
 - c orange, brown, green
 - d black, red, green

- 3 A reverse precaution sign on a patient's room indicated that the patient is
 - a infectious and may infect you
 - b has a compromised immune system and may be infected by you
 - c is on chemotherapy and cannot be disturbed
 - d is of no concern to a Biomed

- 4 Oxygen and nitrous oxide compressed gas cylinders should not
 - a be stored with protective caps in place
 - b be stored in an area cooler than normal room temperature
 - c be transported on a cart when secured with a metal chain
 - d be stored in an area where readily combustible materials are present

- 5 The recommended test procedure for detecting the presence of electrical hazards in clinical settings is to
 - a observe the patient's ECG for electrical interference
 - b observe the patient for indications of muscle twitching
 - c measure the presence of hazardous leakage currents using a specially designed microammeter
 - d measure for stray or interference voltages using a Whitestone bridge circuit

- 6 What basic electrical characteristic usually causes most leakage currents present in modern medical equipment?
 - a capacitive reactance coupling
 - b inductive reactance coupling
 - c restive reactance coupling
 - d defective insulators

- 7 What is the typical cause of death in accidents involving electrocution?

Biomed Certification Study Guide
By Dave Harrington

- a damage to the nervous system
 - b respiratory paralysis
 - c surface tissue destruction
 - d ventricular fibrillation
- 8 What is the safe “direct to the heart” current level?
- a 10 uA
 - b 100 uA
 - c 500 uA
 - d 1000 uA
- 9 The percentage of an external current flowing in the body from arm to arm that will pass through the myocardium is about
- a 0.1%
 - b 1.0%
 - c 10%
 - d 50%
- 10 In what two basically different ways can electrical currents flowing through the body affect tissues?
- a alternating and pulsed
 - b fibrillation and tetany
 - c heating and stimulation
 - d tingling and jerking
- 11 When dealing with the general subject of electrical safety what basic dangers must be considered?
- a shock and electrocutions
 - b explosions
 - c fires
 - d all of the above
- 12 The hospital’s essential electrical system shall be arranged that in the event of failure of normal power, from the outside, the alternate source will be connected to the load within
- a 1 second
 - b 10 seconds
 - c 1 minute
 - d 3 minutes
- 13 According to the Life Safety Code in the event of a power failure the emergency power system shall provide power for
- a emergency illumination and services essential to life
 - b general illumination in all patient areas
 - c all biomedical equipment in the hospital
 - d all the above
- 14 According to the Life Safety Code outlets for emergency power are designated by
- a color

Biomed Certification Study Guide
By Dave Harrington

- b labeled with the letter E
 - c have two green dots on them
 - d are twist lock connectors
- 15 A hospital GFCI
- a verifies the bonding ground resistance
 - b protects the receptacle against corrosion
 - c compares currents between the hot and neutral lines and disconnects the power if the currents are different
 - d establishes an auxiliary ground if the main ground is interrupted
- 16 What is the primary electrical safety problem present in modern hospitals?
- a electrocution and microshock
 - b tolerating the use of faulty or damage equipment
 - c insufficient electrical power in patient areas
 - d isolated power systems in patient care areas
- 17 What is the body's first line of defense against electric shock?
- a the nervous system
 - b the reflex system
 - c the mechanoreceptors
 - d the skin
- 18 Which of the following anesthetic agents is the most flammable?
- a halothane
 - b cyclopropane
 - c sodium pentothal
 - d nitrous oxide
- 19 A nitrous oxide gas cylinder should be painted
- a green
 - b brown
 - c blue
 - d gray
- 20 An oxygen cylinder should be painted
- a gray
 - b orange
 - c red
 - d green
- 21 The human body's "can't let go" reaction to 60Hz current starts at about
- a 1.0 mA
 - b 5.9 mA
 - c 16 mA
 - d 100 mA

Biomed Certification Study Guide
By Dave Harrington

- 22 Electrical leakage current
- a exists only in a faulty or defective medical equipment
 - b no longer is a problem in modern medical equipment
 - c is always present when electricity is flowing
 - d can be eliminated by RF filters at the power input
- 23 In general x-rays are hazardous because they are
- a ionizing radiation
 - b electromagnetic radiation
 - c longitudinal radiation
 - d all of the above
- 24 Each foot of a power cord typically has leakage currents in the order of
- a 1 uA per foot
 - b 0.5 uA per foot
 - c 10.0 uA per foot
 - d 1 mA per foot
- 25 In a hospital what type of a leakage test should be performed on a patient monitor?
- a current sink test of patients leads to the hot conductor
 - b leakage to ground on patient leads
 - c leakage to ground on patient leads and exposed metal to ground
 - d none of the above
- 26 When should a sink test be performed on an ECG input
- a only during design validation
 - b only at incoming into a hospital
 - c as part of the yearly QA inspection
 - d only after repairs to the input
- 27 The major hazard to the body from scattered or reflected laser radiation is
- a genetic mutations
 - b skin damage
 - c cataract formation
 - d retinal damage
- 28 What are the three components of an ordinary fire
- a smoke, fuel, heat
 - b fuel, heat, oxygen
 - c gas, liquid, vapor
 - d flames, sparks, explosion
- 29 What is the typical range of human body resistance?
- a 500 to 1,000 ohms
 - b 5,000 to 10,000 ohms
 - c 50 to 1,000,000 ohms
 - d 50,000 to 100,000 ohms

Biomed Certification Study Guide
By Dave Harrington

- 30 What is the approximate current level known to cause ventricular fibrillation in adult humans with epicardial contact
- a 10 μ A
 - b 50 μ A
 - c 200 μ A
 - d 5,000 μ A
- 31 The “threshold of feeling” current level, at 60 Hz hand to hand is about
- a 0.1 mA
 - b 1.0 mA
 - c 10.0 mA
 - d 100 mA
- 32 Child safe power outlets are identified by
- a two red dots
 - b the outlets are white
 - c by two green dots
 - d by the letter C on the outlet
- 33 High Definition TV will affect biomedical telemetry in what frequency range
- a 50 to 75 MHz
 - b 159 to 410 MHz
 - c 470 to 490 MHz
 - d none of the above
- 34 Mercury thermometers should not be used in infant incubators because
- a they are not allowed in hospitals
 - b the sliver colored line is too difficult to see
 - c mercury is toxic to developing nervous systems
 - d mercury reacts too slowly to temperature changes
- 35 The red light outside an x-ray room is on when
- a the tube filaments are on
 - b the rotor is spinning
 - c when the kV selected is above 100
 - d when the mA selected is above 800
- 36 The term “microshock” means
- a that a low impedance current path directly to the heart is present
 - b that the leakage currents are small
 - c that the shock hazard is small or non-existent
 - d all of the above
- 37 Where should GFCI’s be used in hospitals
- a in intensive care units
 - b in operating rooms
 - c in wet locations
 - d in all patient areas

Biomed Certification Study Guide
By Dave Harrington

- 38 What is the purpose of the JCAHO?
- a to assure that a hospital is cleaned at least every three years
 - b to establish standards for the operation of a hospital
 - c to give a reason for QA programs
 - d to gather data on bad medical practices
- 39 What is ventricular fibrillation?
- a a serious cardiac arrhythmia
 - b the complete stopping of cardiac activity caused by externally applied electricity
 - c uncoordinated and random contractions of the heart without any cardiac output
 - d the rhythms of the ventricles and atria are different
- 40 Which of the following statements are true
- a current kills, so high currents are always dangerous
 - b high voltage kills, so low voltages are not hazardous
 - c grounding the body is required for electrocution to occur
 - d current kills, and lethal currents can be caused by both high and low voltages
- 41 A fuse should be placed in the
- a neutral line
 - b hot line
 - c ground line
 - d all lines
- 42 According to the Life Safety Code the minimum required retention force for the grounding contact of power receptacles in patient care areas is
- a 4 ounces
 - b 8 ounces
 - c 16 ounces
 - d 500 grams
- 9.2.4.2
- 43 When considering the safe application of portable medical equipment, the usage of the three-prong AC power plug
- a assures the electrical safety of the devices
 - b is a potential lethal hazard if proper care in the selection, installation and maintenance of the plug is not assured
 - c assures proper grounding if the plug, cord and receptacle are not damaged
 - d assures proper grounding
- 44 An AC receptacle that is powered from an isolated power system
- a does not have a ground connection
 - b has AC power not reference to ground
 - c is not required in a hospital
 - d all of the above
- 45 When working with Mercury it is important to
- a keep mercury from prolonged exposure to air
 - b insure good ventilation and venting to the outside of the building

Biomed Certification Study Guide
By Dave Harrington

- c work with a smooth non-metallic pan to catch and contain any spills
 - d all of the above
- 46 What are the two general techniques used to provide signal isolation circuits in ECG inputs
- a vibrating reeds and tuned circuit sensors
 - b low capacity/high frequency transformers and radiated energy coupling
 - c diode bridge circuits and low current fuses
 - d series resistors and parallel neon lamps
- 47 Why does a hospital safety program need to incorporate redundancy?
- a to keep Biomedics busy
 - b because many groups write codes and standards
 - c to tolerate the carelessness inherent in human behavior
 - d all the above
- 48 A "UL" label on the power cord of the instrument indicates
- a that the instrument is tested and approved by UL
 - b that the instrument was built to UL standards
 - c that the power cord has been listed by UL
 - d that the manufacturer is a member of UL
- 49 What does NFPA stand for?
- a National Fire and Police Association
 - b National Fire Prevention Agency
 - c National Fire Preparation Agency
 - d National Fire Protection Association
- 50 What three basic groups that must be given specific consideration in an overall hospital safety program?
- a shop technicians, housekeepers and kitchen workers
 - b general, intensive care and ambulatory patients
 - c administrators, medical staff and nurses
 - d employees, visitors and patients
- 51 In biomedical equipment, hazardous leakage currents may be caused by
- a loss of the instrument ground connection
 - b currents originating from within the instrument
 - c introduction of high-energy electromagnetic sources
 - d all of the above
- 52 Macroshock may be defined as
- a when the current is applied through the skin
 - b large fault currents from defective equipment
 - c leakage current from normal equipment
 - d any of the above
- 53 The pressure in a full oxygen cylinder at room temperature is about?
- a 30 PSIG
 - b 900 PSIG

Biomed Certification Study Guide
By Dave Harrington

- c 2000 PSIG
 - d 5000 PSIG
- 54 According to the Life Safety Code LIM'S shall have
- a red, yellow and green indicator lights
 - b the ability to alarm at not more than 0.7 mA
 - c an audible indication whenever an alarm is present
 - d an audible alarm plus red and green indicator lights 3-3.3.4.2
- 55 The GMP requirements for medical equipment are compiled by
- a JCAHO
 - b ECRI
 - c International Standards Organization
 - d USFDA
- 56 The term "intrinsically safe" refers to equipment that is
- a grounded
 - b malfunction proof
 - c incapable of supporting combustion
 - d incapable of initiating a fire or explosion
- 57 Film badges in imaging areas are used to monitor a technician's exposure to
- a alpha radiation
 - b beta and gamma radiation
 - c laser radiation
 - d microwave radiation
- 58 What is the basic difference between codes and standards?
- a codes are enforced by law, standards are not
 - b standards are enforced by law, codes are not
 - c only codes will reflect the current state of the art
 - d codes are written by voluntary organizations
- 59 The continuity of biomedical equipment grounding is
- a dependent on regular maintenance and testing
 - b assured by the use of quality materials
 - c not necessary when isolation transformers are used
 - d all of the above
- 60 A power system ground wire needs to be heavy enough to only
- a drain away static charge accumulations to ground
 - b carries the current for which the circuit is fused
 - c carries the maximum fault current
 - d carries twice the hot current 9-5.1.2.2
- 61 The basic rules and provisions for the safe use of electricity in a hospital are promulgated by
- a AAMI
 - b the FDA
 - c OSHA
 - d the NFPA

Biomed Certification Study Guide
By Dave Harrington

- 62 The pressure inside a steam sterilizer operating at 270 degrees Fahrenheit is about
- a 6 PSIG
 - b 15 PSIG
 - c 28 PSIG
 - d 44 PSIG
- 63 The primary cause of hospitals fires is
- a flammable anesthetics
 - b the use of oxygen
 - c careless smoking and defective electrical equipment
 - d toasters and microwave popcorn
- 64 Using JCAHO standards all equipment in the hospital must be
- a tested at incoming and yearly there after
 - b only tested yearly
 - c tested at incoming and every 6 months there after
 - d tested at incoming and at set intervals there after
- 65 Using JCAHO standards rental and loaner equipment must
- a be tested at incoming only
 - b be tested at incoming and at regular intervals there after
 - c be tested if found
 - d no testing required
- 66 The present NIOSH recommended TWA exposure limit for nitrous oxide in an operating room is
- a 1 PPM
 - b 5 PPM
 - c 25 PPM
 - d 100 PPM
- 67 The majority of heating at the dispersive electrode of and electro-surgical procedure is
- a on the leading edge of the electrode
 - b on the trailing edge of the electrode
 - c even across the electrode
 - d highest in the middle of the electrode
- 68 Devices from an ETO sterilizer must be air for
- a 1 hour
 - b 4 hours
 - c 12 hours
 - d 24 hours
- 69 Power lockouts are required on
- a any x-ray room being serviced
 - b any medical device not too big to be moved to the lab
 - c any medical device using more than 200 volts
 - d is only for sissies

Biomed Certification Study Guide
By Dave Harrington

- 70 Cellular phones should not be
- a allowed in an ICU
 - b allowed in radiology
 - c allowed to be used by a person with an IV pump
 - d all the above
- 71 What should a BMET do if a device has injured a patient
- a do the normal testing and repair
 - b notify risk management
 - c call the FDA
 - d notify risk management and secure the device

Answer Key

- | | | | | | | | | | |
|------|------|------|------|--------|------|-------|------|------|------|
| 1-b | 2-a | 3-a | 4-d | 5-c | 6-a | 7-b/d | 8-a | 9-a | 10-b |
| 11-d | 12-b | 13-a | 14-a | 15-c | 16-b | 17-d | 18-b | 19-c | 20-d |
| 21-2 | 22-c | 23-a | 24-a | 25-c | 26-d | 27-d | 28-b | 29-a | 30-b |
| 31-b | 32-c | 33-b | 34-c | 35-b | 36-a | 37-c | 38-b | 39-c | 40-d |
| 41-b | 42-a | 43-c | 44-d | 45-d | 46-b | 47-c | 48-c | 49-d | 50-d |
| 51-d | 52-a | 53-c | 54-d | 55-c/d | 56-d | 57-b | 58-a | 59-a | 60-c |
| 61-d | 62-c | 63-d | 65-d | 65-b | 66-c | 67-a | 68-d | 69-b | 70-d |
| 71-d | | | | | | | | | |

REVIEW QUESTIONS

1. An isolation transformer is a transformer with:
 - a. primary and secondary windings physically separated
 - b. multiple secondary windings
 - c. an earth ground on the secondary windings
 - d. an earth ground on the primary winding

2. Two coils are said to have mutual inductance when they are linked by:
 - a. a series wiring connection
 - b. a capacitor

- c. an inductor
 - d. a common magnetic field
3. The inductance of a coil is determined primarily by:
- a. the number of turns of conductor
 - b. the permeability of the core material
 - c. the ratio of the cross-sectional area to the length
 - d. all of the above factors
4. The unit of inductance is the:
- a. ohm
 - b. rem
 - c. farad
 - d. Henry

THE NEXT TWO PROBLEMS ARE RELATED TO FIGURE 1

5. What is the total resistance of R1, R2 and R3?

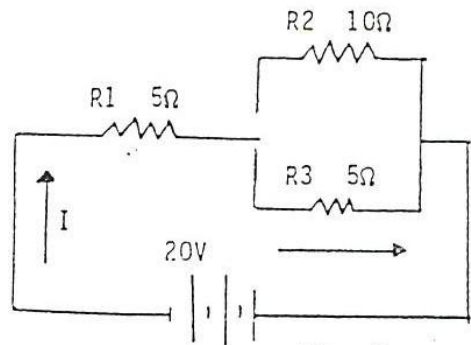


Fig. 1

- a. 7.4 ohms
 - b. 8.3 ohms
 - c. 10.0 ohms
 - d. 10.7 ohms
6. What is the voltage across R1? (See figure 1)
- a. 18v
 - b. 16v
 - c. 12v
 - d. 8v
7. Source gas supplied to ventilators is not comfortable for patients to inhale unless it is:
- a. certified
 - b. humidified
 - c. bacteriostatic
 - d. dry

Biomed Certification Study Guide
By Dave Harrington

8. A device to change one form of energy into another forms of energy, eg. Mechanical to electrical, is called a:
 - a. capacitor
 - b. transformer
 - c. transducer
 - d. transistor

9. Instrumentation amplifiers have which of the following characteristics in common?
 - a. high input impedance
 - b. differential input
 - c. high common mode rejection
 - d. all of the above

10. A common cause of ECG artifact is:
 - a. improper skin preparation
 - b. parkinsonism
 - c. fluorescent lighting in room
 - d. all of the above

11. In making an ECG, lead 2 configuration compares the potential difference between lead connections:
 - a. RA and LA
 - b. RA and RL
 - c. LL and LA
 - d. RA and LL

12. If the internal resistance of the human body is taken to be 500 ohms, how much current could be made to flow through the body from an ordinary 120 volt AC power supply?
 - a. 4.1 ampere
 - b. 4.1 milliampere
 - c. 0.24 ampere
 - d. 24 milliampre

13. Standard color coding of 115 volt AC electrical service wiring calls for the hot, neutral and ground wires to be colored, respectively as:
 - a. black, white and green
 - b. white, green and black
 - c. black, green and white
 - d. red, white, and green

14. A ground fault interrupter:
 - a. measures the voltage being consumed
 - b. isolates the ground against corrosion

Biomed Certification Study Guide
By Dave Harrington

- c. compares currents in the hot and neutral lines and disconnects power if the currents are not the same
 - d. establishes an auxiliary ground if the main ground is interrupted
15. A “flat” EEG, that is, one without waves, could indicate:
- a. coma
 - b. death
 - c. deep sleep
 - d. meditative state
16. In comparing the pressures within the heart, the right atrium pressure in respect to the left atrium pressure is:
- a. less than
 - b. greater than
 - c. the same as
 - d. none of the above
17. The lower chambers of the heart are called:
- a. ventricles
 - b. atria
 - c. aorta
 - d. myocardium
18. The passage of electrical current into a cell will cause it to:
- a. repolarize
 - b. depolarize
 - c. magnetize
 - d. none of the above
19. Total lung capacity consists of:
- a. inspiratory reserve volume, tidal volume, expiratory reserve volume
 - b. inspiratory reserve volume, functional residual volume
 - c. vital capacity
 - d. all of the above
20. When transporting Neo-nates, the most important environmental parameter to maintain would be:
- a. humidity
 - b. sterility
 - c. temperature
 - d. Db level
21. When testing solid state electrosurgical units, it is best to use a test load of:
- a. 50 ohms
 - b. 100 ohms
 - c. 500 ohms

Biomed Certification Study Guide
By Dave Harrington

- d. 1000 ohms
22. In preparing a cord for a hospital grade plug:
- a. the green lead should be cut longer
 - b. the green lead should be cut shorter
 - c. the white and green leads should be the same length
 - d. all wires should be $\frac{1}{2}$ " longer
23. The paper speed most often used for an ECG is:
- a. 10mm/sec
 - b. .5cm/min
 - c. 25mm/sec
 - d. 25mm/min
24. The sensitivity most used on an electrocardiograph is "1", which when the "standard" is pushed and the gain is properly adjusted will give a stylus deflection of :
- a. .2 CM
 - b. 2 CM
 - c. 1 mm
 - d. 10 mm
25. The electrode normally placed on the patient as a reference for an ECG is the:
- a. RA
 - b. RL
 - c. LA
 - d. LL

Answer Key

- | | | | |
|----|---|----|---|
| 1 | A | 22 | A |
| 2 | D | 23 | C |
| 3 | D | 24 | D |
| 4 | D | 25 | A |
| 5 | B | | |
| 6 | C | | |
| 7 | B | | |
| 8 | C | | |
| 9 | D | | |
| 10 | D | | |
| 11 | D | | |
| 12 | C | | |
| 13 | A | | |
| 14 | C | | |
| 15 | B | | |
| 16 | A | | |

Biomed Certification Study Guide
By Dave Harrington

17 A
18 C
19 B
20 C
21 C