Chapter 7: Defibrillators

QUICK POINTS

- A defibrillator is a device that is designed to stop fibrillation. Fibrillation is defined as rapid, irregular, and unsynchronized contraction of muscle fibers.
- The purpose of the defibrillator is to try to correct the electrical activity of the heart. A life-threatening condition called ventricular fibrillation results in a lack of blood pumping through the body and eventual death. The defibrillator delivers a shock to the heart which depolarizes the entire heart and may restore normal sinus rhythm, saving the patient's life.
- A defibrillator may include 4 modes of operation; manual defibrillation, AED, elective cardioversion and pacer modes.
- Most defibrillators include a patient monitor with an ECG parameter and optionally other parameters such as SpO2, NIBP, etc.
- Common issues the biomed will experience with defibrillators include skin burns and battery operation.
- Specific to the defibrillator, the biomed verifies accuracy of the discharge, battery operation and ensures correct operation of all modes available to the user.
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**CHALLENGE QUESTIONS**

1) What is the purpose of a defibrillator?
2) When a defibrillator charges, where is this charge stored?
3) What are the two type of defibrillator waveform outputs?
4) How does a defibrillator correct an arrhythmia and return the heart to a NSR waveform?
5) What mode of operation is used to correct ventricular fibrillation?
6) What mode of operation is used to correct atrial fibrillation?
7) What mode of operation is used to correct sinus bradycardia?
8) What are the four common defibrillator modes of operation and which modes require arrhythmia knowledge to use?
9) In which mode is it important to ensure the defibrillator is tracking the R portion of the patient’s ECG and why?
10) When in sync mode, what is capture?
11) What must a biomed use to test a defibrillator properly?
12) When testing AED mode, what are two ECG rhythms the biomed can use to ensure a shock is advised properly?
13) When using PACER mode, outline how demand mode works?
14) How does a biomed check the paper recorder and/or archiving for accuracy?
15) What is the most common complication after
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defibrillation?
16) If the batteries will not recharge, what is the most likely reason?
17) Outline the specific tests a biomed performs on the defibrillator during a PM.
The heart is a pump

Your heart has a right and a left side. Each side has an upper chamber called the atrium and a lower chamber called the ventricle. The two upper chambers (atria) receive blood from the body. The atria contract and prime the ventricles followed by the ventricles contracting which pump blood back to the body. The right atrium receives deoxygenated blood from the body. It pumps this blood to the right ventricle which pumps this blood towards the lungs, to pick up oxygen. This oxygenated blood, from the lungs, returns to the left atrium. It pumps this blood to the left ventricle which pumps the oxygenated blood to the body.
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The heart is controlled by electrical impulses

Each contraction of the heart starts as an electrical impulse. The impulse is released by a special group of cells called the SA node. These cells, found in the right atrium, function as the heart’s natural pacemaker. The impulse travels through the atria and pauses at another special group of cells called the AV node. The AV node transmits the impulse to the rest of the heart. Once it receives the impulse, the heart muscle contracts which is referred to as depolarization. After each contraction, the muscle recharges which is referred to as repolarization. This cycle repeats between 60 to 100 times a minute. These electrical impulses are referred to as an ECG (or EKG).
What is an arrhythmia?

An arrhythmia can be defined as any ECG that is not a normal sinus rhythm (NSR). It can also be described as an irregular or abnormal rhythm. Two life-threatening arrhythmias, ventricular fibrillation (V-fib) and ventricular tachycardia (V-tach) may be corrected by using a defibrillator. Both conditions result in little or no blood flow.

How can a defibrillator correct certain arrhythmias?

The electrical activity of the heart keeps the heart pumping blood throughout the body in a timed fashion referred to as normal sinus rhythm. When the patient is experiencing certain arrhythmias, the defibrillator's brief output of current can electrically shock the heart and depolarize it. This may return the heart to a normal sinus rhythm. A defibrillator delivers about 300 joules of energy using between 200–1000 volts to treat V-fib.
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What arrhythmias can a defibrillator correct?

- **Ventricular Fibrillation** (V-fib): This arrhythmia results in cardiac arrest and death. V-fib is a condition by which the heart loses its pumping ability due to a disorganized electrical activity. There are no identifiable P waves, QRS complex or T waves in the patient's ECG waveform. Death is likely to occur without cardiopulmonary resuscitation (CPR) and defibrillation quickly! The chance of survival decreases by about 10% for every minute the patient is in ventricular fibrillation! A defibrillator's manual or AED mode may correct V-fib.
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- **Ventricular tachycardia** (V-tach): this is a wide and very rapid rhythm. The heart has lost most its pumping ability and very little blood flows as a result. Ventricular tachycardia is an arrhythmia due to improper electrical activity in the ventricles resulting in a fast heart rate. A short period of V-tach may not result in problems, longer periods are dangerous and can lead to V-fib. A defibrillator’s elective cardioversion mode may correct V-tach.

<table>
<thead>
<tr>
<th>Heart Rate</th>
<th>Rhythm</th>
<th>P Wave</th>
<th>PR interval (in seconds)</th>
<th>QRS (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>Regular</td>
<td>Absent or not related</td>
<td>N/A</td>
<td>≥ .12</td>
</tr>
</tbody>
</table>
Chapter 7: Defibrillators

- **Atrial Fibrillation (AF or A-fib):** atria beat out of sync with the ventricles and beat rapidly and irregularly. This condition may cause heart palpitations, fatigue or shortness of breath. This condition will reduce the efficiency of your heart. Atrial fibrillation resembles a NSR with a missing P-Wave. Patients experiencing A-fib that do not respond to medications, may need elective cardioversion to restore normal sinus rhythm. A defibrillator’s elective cardioversion mode may correct A-fib.

![Atrial Fibrillation Diagram](image)

<table>
<thead>
<tr>
<th>Heart Rate</th>
<th>Rhythm</th>
<th>P Wave</th>
<th>PR interval (in seconds)</th>
<th>QRS (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: 350-650 bpm</td>
<td>Irregular</td>
<td>Fibrillatory (fine to course)</td>
<td>N/A</td>
<td>&lt;.12</td>
</tr>
<tr>
<td>V: Slow to rapid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Sinus bradycardia: For some people a slow heart rate is normal, but it can be a serious problem if the heart cannot pump enough oxygen-rich blood to the body. In patients whose bradycardia do not respond to drugs, pacing is an option.
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**How does a defibrillator deliver a shock?**

Defibrillators offer an energy range from about 2 to 360 joules. A charging button located on the defibrillator or on the paddle allows the user to initiate the charge. An alert lets the user know when the defibrillator is charged and ready to discharge. Large capacitors store the energy within the defibrillator and inductors are used in the output circuit so the output pulse will contain a lower peak amplitude but at a longer shock duration.

![Diagram of defibrillator circuit](image)

There are two types of output waveforms used by defibrillators: monophasic (current flows in 1 direction) and biphasic (current flows in 2 directions).
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The user places the paddles on the patient's chest (sternum and apex locations) after conducting gel or conducting pads are placed on the paddles and/or the patient. This will lower the electrical resistance between the patient's skin and defibrillator's paddles. It is important that the user ensure the entire paddle is contacting the entire skin area avoiding skin folds or breast tissue.

A discharge button located on the defibrillator or on the paddle allows the user to deliver the charge to the patient referred to as shocking the patient. If the special gel or pads were not used, the current from the defibrillator could burn the skin area (caused by $I^2R$ heating). Many defibrillators will adjust their output waveform based upon the skin/paddle contact resistance to maximize their effectiveness. Some manufacturers record the contact resistance on the ECG strip (recorded during the defibrillation) that the biomed/user can review after use. Most manufacturers design defibrillators today for an optimum output with a paddle/skin contact at about 50 to 75Ω. The higher the paddle/skin contact, the higher the energy absorbed by the skin area and therefore the greater the chances of skin burn.
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What defibrillator modes are available?
A Defibrillator may include 4 modes of operation; manual defibrillation mode, AED mode, elective cardioversion mode and pacer mode.

Manual mode gives the user an ability to manually select an energy level and deliver a manual shock to the patient. The user must be trained to recognize the patient’s condition and determine if a shock is required.

AED or automatic external defibrillator mode is an option that allows the user to attach the defibrillator to a patient and have the defibrillator decide if a shock is required.

Elective cardioversion mode is used for very specific types of arrhythmias. This means the user (usually a cardiologist) determines how the patient receives the shock.

Pacer mode is an option that allows the user to externally pace the heart when the heart’s pacing is not working properly. Pacer mode is also used by trained users who know when this mode is required.

How does a defibrillator monitor the patient’s condition?
Most defibrillators have a patient monitor with an ECG parameter and optionally a few other patient parameters such as SpO2, NIBP, etc. These parameters may be connected to a paper recorder or have an ability to electronically transfer this data to other systems.
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COMMON FUNCTIONS OF DEFIBRILLATORS

Manual mode:
To use manual mode, the user must know the life-threatening ECG arrhythmias that may be corrected using manual mode. A manual mode defibrillator contains a variable energy selector, an energy meter showing charging state and a set of paddles used to deliver the charge to the patient. In manual mode the user must decide how much energy they will use on the patient which will vary based upon the age, size and other factors of the patient. The user places the pads/paddles on the patient, selects the energy, charges the defibrillator and finally delivers the shock to the patient.
AED mode:

To use the AED mode, the user does not need to know how to read ECG waveforms. Automatic external defibrillation or AED is used on patients in cardiopulmonary arrest most often caused by ventricular fibrillation. The AED option advises the users if defibrillation is required by analyzing the patient’s ECG rhythm. The defibrillator must have a comprehensive ECG rhythm analysis and decision criteria. To obtain an accurate analysis, the pads or paddles must be applied properly to obtain a good ECG. Once the system analyzes the patient’s ECG, it will advise the user if a shock is required. Voice prompts are commonly used with the AED option. These voice prompts will talk the user through electrode placement, defibrillation steps and may advise the user on CPR (cardiopulmonary resuscitation) steps.
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**Elective cardioversion mode:**

To use the elective cardioversion mode, the user must know the ECG arrhythmias that may be corrected using this mode. Elective cardioversion (also called sync mode) is a common defibrillator option to treat such conditions as ventricular tachycardia or atrial flutter/fibrillation. The user must ensure the defibrillator is in sync mode which will track the QRS portion of the patient’s ECG. The defibrillator will give an audible/visual indicator when it senses the R portion of the QRS and only discharge about 30 milliseconds after the R portion. At this period the ventricles are at a state of depolarization. If the user is not in sync mode, they could incorrectly discharge on the T portion of the ECG which could induce ventricular fibrillation, a life-threatening condition.

![Diagram of Elective Cardioversion](image)
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Pacer mode:

To use the pacer mode, the user must know the ECG arrhythmias that may help the patient’s condition by externally pacing the heart. This defibrillator option also known as transcutaneous pacing is used to treat arrhythmias such as bradycardia. A normal healthy heart has its own pacemaker which regulates the heart called the SA node. When the heart’s internal pacemaker is not working properly and results in certain arrhythmias, a defibrillator’s pacer mode may be used to temporarily pace the heart. The electrical pulses cause cardiac depolarization and myocardial contraction. The user can adjust the rate and/or current as required during pacing. The current must be increased high enough to obtain capture which means the heart contracts with each pacer pulse. Pacer mode can work either in demand mode (also called synchronous mode) or non-demand mode (also called asynchronous mode). When demand mode is used the pacer will sense the patient’s
cardiac rhythm and it will decide if pulsing is required. In non-demand mode the pacer will simply supply an electrical pulse at a constant rate regardless of the patient’s ECG rhythm. It is not uncommon for the patient to receive some sedation if uncomfortable while being paced.

Pacing in Demand Mode
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**Patient monitor - ECG parameter:**

Before a defibrillator can be used, the user requires the patient’s ECG waveform in all modes of operation. The patient monitor with the ECG parameter displays the electrical activity of the patient's heart. A lead selector button is used to select the ECG source which is usually leads 1, 2, 3 or paddles. Leads 1, 2 or 3 require a patient cable connected to the patient via ECG electrodes. Alternatively, ECG can be picked up and monitored through the paddles, when placed on the patient's chest. An ECG size button is usually available to adjust the ECG sizing if required. Some ECG/arrhythmia alarms may be available depending upon the defibrillator’s design.
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Patient monitor – other parameters:
Many defibrillators include other optional parameters such as SpO2, RESP, NIBP, etc. Refer to the patient monitor section and the specific parameter for information on the parameter’s operation.

The Recorder:
Most defibrillators have a paper recorder used to record the patient's ECG and other data. A recording can be manually started, or the unit automatically starts recording when a charging cycle starts. It is important to have a recording of the electrical activity of the heart before and after defibrillation, elective cardioversion or pacing mode. The recorder may also print other patient parameters such as heart rate (BPM), selected energy (joules), paddle/patient contact resistance, operation mode and date/time. Many defibrillators have an ability to record numerous parameters and waveforms prior, during and after usage. This paper recording can also occur electronically via exporting this data through network or even Bluetooth options.

Battery Operation:
Most manufacturers include battery operation. This will allow the user to operate the defibrillator in situations that may not have AC power available such as during transporting a patient. The battery will allow the user to defibrillate and/or monitor a patient for a specific period, dependent upon the manufacturer’s design. It is imperative that the biomed ensure the defibrillator's battery is working as a patient’s life may depend upon it!
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**USER SETUP: Manual mode**

1. The user verifies the patient requires defibrillation by reviewing the patient’s ECG.
2. The user places paddles on the patient's chest (sternum and apex locations) after conducting gel or conducting pads are placed on the patient. The user ensures the entire paddle is contacting the skin area avoiding skin folds or breast tissue.
3. The user selects the desired energy and charges the defibrillator.
4. The user waits for a defibrillator alert that it is fully charged.
5. The user ensures all personal are clear of the patient, again confirms the ECG rhythm requires defibrillation and then presses the discharge or shock button.
6. During the defibrillator's discharge, it is not uncommon to see the patient jump or twitch while receiving the discharge or shock.
7. The user may repeat the process and may increase the energy if the previous discharge did not restore the patient’s normal sinus rhythm (NSR).
8. At the end of the procedure, the user may print and/or transmit procedure data (ECG, defib output, paddle and skin contact resistance, etc.) to create a record of the defibrillator’s use.
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**USER SETUP: AED mode**

1. The user places paddles on the patient's chest (sternum and apex locations) after conducting gel or conducting pads are placed on the patient. The user ensures the entire paddle is contacting the skin area, avoiding skin folds or breast tissue. Alternatively, conductive pads are used instead of the paddles.

2. The user places the defibrillator in AED mode. The defibrillator may guide the user on electrode placement.

3. The defibrillator, after connected to the patient, will ask the user to start the analysis of the ECG waveform.

4. The user waits for the defibrillator to recommend a *shock* and it will automatically charge if a shock is advised. If the patient’s ECG is not a shockable rhythm, the defibrillator will not advise a shock and will not charge.

5. The user must press a button to deliver the shock.

6. After the shock, the defibrillator may automatically analyze the patient’s ECG again and alert the user if another shock is advised. Alternatively, the user may need to manually start the analysis.

7. At the end of the procedure, the user may print and/or transmit procedure data (ECG, defib output, paddle and skin contact resistance, etc.) to create a record of the defibrillator’s use.
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**USER SETUP: Elective Cardioversion mode**

1. The user verifies if the ECG and condition of the patient requires an elective cardioversion discharge.
2. The user identifies where the electrodes will be placed on the patient and applies the electrodes to the patient.
3. The user places the paddles on the patient's chest (sternum and apex locations) after a conducting gel or conducting pads are placed on the patient. The user ensures the entire paddle is contacting the skin area avoiding skin folds or breast tissue. Alternatively, conductive pads are used instead of the paddles.
4. The user may sedate the patient.
5. The user selects \textit{sync} and ensures the defibrillator is \textit{tracking} the R portion of the patient’s ECG.
6. The user selects the desired energy to deliver to the patient and charges the defibrillator.
7. The user waits for a notification that the defibrillator is fully charged, ensures all personal are clear of the patient, again confirms the ECG rhythm requires defibrillation and finally presses the \textit{shock} button.
8. During the defibrillator’s discharge, it is not uncommon to see the patient jump or twitch while receiving the discharge or shock.
9. The user may repeat the process if the shock did not correct the arrhythmia.
10. At the end of the procedure, the user may print and/or transmit procedure data (ECG, defib output, paddle and skin contact resistance, etc.) to create a record of the defibrillator’s use.

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**USER SETUP: Pacer mode**

1. The user verifies if the ECG of the patient requires pacing.
2. The user identifies where the electrodes will be placed on the patient and applies the electrodes to the patient.
3. The user identifies where the paddles/pads will be placed on the patient and applies the paddles/pads to the patient.
4. The user places the defibrillator in *pacer* mode.
5. The user may sedate the patient.
6. The user selects the rate of pulsing.
7. The user increases the current until *capture* is achieved.
8. The user puts the pacer in demand or non-demand mode.
9. At the end of the procedure, the user may print and/or transmit procedure data (ECG, defib output, paddle and skin contact resistance, etc.) to create a record of the defibrillator’s use.
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HOW TO TEST/PM a DEFIBRILLATOR

A PM should be performed after every repair and on a routine scheduled based upon the manufacturer’s recommendations or your local authority. A defibrillator PM can take some time to complete as it includes full testing on the defibrillator and all patient monitor parameters included in the defibrillator’s design. Listed below are generic defibrillator tests intended as a guide only. *Always refer to the manufacturer’s service manual for a complete recommended PM guideline.*

THE DEFIBRILLATOR TESTER

The biomed uses a defibrillator tester to measure a defibrillator’s output accurately which is usually calibrated yearly. It also may have the ability to test AED, sync and pacer modes of operation. The tester usually includes a patient simulator to provide some ECG arrhythmias.
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GENERIC TESTS
These are generic tests done on all medical equipment.

Perform a visual inspection:
• The biomed checks the overall monitor looking for obvious issues such as a broken case, etc.
• The biomed checks the patient leads and patient cables to ensure they are in good order and do not have any cracks in the cables.

Ensure all user controls are operational:
• The biomed checks all the user controls are functioning during testing.
• A biomed will often find user controls not working during testing. If a button/control is not working, repair it prior to placing the patient monitor back into service.

Ensure the date and time are accurate:
• It is very important all systems including defibrillators are at the same time to correlate patient treatment. Correct the date/time if required.

Review error logs:
• The biomed should check the error logs accumulated by the defibrillator during use, if available.
• Most defibrillators in service mode allow the biomed to review these logs which may include basic to very detailed information. Often these logs will give the biomed information showing operational issues the user may be unaware of during use.
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DEFIBRILLATOR TESTS
These are tests that are specific to the defibrillator’s operation.

Defibrillator output power:
- The biomed checks the defibrillator’s output by charging the defibrillator and discharging it into the defibrillator tester. The delivered charge’s accuracy measured by the defibrillator tester should be within the manufacturer's specifications. The biomed checks all energy levels available for accuracy.
- During these delivery checks, ensure all user controls and alerts are operational. These checks include ensuring the charge ready tone operates and ensuring a discharge only occurs when both discharge buttons are pressed on the paddles.

Defibrillator maximum charge time:
- The biomed verifies the defibrillator reaches maximum charge within the manufacturer's performance settings, usually under 10 seconds. Maximum charge is usually 360 or 400 joules.

AED mode operational tests:
- The biomed uses a normal sinus rhythm and different ECG arrhythmias to ensure the defibrillator advises a shock when required.
- In AED mode, when the biomed has the defibrillator analyze a ventricular fibrillation, a shock should be advised.
- In AED mode, when the biomed has the defibrillator
analyze a *normal sinus rhythm*, a shock should *not* be advised.

- The biomed must step through the defibrillator’s complete AED procedure and test each shockable arrhythmia as per the manufacturer’s AED testing procedure.

**Elective cardioversion operational tests:**

- Elective cardioversion or sync mode can be checked by using a low ECG rate of about 30BPM. The defibrillator will display tracking of the R wave by a visual and/or audible indicator that will toggle with the R wave. The defibrillator’s display will also have an indicator to show R wave synchronization. Once the biomed selects the energy and the defibrillator is fully charged, holding down the discharge buttons will cause the defibrillator to discharge only after the *next R wave*. Using a low 30BMP allows the biomed to observe this discharge delay by holding down the discharge buttons immediately after the R portion of the patient’s ECG. If there is no delay, the elective cardioversion mode is not working and should *not* be placed back into service until repaired.

- Many defibrillator testers can measure the delay while in sync mode. Some testers will allow the biomed to measure the delay with the aid of an oscilloscope. Ensure the delay is within manufacturer's specifications or approximately 30 milliseconds after the R portion of the patient’s ECG. Always refer to the manufacturer’s recommended test procedure.
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Pacer mode operational tests:

- Connect the pacer leads to a defibrillator testing device with the pacer testing option and enable pacing on the defibrillator.
- Test the rate accuracy at the pacer’s lowest, highest and a few rates in-between. Verify the accuracy is within the manufacturer’s specifications by comparing the rate selected on the defibrillator and the rate measured on the defibrillator tester.
- Test the current accuracy at the pacer’s lowest, highest and a few in-between current settings. Verify the current accuracy is within the manufacturer’s specifications by comparing the current selected on the defibrillator and the current measured on the defibrillator tester.
- Some defibrillator testers with the pacing ability allow the biomed to test the demand mode. This allows the biomed to introduce pacing and non-pacing ECG rhythms to ensure pacing only occurs on pacing rhythms and will toggle off when introducing non-pacing rhythms.
- Always refer to the manufacturer’s recommended pacer mode testing procedure.
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PATIENT MONITOR - ECG PARAMETER TESTS

These checks are no different than contained in the Patient monitor – ECG parameter section. The biomed performs all ECG tests applicable to the ECG parameter’s functions within the defibrillator.

Ensure ECG rate accuracy at multiple rates:
- Connect the patient monitor’s ECG leads to the patient simulator and setup for a normal sinus rhythm (NSR).
- Ensure the ECG rate is accurate at multiple rates. Test the ECG rate accuracy at the monitor’s lowest rate, highest rate and a few in between. This is performed by setting the patient simulator at these ECG rates and ensuring the monitor displays these rates, within the manufacturer’s accuracy.

Ensure ECG sizing control is operational:
- The sizing control should vary the ECG’s amplitude if not in automatic mode. In automatic mode the circuitry should not double count the ECG complex. This occurs when the ECG size is too large, and the patient monitor incorrectly counts the patient’s T portion of their ECG as a beat as well as the QRS portion.

Ensure all ECG lead views are working:
- Ensure all lead views are working by cycling through all lead views available and observing a NSR waveform. If one or more lead view waveforms do not display properly, this usually points to one or more broken patient leads.
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- Verify ECG monitoring through the paddles is also working. Many defibrillator testing devices can introduce ECG waveforms through the paddle discharge plates on the tester.

**Ensure ECG high/low alarms are working:**
- These two alarms may or may not be available on all defibrillators.
- Ensure the high (tachycardia) and low (bradycardia) ECG alarms are working. To test the high ECG alarm (tachycardia), set the patient simulator BPM at a higher rate than the current high ECG alarm setting. Ensure the high HR alarm signals the user by an audible and/or visual indicator.
- To test the low ECG alarm (bradycardia), set the patient simulator BPM at a lower rate than the current low ECG alarm setting. Ensure the low alarm signals the user by an audible and/or visual indicator.

**Ensure all arrhythmia alarms are working:**
- Ensure all arrhythmias monitored are operating properly by introducing the specific arrhythmias from the patient simulator. Depending upon the ECG parameter’s design, these tests could include only a few arrhythmias to numerous arrhythmias. Always review the defibrillator’s manual to ensure you test all arrhythmias available and they alert the user as designed.
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Ensure the optional ST segment monitoring is working:

- Set the patient simulator for a ST elevation of 0mV.
- Raise the ST segment level *above 0mV* on the patient simulator and ensure the patient monitor displays this value.
- Lower the ST segment level *below 0mV* on the patient simulator and ensure the patient monitor displays this value.
- Ensure the patient monitor alerts the user and/or alarms, as per the manufacturer's design.

PATIENT MONITOR - OTHER PARAMETER TESTS

The defibrillator may have other patient parameters. Refer to the patient monitor section of this book and look for the specific parameter. These parameters may include, NIBP, SpO2, RESP, TEMP and IBP. Each of these parameters must be checked by the biomed fully.

Ensure paper recording or electronically storing the ECG waveform is accurate:

- Connect the patient monitor to a patient simulator and set the simulator for a NSR of 60BPM
- If the biomed is checking a paper printer, set the chart speed to 25mm/sec and print a strip. Then set the chart speed to 5mm/sec and print a strip.
- If the biomed is checking sending the ECG waveform to an archive, set the chart speed to 25mm/sec and send a strip to the archive. Then set the chart speed to 5mm/sec and send a strip to the archive.
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- In either situation, review the printed ECG waveform or archived waveform for the following:
  1. **HORIZONTAL CHECK**: If the chart speed is 5mm/second and the ECG input is 60BPM, each R-wave should be spaced by 5mm. If the chart speed is 25mm/second and the ECG input is 60BPM, each R-wave should be spaced by 25mm.
  2. **VERTICAL CHECK**: Check the one mV calibration pulse, it should be exactly 10mm.

**Ensure the battery is working:**
- Always test the defibrillator’s battery as per the manufacturer’s guideline. Battery failure during use may result in a patient’s death!
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- If any of the battery tests fail, replace the battery prior to placing the defibrillator back into service!
- Often the manufacturer will recommend routine replacement of the battery.
- A defibrillator is a *life-saving* device that requires a reliable battery. A biomed can be held liable if a battery fails while in use if not maintained properly.
- The biomed must document that the battery was working as per the manufacturer’s specifications after any repair or PM.

**Ensure the defibrillator is electrically safe: (IEC)**
- Measure the ground resistance (0.15 OHM max.).
- Measure the chassis leakage (300ua max.).
- Measure the lead to ground leakage (50ua max.).
- Measure the lead to lead leakage (50ua max.).
- Measure the paddles - applied part (50ua max.).
- Leakages should be within the manufacturer’s or local government specifications, whichever is *less*.

**Always perform a final functional check:**
- As a final test, the biomed should do a quick defibrillator functional test to ensure proper operation, prior to placing it back into service.
- All operation, controls and alarms should operate as per the manufacturer’s design.

**Ensure your documentation is accurate:**
- All repairs and performance tests need to be documented so that they can be retrieved at any time.
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- This documentation should include all parts used for repair and that all the above tests showing the equipment is within manufacturer’s and local authorities acceptable limits.
- *These documents may be used legally to validate proper maintenance was performed by the biomed. Ensure your documentation is accurate!*

**What do I do if any test fails?**
- If any device maintained by the biomed fails a functional and/or electrical safety test, *it is the biomed’s responsibility to pull it out of service!*
- Failure means a *patient safety issue exists!*
- Fix the issues *prior* to placing the defibrillator back into service!
Chapter 7: Defibrillators

QUICK SERVICE TIPS

SHOCK HAZARD WARNING
Working or testing defibrillators incorrectly can be dangerous, never touch the paddles while defibrillating.

Skin Burns:
- It is not uncommon for the biomed to receive a complaint regarding patient skin burns after defibrillation as it is the most common complication of defibrillation. The biomed should first test the defibrillator for an accurate output at all energy levels. If the output tests show energy levels outside manufacturer’s specifications, the biomed should repair or calibrate the output of the defibrillator.
- If the output is within manufacturer’s specifications, the problem is usually caused by a high contact resistance between the paddle and patient. Some manufacturers record the contact resistance on the paper recording (recorded during the defibrillation) that the biomed/user can review after use. Most manufacturers design defibrillators for an optimum output with a paddle/skin contact at about 50 to 75Ω. The higher the paddle/skin contact, the higher the energy absorbed by the skin area and therefore the greater the chances of skin burn. If the biomed finds a high recorded skin contact resistance during use, it is likely caused by a user not applying the paddles/pads properly to the patient.
- If the surface of the paddles looks pitted or damaged, replace the paddles immediately before placing the defibrillator back into service! This may also cause a
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high skin contact resistance resulting in skin burns.

- The biomed should also view the defibrillator’s output waveform to ensure it looks normal for the defibrillator being tested. If the waveform does not look normal, this would indicate issues such as the main charging capacitor failing, etc. Repair the issue prior to placing the defibrillator back into service.

Batteries won’t charge:

- It is not uncommon to receive complaints regarding battery charging issues. Defibrillators often travel throughout the hospital and are frequently disconnected and reconnected many times from the AC power. Unfortunately, many users pull the AC cable to disconnect the defibrillator from the power instead of the proper way, via the plug casing. As a result, it is not uncommon to see power cable breaks at the plug which result in the batteries not charging. The biomed should inspect the power plug’s connections to ensure they are tight and not broken. This involves taking the plug apart to do the inspection and repair unless it is a molded plug. Alternatively, the biomed could install a new power cable.

Battery capacity:

- Battery operation of a defibrillator is very common. If the user has any battery operation issues, test the battery as per the manufacturer’s recommendation. If any of the battery capacity tests fail, replace it immediately!
- A defibrillator is a life-saving device that requires a
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reliable battery. A biomed can be held liable if a battery fails while in use if not maintained properly.

Poor electrode application:

- Unfortunately, this is a common issue.
- Symptom: the ECG waveform of the patient will deflect erratically when the patient moves.
- Connect the ECG parameter to a patient simulator. Set the simulator for a NSR. If the patient monitor displays the NSR waveform normally on all lead views, the patient electrodes are the issue. Suggest the user re-apply the electrodes. Skin preparation is a common issue.

Broken patient leads:

- It is common for the manufacturer to have the patient cable and patient leads as separate items.
- The patient leads are always connected, disconnected and reconnected to multiple patients. It is not uncommon to have patient lead wire breaks as a result.
- This can be checked by connecting the defibrillator to a patient simulator. Set the patient simulator for a NSR. Observe the NSR waveform while moving the wires to see if the ECG signal is erratic (deflects wildly up and down). If the NRS waveform is erratic, this would be caused by a broken wire. To check ALL wires in this manner, you must cycle through all lead views while doing this. Most wire breaks occur at the patient end.
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- Alternatively, you can ring-out the patient leads to look for continuity issues. Often biomeds will create specific test jigs to perform this test.
- Another method for fixing suspected broken wires quickly is to simply replace the patient leads. Usually a spare set of patient leads are available in the department or in the Biomedical engineering department. If swapping the patient leads fixes the issue, test the suspected bad patient leads in the Biomedical department.

**Broken patient cables:**
- Less common is a broken patient cable which also may have intermittent wire breaks.
- The same patient lead tests listed above can be used.

*Patient Cable/Leads together*
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Patient Cable

Patient Leads
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**CHALLENGE ANSWERS**

1) The purpose of a defibrillator is to stop fibrillation.
2) Defibrillators store the charge in large capacitors.
3) The two types of output waveforms used by defibrillators are monophasic (current flows in 1 direction) and biphasic (current flows in 2 directions).
4) A defibrillator's brief output of current can electrically shock the heart and depolarize it. This may return the heart to a normal sinus rhythm.
5) The mode of operation to correct ventricular fibrillation is *manual mode*.
6) The mode of operation to correct atrial fibrillation is *sync mode*.
7) The mode of operation to correct sinus bradycardia is *pacer mode*.
8) The four common defibrillator modes are:
   - Manual mode: arrhythmia knowledge required
   - AED mode: arrhythmia knowledge not required
   - Sync mode: arrhythmia knowledge required
   - Pacer mode: arrhythmia knowledge required
9) The defibrillator needs to be in sync mode, so it discharges about 30 milliseconds after the R portion of the QRS when the ventricles are depolarized. If the defibrillator is not in sync mode, it could discharge on the T portion of the ECG which could induce ventricular fibrillation.
10) Capture is achieved when the current is adjusted high enough to contract the heart with each pacer pulse.
11) The biomed must use a defibrillator tester to
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measure a defibrillator’s output accurately.

12) In AED mode, when the biomed has the defibrillator analyze a ventricular fibrillation, a shock should be advised. When the biomed has the defibrillator analyze a normal sinus rhythm, a shock should not be advised.

13) Demand mode works by pacing the heart when the patient's ECG requires it.

14) The biomed checks the paper recorder and/or archiving for accuracy by:

HORIZONTAL CHECK: If the chart speed is 5mm/second and the ECG input is 60BPM, each R-wave should be spaced by 5mm. If the chart speed is 25mm/second and the ECG input is 60BPM, each R-wave should be spaced by 25mm.

VERTICAL CHECK: the one mV calibration pulse should be exactly 10mm.

15) The most common complication after defibrillation is patient skin burns.

16) If the batteries will not recharge, the most likely reason is a broken power cable.

17) The specific tests a biomed performs on the defibrillator during a PM include:

- Test defibrillator output power accuracy.
- Test the defibrillator’s maximum charge time.
- Test AED mode operation.
- Test elective cardioversion operation.
- Test pacer mode operation
- Test battery capacity and operation