Intra-Aortic Balloon Pump

Intensive Care Unit
Nepean Hospital
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Introduction

The IABP increases blood pressure and flow during inflation by creating an additional perfusion event to both the central and the peripheral circulation during diastole. The IABP remains inflated during diastole, augmenting pressure throughout this phase. Just prior to systole, during isovolumetric contraction, the IAB is deflated causing a rapid drop in blood pressure and reducing left ventricular afterload. These actions known as counterpulsation increase oxygen supply and decrease oxygen demand thereby balancing oxygen availability and requirements. The IABP also directly affects the baroreceptors in the aorta and carotid arteries, which reduces parasympathetic output from these receptors.

Expected Haemodynamic Results of Counterpulsation

<table>
<thead>
<tr>
<th>Increased</th>
<th>Decreased</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Diastolic aortic pressure</td>
<td>➢ Systolic aortic pressure</td>
</tr>
<tr>
<td>➢ Coronary blood flow</td>
<td>➢ LV wall tension</td>
</tr>
<tr>
<td>➢ Cerebral / renal blood flow</td>
<td>➢ Preload</td>
</tr>
<tr>
<td>➢ Cardiac output/ index</td>
<td>➢ Afterload</td>
</tr>
<tr>
<td>➢ Ejection fractions</td>
<td>➢ Heart rate</td>
</tr>
<tr>
<td>➢ Systemic perfusion</td>
<td>➢ Pulmonary congestion</td>
</tr>
<tr>
<td>➢ Pulse rate and pressure</td>
<td></td>
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</tbody>
</table>

Factors That Impact On IAB Effectiveness

<table>
<thead>
<tr>
<th>Physical</th>
<th>Biological</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ IAB position</td>
<td>➢ Arterial pressure</td>
</tr>
<tr>
<td>➢ Balloon volume Vs stroke volume</td>
<td>➢ Heart rate</td>
</tr>
<tr>
<td>➢ Inflated diameter</td>
<td>➢ Hypovolemia</td>
</tr>
<tr>
<td>➢ Occlusivity (size)</td>
<td>➢ Arrhythmias</td>
</tr>
<tr>
<td>➢ Driving gas</td>
<td>➢ Low stroke volume and cardiac output</td>
</tr>
<tr>
<td>➢ Timing of inflation and deflation</td>
<td>➢ Reduced preload</td>
</tr>
<tr>
<td></td>
<td>➢ MAP &lt; 40mmHg</td>
</tr>
<tr>
<td></td>
<td>➢ Decreased contractility</td>
</tr>
</tbody>
</table>
The balloon is situated 1-2 cm below the origin of the left subclavian artery and above the renal artery branches. On chest x-ray, the tip should be visible between the 2\textsuperscript{nd} and 3\textsuperscript{rd} intercostal space.

If the balloon is placed too low, then the origin of the renal arteries could be obstructed thereby compromising renal perfusion.

If the catheter is placed too high, obstruction of the left subclavian and carotid artery may occur.

The balloon should not totally occlude the aortic lumen during inflation. Ideally it should be 85 to 90\% occlusive. Total occlusion could result in aortic wall trauma and damage to red blood cells and platelets.

The balloon exerts its effects by volume displacement and pressure changes by rapidly shunting helium gas in and out of the balloon chamber. The sudden occupation of space by the gas on inflation causes blood to be moved from its original position superiorly and inferiorly to the balloon. Since the volume in the aorta is suddenly increased and the aortic wall is fairly rigid, the intra aortic pressure increases sharply. With deflation of the balloon, the chain of events is reversed. The sudden loss of the volume causes a sudden decrease in aortic pressure within that localised area. In response to the local fall in pressure, the blood in adjacent areas moves to normalise the pressure within the aortic cavity as a whole. This displacement of blood volume is the mechanism by which the IABP alters the haemodynamic state. In order to obtain beneficial changes, the inflation and deflation of the balloon must occur at optimum times in the cardiac cycle.
Balloon Inflation – Haemodynamics

- Inflation of the balloon is set to occur at the onset of diastole. At the beginning of diastole, maximum aortic blood volume is available for displacement. If balloon inflation occurs later in diastole, the pressure generation from volume displacement will be lower. This is because during late diastole, much of the blood has flowed out to the periphery and there is less blood volume in the aorta to displace.

- Benefits of accurately timed inflation:
  - Coronary blood flow and pressure are increased. Increased perfusion will increase oxygen delivery to the myocardium
  - Increased diastolic pressure also increases the perfusion to the distal organs and tissues i.e. Increased urine output, cerebral perfusion
  - Coronary collateral circulation is potentially increased
  - Systemic perfusion pressure is increased
**Balloon Deflation – Haemodynamics**

- The balloon remains inflated during the diastolic phase. Deflation of the balloon should take place at the onset of systole. Properly timed deflation will cause a fall in pressure therefore, the left ventricle will not have to generate as much pressure to achieve ejection.

- **Benefits of accurately timed deflation:**
  - The pressure that the left ventricle must generate is less throughout the systolic phase. Therefore afterload is reduced which decreases myocardial oxygen demands.
  - The intraventricular contraction phase is shortened which decreases oxygen demands.

- Reduced afterload allows the left ventricle to empty more effectively so stroke volume is increased. In addition, preload is reduced if elevated.

- Enhanced forward movement of cardiac output decreases the amount of blood shunted from the left to right in cases of intraventricular septal defects and incompetent mitral valves.
**Indications:**

- Cardiogenic shock
- Pre-shock syndrome
- Threatening extension of myocardial infarction
- Unstable angina
- Intractable ventricular arrhythmias
- Septic shock syndrome
- Cardiac contusion
- Prophylactic support for:
  - Coronary angiography
  - Coronary angioplasty
  - Thrombolysis
  - High risk interventional procedures such as stents

- Bridging device for:
  - Cardiac transplant
  - Total mechanical assistance

- Support during transport to tertiary institution
- Mechanical defects:
  - Valvular stenosis
  - Valvular insufficiency - mitral
  - Ruptured papillary muscle
  - Ventricular septal defect
  - Left ventricular aneurysm

- Surgical indications:
  - Post surgical myocardial dysfunction
  - Inability to wean from coronary bypass
  - Prophylactic support
**Contra Indications:**

- **Absolute:**
  - Aortic valve insufficiency
  - Dissecting aortic aneurysm

- **Relative:**
  - End-stage cardiomyopathies - unless bridging device to transplant
  - Severe arthosclerosis
  - End stage terminal disease
  - Abdominal aortic aneurysms - not resected

**Complications:**

- Aortic wall
  - Dissection
  - Rupture
  - Local vascular injury

- Emboli
  - Thrombus
  - Plague
  - Air

- IAB rupture
  - Helium embolus
  - Catheter entrapment

- Infection

- Obstruction
  - Malposition
  - Compromised circulation due to catheter causing ischaemia or compartment syndrome

- Haematologic
  - Bleeding
  - Thrombocytopenia
**Nursing Care:**

- Nursing care of the patient on IABP support requires assessment and evaluation of the patient’s neurologic, respiratory, cardiovascular and renal status

- Assessment should be carried out with 3 primary goals in mind:
  - Evaluation of patient response to counterpulsation in terms of haemodynamic status, control of arrhythmias, systemic perfusion and relief of symptoms of cardiac ischaemia
  - Observation of early signs of complications such as limb ischaemia, bleeding, infection, thrombus formation, malposition of balloon catheter and arterial damage
  - Ensuring proper functioning of the IABP itself including correct timing, consistent triggering, appropriate troubleshooting of all alarm situations and safe operation

**Pre Insertion:**

- Good assessment prior to insertion documents the need for therapy and provides a baseline for evaluation of treatment efficacy. The circulation to both legs should be evaluated to determine the best side for insertion.

- A complete pre insertion assessment should include:
  - Neurovascular observations to both legs
  - Complete neurological check

For insertion of catheter, please see Insertion of Intra-aortic Balloon Catheter protocol.

**Other Considerations:**

- If the pump malfunctions or becomes inoperable, don’t allow the balloon catheter to remain dormant for longer than 30 minutes as the potential for clotting on the catheter is too great to use the catheter after this time.

- Monitor lower limb circulation observations 15 minutely for 1 hour after insertion then hourly

- Monitor urine output
Cardiac Physiology

The Cardiac Cycle:

The succession of cardiac events needs to be understood in order to understand the interaction of the IABP with cardiac physiology.

Blood always flows from an area of high pressure to an area of low pressure. When two chambers of differing pressures suddenly join, the pressures in both chambers change until they become approximately the same. This occurs when the valves between two cardiac chambers open. When the valves close, the pressure changes that occur do so independently of each chamber.

The cardiac cycle is divided into two major phases: diastole and systole. The periods of diastole and systole can be further subdivided into several mechanical periods.

Diastolic Events:

- **Isovolumetric Relaxation:**
  The onset of diastole brings relaxation of the myocardium, which begins immediately before the dicrotic notch on the arterial pressure waveform. The pressures in the ventricles fall below the pressures in the aorta and pulmonary artery with the beginning of diastole. The now higher pressure in the aorta and pulmonary artery causes the semilunar valves to close. This is seen on the arterial pressure waveform as the dicrotic notch. During this phase, the semilunar valves are closed but the pressures in the ventricles are greater than that in the atria, which prevents the opening of the mitral and tricuspid valves. The ventricles relax and for a short period, there are no volume changes within the ventricles.

- **Ventricular Filling:**
  When the ventricular pressure fall below atrial pressures, the mitral and tricuspid valves open. The ventricles rapidly fill with blood from the atria. The ventricles continue to relax which causes a further drop in pressure and an increasing gradient of pressure from the atria to ventricles. The increasing gradient causes rapid inflow of blood into the ventricles. With controlled
ventricular filling, atrial pressures fall and ventricular pressures rise, thereby reducing the pressure gradient. As the gradient is reduced, the ventricular filling rate decreases.

- **Atrial Contraction:**
  Relatively late in the diastolic phase, the atria undergo depolarisation, soon followed by contraction of the atria. The volume of blood in the ventricles is increased when the atria contract and force the remaining contents into the ventricles.

**Systolic Events**

- **Isovolumetric Contraction:**
  At the beginning of systole, the ventricles are full of blood from the previous diastolic period and the pressure in the atria and ventricles are approximately the same. At the onset of contraction, the pressure in the ventricles rises above the pressure in the atria and this causes the closure of the mitral and tricuspid valves. During this time, both the atrio-ventricular valves and the semilunar valves are all closed. There are no volume changes taking place until the ventricles generate a pressure greater than the pressure in the aorta and pulmonary artery. This phase has been termed the isovolumetric contraction (IVC) phase. The major purpose of this phase is to build up enough pressure to achieve ejection of the ventricular contents. This time of pressure building requires a lot of energy. Approximately 90% of myocardial oxygen consumption occurs during the IVC phase. The length of this phase is a major variable in establishing the oxygen demand. The length of the IVC phase is determined by the speed of contraction and the pressure generation necessary (aortic or pulmonic end diastolic pressure) to open semilunar valves.

- **Rapid Ventricular Ejection:**
  The opening of the aortic and pulmonic valves signifies the onset of rapid injection phase and the end of the IVC phase. The aortic valve opens at the precise moment the left ventricular pressure exceeds the aortic end diastolic pressure (AEDP). The left ventricle and aorta essentially becomes one chamber with pressure rising very rapidly. Approximately 65-75% of stroke
volume is ejected during this period. The rapid ejection phase is seen on the ascending limb of the arterial pressure waveform. Rapid ventricular ejection continues until the point of maximum ventricular pressure. This point is called peak systolic pressure.

- Reduced Ventricular Ejection:
  Pressure in the ventricles begins to decrease after the peak systolic pressure. During this time the ventricles are not contracting as forcefully but blood continues to flow out of the ventricles because of the momentum of forward flow. The remaining 25-35% of stroke volume is ejected during this time. The reduced ejection phase is seen on the descending limb of the arterial pressure waveform.

Systole ends with the onset of myocardial relaxation and the cycle begins again.

**Determinants Of Cardiac Output**

The performance of the heart is expressed in terms of cardiac output. Normal cardiac output is between 4 to 8 l/min and is obtained by multiplying the stroke volume by the heart rate. The stroke volume is influenced by the intrinsic state of the vascular system and myocardium. The heart rate is controlled by the rate set point of the sinus node and influenced by the central nervous system, endocrine system and the pressure and stretch receptors located in the central vascular system. If the stroke volume is insufficient then the heart rate must increase to maintain cardiac output.

**Preload:**

Refers to the amount of stretch on the ventricular myocardium prior to contraction. Starling's Law shows that an increase of volume in the ventricle at the end of diastole resulted in an increase in the volume of blood pumped.

The left ventricular end diastolic pressure (LVEDP) is used as an indication of ventricular volume and is clinically measured by the pulmonary capillary wedge pressure. The most important concept to keep in mind with Starling's Law is that there is an optimal preload pressure in each clinical situation. In a diseased heart necessitating
IAB support, preload is usually increased to such a point that “over stretching” of the ventricle occurs resulting in a decreased cardiac output. The goal of IAB in such patients is to decrease or Optimise preload by ensuring a filling pressure high enough to obtain the highest cardiac output but not so high as to cause pulmonary congestion.

**Afterload:**
The impedance to ventricular ejection. The first impedance to ejection is the mass of blood that must be moved. The haematocrit has a large influence on the mass of blood. The higher the mass the more inertia that needs to be generated to achieve blood movement. The next impedance is the aortic end diastolic pressure. If the AEDP is 80mmHg, then the left ventricle must generate 81mmHg to open the aortic valve to achieve some forward flow of blood. After the aortic valve opens, the left ventricle then needs to overcome the resistance of the arterioles to complete the ejection process. As the afterload increases, the speed of ejection slows and stroke volume falls.

**Contractility:**
The myocardium’s intrinsic ability to contract independently of the effects of preload and afterload. Contractility is not directly measurable, but it is a property that is critically important. An indication of contractility is given by the ejection fraction. The normal ejection fraction is 65 to 75%. Preload/afterload may increase/decrease contractility. An increase in contractility will increase the force of contraction, stroke volume, oxygen demand and delivered oxygen to the ventricles. Therefore generally, the myocardial supply/demand ratio improves.
Factors That Effect Contractility:

<table>
<thead>
<tr>
<th>Increases contractility</th>
<th>Decreases contractility</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Inotropic agents</td>
<td>✓ Acidosis</td>
</tr>
<tr>
<td>✓ Exercise</td>
<td>✓ Hypoxia</td>
</tr>
<tr>
<td>✓ Sympathetic stimulation</td>
<td>✓ Hyperkalaemia</td>
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<tr>
<td>✓ Endogenous catecholamines</td>
<td>✓ Parasympathetic stimulation</td>
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<td></td>
<td>✓ Pharmacologic agents such as</td>
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<tr>
<td></td>
<td>▪ Beta blockers</td>
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<td>▪ Calcium channel blockers</td>
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<td>▪ Barbiturates</td>
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<td>▪ Alcohol</td>
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<td></td>
<td>▪ Thyroid hormone</td>
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<tr>
<td></td>
<td>▪ Myocardial ischaemia/infarction</td>
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<td></td>
<td>▪ Myocardial stunning</td>
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Initiation of Balloon Pumping

Turning the pump console on and pressing the HELP key can also gain assistance with initiation.

1. POWER:
   - Plug in power cord
   - Turn on power switch

2. HELIUM:
   - Turn on the tank
   - Verify helium supply

3. ECG:
   - Connect the ECG signal using the 3 lead patient cable for a direct signal or the Nicolay cable to slave the signal from the bedside monitor. These cables fit into the green colour coded connection on the pump
   - Select the best ECG lead – should be unidirectional, R wave is larger than T or P waves, artifact free
   - Verify trigger recognition, indicated by the following:
     ✓ Presence of white bands on the ECG tracing
     ✓ Flashing red heart next to HR on display screen
     ✓ Flashing LED on selected trigger mode

4. ARTERIAL PRESSURE:
   - An arterial pressure waveform can be obtained from either the transducer cable for a direct signal or from the patient monitor via a phono-phono cable
   - If using the transducer cable:
     ✓ Plug the cable into the orange arterial pressure connection
     ✓ Attach transducer and open stopcock to air
     ✓ Press AP SELECT key once, then press transducer zero
     ✓ Close the transducer to air
If using the phono-phono cable:
✓ Plug one end of the cable into “arterial pressure output” on patient monitor
✓ Plug the other end into “arterial pressure input” on IABP
✓ Press AP SELECT key twice to select MONITOR
✓ Zero transducer on bedside monitor as normal

5. PURGE:

➢ After the balloon has been inserted and the position confirmed, remove the one way valve and plug balloon into pump input
➢ Press STNDBY on keypad for an automatic 4 beat purge cycle

6. PUMP:

➢ Press ON when purge cycle complete
➢ Verify correct arterial pressure timing
➢ Alarm and refill systems are automatically on
➢ Pump will automatically be in 1:2 assist mode, ECG Pattern Trigger


**Troubleshooting**

1. **PUMP DIED:**
   - Determine that pump is plugged in or if it was left on battery after transport
   - Verify that battery switch (located on top right hand side in helium tank compartment) is in ON position (1=on, 0=off)
   - Ensure that AC power source is active - green power indicator light is on

2. **NOT TRIGGERING:**
   - White bands on ECG tracing signify that the console recognised selected trigger and will pump - no white bands, no pumping
   - Ensure that the selected trigger mode is available to the pump 100% of the time
   - ECG tracing should be free from artifact and have sufficient amplitude as it will be the trigger signal of choice in most patients
   - Determine that the correct ECG source is selected. In the ECG SELECT section of the keypad, the SKIN LED should be ON if using skin leads or phono-nicolay cable. In addition, if phono-nicolay, Lead II must be selected. If using phono-phono cable, LED for MONITOR should be ON. If the wrong source is selected press ECG SELECT key twice to toggle to the correct source
   - If pacer trigger is selected, the patient must be paced 100% of the time and the ECG SELECT must have SKIN selected. Use VPACE for AV sequential pacemaker triggering
   - If loss of trigger is experienced in PATTERN trigger mode, the QRS may be too wide and PEAK trigger mode should be selected
   - When using a 3 lead cable, if Leads I, II and III cannot provide a satisfactory R-wave change lead configuration to an MCL. Select Lead I, which should provide a "QS" pattern mimicking a VI lead

3. **NOT AUGMENTING:**
   - Check that the balloon volume is set at desired value. The pump automatically sets full volume when the balloon is plugged in, but the volume may have decreased and not returned to full volume.
Certain patient conditions will make it likely that the peak diastolic pressure is less than the peak systolic pressure - patients with low systemic vascular resistance, hypovolaemia, readiness to wean from the pump etc.

Is the balloon fully unwrapped and is the sheath clear of the proximal end of the balloon? Check balloon pressure waveform for assurance of free flow of helium

Check the helium level in the tank and that the tank is turned ON

Check the balloon position within the aorta. Low positioning will generally produce a low PDP

4. PUMP KEEPS ALARMING:

Identify alarm and follow directions on the screen for that alarm condition

If blood is present in the balloon tubing, immediately disconnect the balloon from console and notify the Intensivist

The pump does not give false alarms with arrhythmias, so any and all alarms should be aggressively evaluated and corrected

If the balloon has just been inserted and HIGH PRESSURE alarms occur, probable cause is a partially wrapped balloon, turn the pump off and restart, giving 4 quick inflations.

If excessive ECG artefact is causing an alarm condition, apply new electrodes after a good skin prep or use arterial pressure trigger mode

If HIGH BASELINE or HELIUM LOSS alarms repeat, check all connections for a tight seal

5. NOTHING HAPPENS WHEN THE KEYS ARE PUSHED OR THE RECORDER WON'T STOP:

If the computer “locks up” or “system error” alarms occur and you are unable to reset or change functions, turn the power switch off, count to 3 turn the power back on and push “pump on” - pump will automatically go into “standby” for a purge

If the recorder fails to stop, press RECORDER ON/ OFF key twice. If it still fails to stop, follow the above instructions
Factors That Affect Diastolic Augmentation

The primary goals of IABP therapy are: increased myocardial oxygen supply and decreased oxygen demand. These goals can be achieved with proper timing, which is triggered by the patient's cardiac cycle as represented by the arterial waveform. Timing should be adjusted so that inflation occurs at the dicrotic notch & IAB deflation occurs just prior to the next systolic event. The inflation of the IAB at the onset of diastole increases the aortic and systemic pressures (known as diastolic augmentation) by displacing blood volume both proximally and distally. Deflation of the IAB prior to the next systole decreases the aortic end diastolic pressure, thereby reducing the left ventricular workload.

The diastolic augmented pressure created by IAB inflation is ideally higher than the patient’s systolic pressure. However, augmentation may not always be improved. Many factors will affect the amount of volume displacement observed.

Patient Related:

Since displacing stroke volume generates the augmented pressure, any factor that would affect the ability of the ventricle to eject stroke volume could also adversely affect the augmented pressure. This would include:

- Decreased mean arterial pressure
- High or low systemic vascular resistance
- Haemodynamically compromising arrhythmias
- Aortic diameter
- Patient who is ready to be weaned from IABP therapy

IAB Catheter Related:

- Proper balloon catheter placement is essential for adequate haemodynamic support. For a femoral insertion, the tip of the balloon should be positioned 1-2cm distal to the subclavian artery. When viewed on a chest x ray, the tip should be at approximately the 2nd - 3rd intercostal space
- A kink in the IAB catheter can obstruct the shuttle of gas from the console into the balloon. The kink may affect diastolic augmentation by not permitting full inflation of the balloon causing a decrease in the amount of volume displaced
The balloon introducer sheath may obstruct inflation if not properly positioned. It is important to ensure that the entire balloon membrane has exited the introducer.

The IAB must fully unwrap upon initial insertion to achieve optimal diastolic augmentation. Incomplete opening of the membrane can inhibit volume displacement decreasing coronary perfusion pressures.

A decrease in the helium volume within the IAB catheter may affect diastolic augmentation by not optimising the amount of volume displaced in the aorta. This could result from high or irregular heart rates, fevers, or overriding the consoles automatic helium replacement.

**Pump Console Related:**

- Proper timing of the IABP console synchronised to the patient’s cardiac cycle is required to provide optimal assistance. Early inflation can minimise the haemodynamic effects of IABP therapy by causing:
  - Premature closure of the aortic valve
  - Incomplete ventricular emptying
  - Decreased cardiac output/index
  - Increased preload
  - The potential for regurgitation of blood into the left ventricle.

Late inflation of the balloon can cause decreased diastolic augmentation as well as decreased coronary perfusion.

- The IABP console must be adjusted to deliver the proper amount of helium as indicated by the balloon size of the catheter. If the volume delivered by the console is less than the amount required for the IAB to fully inflate, diastolic augmentation can be affected. Complete inflation should occur in order to optimise the coronary perfusion pressure.
## Factors That Effect Diastolic Augmentation

<table>
<thead>
<tr>
<th>Potential Cause</th>
<th>Corrective Action</th>
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<tbody>
<tr>
<td><strong>Patient Related:</strong></td>
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<tr>
<td>Change in haemodynamic status: ↑ HR, ↓ stroke volume, ↓ MAP, ↑/↓ SVR, arrhythmias, patient ready to wean from IABP</td>
<td>Assess and treat underlying cause as ordered by the physician</td>
</tr>
<tr>
<td><strong>Catheter Related:</strong></td>
<td></td>
</tr>
<tr>
<td>Kink in the IAB catheter</td>
<td>Alleviate the kink. If the kink is internal, removal and replacement may be necessary if the physician is unable to manipulate the catheter to resolve the kink</td>
</tr>
<tr>
<td>Balloon membrane in sheath</td>
<td>Notify the physician to pull sheath back to the appropriate marking on the catheter</td>
</tr>
<tr>
<td>Balloon not fully unwrapped</td>
<td>Manually inflate the IAB (consult the specific manufacturers directions for use)</td>
</tr>
<tr>
<td>Balloon positioned too high or too low</td>
<td>Verify with chest x-ray. Physician will need to reposition catheter</td>
</tr>
<tr>
<td>Balloon leak</td>
<td>Discontinue pumping &amp; notify physician for immediate removal of catheter</td>
</tr>
<tr>
<td>Low helium concentration</td>
<td>Check helium gauge and change tank as indicated. Ensure pump control is in auto</td>
</tr>
<tr>
<td><strong>Pump Console Related:</strong></td>
<td></td>
</tr>
<tr>
<td>Timing error</td>
<td>Correct timing error. Utilise timing markers on arterial waveform ensuring that inflation &amp; deflation correspond with diastole</td>
</tr>
<tr>
<td>Console volume not set to correspond with IAB volume</td>
<td>Verify balloon volume and make necessary adjustment</td>
</tr>
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**Balloon Pressure Waveform**

**Normal Morphology**

The balloon pressure waveform has a normal configuration and also has variations that are considered normal or expected in a given clinical situation. An understanding of the normal waveform is necessary to enable identification of abnormal waveforms, unsafe operating states and to speed the troubleshooting process in the event of an alarm.

![Normal Balloon Pressure Waveform](image)

- **Normal Balloon Pressure Waveform**
  1. Zero Baseline (on console)
  2. Balloon Pressure Baseline
  3. Rapid Inflation
  4. Peak Inflation Artifact
  5. Balloon Pressure Plateau (IAB fully inflated)
  6. Rapid Deflation
  7. Balloon Deflation
  8. Balloon Deflation (return to baseline)
  9. Duration of Balloon Cycle

The balloon pressure waveform (BPW) is shown in blue below the arterial pressure tracing on the pump console. Two important points about the shape of the BPW that are valuable considerations:

- The width of the BPW corresponds to the duration of balloon inflation during the cardiac cycle
- The plateau of the BPW reflects pressure within the aorta when the balloon is inflated. The balloon pump has to overcome the pressure within the aorta to fill the balloon with gas. Since the balloon material is very compliant, the pressure on either side will
be approximately the same. Therefore the plateau pressure on the BPW should be within ± 20 mmHg of the PDP on the arterial pressure waveform.

**Variations of Normal**

The most commonly seen changes in the BPW shape are due to changes in the cardiac cycle or heart rate and in aortic pressure.

- Variations due to heart rate - heart rates & rhythms with longer diastolic phases will widen the BPW

**Effects of Heart Rate on Balloon Pressure Waveform**

- **Tachycardia**
- **Bradycardia**

- Changing BPW width due to an irregular diastolic phase - if the heart rate is erratic, as in atrial fibrillation or there are frequent premature complexes, the BPW will have varying widths.

*Changing Balloon Pressure Waveform width due to Irregular Diastolic Phase*
- The normal variants of the BPW should coincide with the patient’s clinical presentation. If the patient’s heart rate is 65 and the BPW is very narrow, the check the accuracy of the timing as this finding is not appropriate. If the BPW width is erratic and the patient’s rhythm is regular, check to see if the trigger stimulus is clear and appropriate.

- Variations due to aortic pressure – the plateau pressure of the BPW reflects the driving pressure necessary to complete full inflation. If the pressure within the aorta is relatively low, then the pressure needed to inflate the balloon is great and therefore the pressure in the balloon is also relatively low. The diagrams below show the effects of aortic pressure on the BPW.

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**Abnormal Morphology**

There are several changes in the characteristic shape of the BPW that are not considered normal and signal the presence of a potentially unsafe condition.

- **Changes that effect BPWs baseline pressure**
  - If the baseline pressure is greater than +20mmHg, there will be an associated alarm – caused by over pressurization of gas system or internal transducer needs recalibration. Possibly there is a kink in the balloon connecting tubing or internally in the balloon catheter itself.
Possible helium loss - the BPW falls below ~10mmHg. A Possible Helium Leak alarm will sound and the console will suspend pumping until the condition is corrected and the “pump on” key is pressed. Caused by a leak somewhere within the gas circuit allowing helium to escape. This may indicate a balloon rupture.

High Pressure - indicated by loss of peak overshoots and squared/rounded plateau - Causes, impedance of shuttle gas especially at peak inflation.
- There could be a kink in the catheter
- The balloon may be too big for the aorta
- The balloon may not be fully unwrapped
- The patient may be very hypertensive
- The balloon may be incorrectly positioned
- The tail of the balloon may still be within the sheath
- A "High Balloon Pressure" or "He Loss" alarm may be generated

- Situations that require immediate attention from the Intensivist
  - Suspected balloon leak
  - Suspected insertion within the aortic wall
  - Signs of aortic perforation
  - Any condition that reduces the effectiveness of balloon pumping in a dependant patient such as incompletely unwrapped balloon or an internally kinked balloon catheter

**Assessing The Five Points Of The Waveform**

Through proper waveform analysis, the critical care nurse can assess the haemodynamic effects achieved through IABP counterpulsation and remain alert to the need for adjustment in IABP timing sequence.

**Timing Principles For Inflation And Deflation**

The IABP is timed to inflate in the diastolic phase of the cardiac cycle, after the closure of the aortic valve. When a central aortic root arterial line is used, inflation should be timed to occur precisely at the point of the dicrotic notch. When a peripheral arterial line is used; it needs to be slightly adjusted in timing to allow for delayed waveform transmission (consult the operation manual for specifics).

Inflation abruptly increases the pressure within the ascending and proximal descending aorta. Inflation also increases peripheral blood flow distal to the balloon. This normal physiologic event occurs when the bolus of blood ejected form the left ventricle is received in the aorta, causing aortic wall distension. Prior to the next systolic ejection, the aorta’s elastic walls recoil, compressing the aortic blood volume. This fosters forward propulsion of blood, resulting in continuous diastolic blood flow. IAB inflation increases aortic wall distension and stretch resulting in greater elastic recoil upon balloon deflation and enhanced forward blood flow.

The end result of IAB inflation is elevated diastolic perfusion pressure and enhanced circulatory flow in an omni-directional pattern, benefiting both coronary artery and systemic perfusion.
Just prior to and throughout the systolic phase of the cardiac cycle, the IABP is timed to deflate so that the impedance of blood flow from the left ventricle is avoided and afterload reduction is achieved. Deflation of the IAB occurs immediately before systolic ejection from the left ventricle. The sudden decrease in pressure within the aorta produces a vacuum like effect, reducing systemic vascular resistance (SVR) and enhancing forward movement of blood. This effect causes the left ventricle’s afterload or isovolumetric contractile force is also reduced. This results in reduced myocardial oxygen consumption and decreased IABP assisted peak systolic pressure.

Cardiac output increases due to the effects of both inflation and deflation. Improved coronary artery perfusion enhances myocardial performance whereas the reduction in afterload increases cardiac output directly.

**Nursing Assessment Of The Waveform**

Nursing assessment includes analysis of the arterial waveform during inflation and deflation. Begin analysis by identifying the normal components of the arterial waveform without IABP augmentation by turning down the pumping ratio to 1:2. Note the events of systole, closure of the aortic valve (dicrotic notch) and diastole.

Now compare this unaugmented arterial pressure waveform with that of the IABP assisted waveform. Note that IABP inflation occurs at the dicrotic notch, the point of aortic valve closure. IABP inflation raises diastolic pressure to a level higher than peak systole. This peak diastolic augmented pressure (PDAP) point denotes peak perfusion pressure. Optimal augmentation produces peak diastolic pressures that are higher than peak systolic pressure, maximising coronary artery and systemic perfusion.
Now find the point of IABP end diastole, which occurs with balloon deflation just prior to the next systole. Compare this point with that of the unaugmented end-systolic waveform. Note that with proper timing, the balloon aortic end diastolic pressure (BAEDP) is lower than the unaugmented or patient aortic end diastolic pressure (PAEDP) point. This lower pressure reflects a reduction in afterload.

Further assessment of afterload reduction requires a look at the peak systolic pressure (PSP) generated in the complex directly following the IABP complex. This IABP assisted systolic pressure (ASP) should optimally be lower than the PSP due to a reduction in the necessary contractile force from the decrease in afterload. The lowered assisted systolic pressure denotes reduction in the myocardial oxygen consumption.
IABP And Arterial Waveform

Physiologic pressure changes induced by IABP alter the conventional landmarks on the arterial pressure waveform.

Normal Arterial Pressure Waveform

Peak systolic pressure is governed by left ventricular stroke volume, peak rate of ejection and the distensibility of the aortic walls. Slow ejection of a small stroke volume into a distensible aorta produces a small elevation in systolic pressure. Rapid ejection of a large volume into a rigid channel produces a large rise in systolic pressure, as does a normal stroke volume injected at a normal velocity into a rigid atherosclerotic artery. Once ventricular systole is completed, a retrograde surge of blood from the left atrium closes the aortic valve cusps represented on the pressure waveform by the dicrotic notch. Arterial pressure gradually falls as blood flows out through the peripheral vascular network. The rate of diastolic pressure decline is determined by the pressure at the end of systole, rate of outflow through the peripheral resistances and duration of diastolic interval.

Systole is normally the highest pressure point generated. The aortic valve opens, rapid ejection occurs and the ventricle delivers 66-75% of its stroke volume. Thereafter flow velocity declines until the pressure in the ventricle falls below aortic pressure and the aortic valve closes which is marked by the dicrotic notch.
An arterial pressure waveform altered by intra-aortic balloon pumping has 5 reference points:

1. Balloon inflation – termed “diastolic augmented pressure”
2. Balloon deflation during end-diastole producing a low pressure point termed “assisted aortic end-diastolic pressure” (AOEDP)
3. Patient’s aortic end-diastolic pressure without the IABP impact termed “unassisted aortic end-diastolic pressure”
4. “Assisted systole” or the systolic pressure which is generated after a balloon inflation-deflation cycle
5. Systole without a preceding IABP beat, termed “unassisted systole”

Bedside Monitoring Assessment Of The IABP Waveform

Bedside monitors analyse the arterial waveform over several seconds and displays an average of the highest and lowest pressure points measured during the sampling period. They are not programmed to distinguish between a high pressure point generated by a patient’s intrinsic systole or by balloon inflation during diastole. Therefore it is inaccurate to record “blood pressure” from the bedside digital display during balloon pumping. Serious error can occur if 1 nurse records systole as the patient’s actual systolic pressure and another nurse erroneously documents systole as the high pressure point actually occurring during diastolic balloon inflation. Thus it is recommended that the bedside monitor not be used for arterial pressure monitoring during IABP.
Recommended Flowsheet:

<table>
<thead>
<tr>
<th>Time</th>
<th>PDP</th>
<th>BAEDP</th>
<th>PAEDP</th>
<th>APSP</th>
<th>PSP</th>
<th>Mean Pressure</th>
</tr>
</thead>
</table>

Mean Blood Pressure

The mean arterial pressure is an average or calculated value that does not exist except during an instantaneous measurement during the rise and fall of the patient’s pulse. Two methods can be utilised for computation, arithmetic and integration. Arithmetic MAP is calculated by the sum, systolic pressure + 2(diastolic pressure) / 3. This is problematic in IABP when the highest pressure generated is actually "diastolic augmentation". The computer will erroneously misinterpret that pressure point as the systolic pressure and thus the MAP calculation will be inaccurate. The integration method divides the area of the pressure waveform by the length of the sample.

Inotropic Drugs and IABP

IABP pumping every other heartbeat expands the arterial waveform to 5 reference points. The effect of vasopressor and vasodilator drugs can no longer be assessed via a simple 2-point systolic and diastolic blood pressure. Each reference point must be assessed with regard to the potential effect of various pharmacological agents.

Mild vasoconstriction improves stroke volume and may increase diastolic augmented pressure. Higher pressor doses will provoke greater vasoconstriction and an increase in systemic vascular resistance. The ventricle now has to work harder, stroke volume is decreased and diastolic augmentation will also be decreased.

Therefore it is important to assess the entire haemodynamic profile when administering inotropic or vasopressor drugs to the IABP patient. If the nurse receives an order to titrate adrenaline to maintain a pressure of 90, it is crucial to clarify what that means for the IABP patient.
Timing

- The precise timing of balloon inflation and deflation is essential to achieve the haemodynamic effects that increase coronary blood flow and decrease the workload of the heart.
- Timing is set and changed using two separate controls that move the timing markers to the left and right.
- The inflate control is moved to the left to adjust the inflate time to occur earlier and to the right to occur later. The deflate control works the same way.
- Timing of the IABP is always performed using the arterial pressure waveform as a guide.
- When assessing the timing of the pump, the assist interval needs to be set at 1:2 so that all landmarks can be identified and the effects of inflation and deflation can be compared to the baseline haemodynamic status.

Inflation

- **Goal:**
  - Increase myocardial oxygen supply
  - Increase systemic perfusion pressure
- To accomplish the goals of inflation, the balloon must be inflated at the onset of diastole. The dicrotic notch is the landmark used and inflation should occur just prior to this point.
- The result of a properly timed inflation is a pressure rise, peak diastolic pressure (PDP) during diastole.
- The PDP influences the gradient for coronary artery perfusion. While it may not only be a reflection of timing, the PDP should be higher than the patient systolic pressure (PSP) unless:
  - The patient’s stroke volume is significantly higher or lower than the balloon volume
  - Balloon is positioned too low
  - Severe cases of hypovolaemia
  - Balloon is too small for patient’s aorta
  - Low systemic vascular resistance
  - Improper timing
  - Catheter is partially kinked, in sheath, no unwrapped, too high or too low
- Inflation timing should be set to occur 40 to 50 milliseconds early to compensate for the delay.
Deflation

- **Goal:**
  - Decreased myocardial oxygen demand
  - Increased stroke volume
- Deflation timing does not have the benefit of absolute landmarks but entails assessment of pressure responses
- Balloon deflation during the intraventricular contraction phase of systole causes a fall in pressure immediately preceding ventricular ejection.
- This fall is represented by the balloon aortic end diastolic pressure (BAEDP).
- For effective afterload reduction, the BAEDP must be lower than the patient's own unassisted aortic end diastolic pressure.
- The following systole (assisted systole) benefits from the effects of afterload reduction as the left ventricle does not have to generate as high a pressure to eject stroke volume and is therefore lower than the patient's own PSP.
- The result of properly timed deflation should be:-
  - BAEDP < AEDP
  - Assisted PSP < PSP
- Aside from improper timing, poor afterload reduction may be caused by:
  - Balloon not inflated to full volume causing a decrease in volume displacement
  - Compliant aortic wall which allows for only small changes in volume
  - Improper balloon placement
The Timing Three

1. Inflation
   - Just prior to the dicrotic notch
   - If > 40 ms before → EARLY INFLATION
   - If dicrotic notch exposed → LATE INFLATION

2. Deflation
   - BAEDP < PAEDP
     - BAEDP = Balloon Aortic End Diastolic Pressure
     - PAEDP = Patient Aortic End Diastolic Pressure
   - If violated → LATE DEFLATION

3. Deflation:
   - Assisted Systole (APSP) < Peak
     - PSP = Peak Systolic Pressure
     - APSP = Assisted Peak Systolic Pressure
   - If violated → EARLY DEFLATION
Nursing Responsibilities in IABP Timing

Nursing assessment starts with the identification of the following five points:
- Balloon assisted aortic end diastolic pressure
- Patient aortic end diastolic pressure
- Assisted systolic pressure
- Patient systolic pressure
- Peak diastolic augmented pressure

The nurse responsible for patient care should attempt to maximise diastolic augmentation and afterload reduction to achieve the following effects:
- Peak diastolic augmented pressure greater than peak systolic pressure
- Balloon assisted aortic end diastolic pressure lower than patient aortic end diastolic pressure
- Assisted systolic pressure lower than patient systolic pressure.

Timing should always be reassessed with any changes in the patient’s rhythm or rate or haemodynamic deterioration.

Errors in Timing

Inflation or deflation errors can be made in two ways: too early or too late. Early inflation and late deflation are potentially dangerous to the patient. Late inflation and early deflation are considered suboptimal as the patient may not receive the full benefits of IAB pumping and may cause further deterioration of myocardial status.

Early Inflation:

The IAB has inflated before the aortic valve has closed (during systole) causing premature closure of the aortic valve and reduction in stroke volume. The haemodynamically unstable patient cannot afford to lose any forward cardiac output and an impediment of only 10% may cause deterioration.
**Late Inflation:**

During the diastolic phase, there is blood flow from the aorta to the periphery. As a result, the volume of blood in the aorta will decrease following aortic valve closure. If the balloon is inflated after the aortic valve closes, there is not as much blood available for displacement, resulting in a lower pressure increase. The major effect of late inflation is a suboptimal increase in coronary perfusion.

**Early Deflation:**

The balloon should deflate during IVC. In early deflation, the balloon is deflated before IVC so that the corresponding reduction in aortic pressure occurs too soon to be of benefit. The net effect is that afterload reduction is not present and the workload of the heart is not decreased.

**Late Deflation:**

The balloon is inflated (or partially inflated) at the beginning of ventricular ejection. The left ventricle now has to force blood out of the aorta against the resistance of the inflated balloon. The result is an increase in the workload of the ventricle and impedance of stroke volume. Action to correct this error should be taken immediately as a severely compromised left ventricle will fail swiftly.
Trigger Acquisition

- The IABP must have a consistent signal in order to perform trigger and timing functions
- In order to effectively implement IABP therapy, it is required to obtain the clearest signal possible from the patient
- Ideally, both the ECG and the arterial pressure (AP) waveforms should be monitored on the IABP
- Direct signals:
  - Come from the patient to the balloon pump
  - The skin lead ECG signal from the patient obtained in the same way as for the bedside monitor
  - The arterial pressure waveform is from the central lumen of the catheter where a transducer is attached in the same way as for any arterial line. If the central lumen cannot be utilised, then an alternative site (IE radial artery) can be used
- External Monitor:
  - Slave from the bedside monitor to the IABP via compatible interface cables. It requires the patient to be connected to the bedside monitor in the normal fashion. These interface cables are connected to the monitor ECG and/or AP output jacks on the bedside monitor. The other end of the stereo phone jack cable is plugged into the IABP at the ECG/AP input jacks on the pump console
  - When signals are being slaved from the bedside monitor to the IABP, any interference in the signal needs to be corrected at the bedside monitor
- Both direct signals and slaving can be done to maximise flexibility and back up during assist
- Signal acquisition is the most important factor in consistent, reliable balloon pump therapy. Once the signal has been acquired, the operator then selects a trigger.

Trigger Acquisition:

- The signal that the pump uses to identify the onset of systole and therefore initiates the deflate/inflate cycle of the IAB
- Also acts as a safety device. If the command for deflation has not been given by the operator, and the pump recognises the onset of systole, or a trigger event, it will initiate deflation so that the IAB does not remain inflated during patient systole
The most reliable trigger event is the R wave of the ECG. Most patients have a QRS complex though it may vary in voltage and width. If the QRS complex does not meet the criteria for detection, manipulation of the ECG may be necessary through lead selection.

**No Trigger Alarms:**

- Troubleshooting to maintain an adequate trigger should start with the patient.
- The loss of an adequate ECG should prompt the operator to check the patient for a pulse and treat the patient accordingly.
- The next step would be to begin assessing the source of the signal. Is the signal direct or slaved?
- Check all connections and ensure normal placement of the electrodes.
- Check to see if the patient has a more precise signal in a different lead.
- Increase the gain control to maximise the console's ability to detect the R wave.
- When unable to trigger from the R wave, other ventricular events, such as ventricular pacing spikes can be used as the trigger. AP is considered to be the last trigger resort. The trigger event of the AP waveform is the upstroke of systole; the actual mechanical ejection of blood from the ventricle that causes the increase in aortic pressure.
- AP trigger is dependant on a consistent arterial pressure.
- The use of AP trigger is contraindicated in the presence of arrhythmias due to the inconsistency of the size and interval of the pulse pressure.
- In the event of a cardiac arrest, neither the ECG nor AP will provide a trigger. CPR may produce an R wave or AP trigger source with chest compressions. If the chest compressions fail to meet R wave criteria, the AP trigger may be selected. As a last resort, the operator may use the Internal Trigger. This generates an asynchronous signal to prevent thrombus formation on the balloon membrane. Internal trigger should never be used on a patient with a cardiac cycle.
Use Of The IABP During Cardiac Resuscitation.

In the event of cardiac arrest in a patient on the IABP, the loss of the ECG and arterial pressure waveform will result in a loss of the trigger signal to the IABP. This will generally cause a TRIGGER LOSS alarm and stop counter pulsation. It is strongly recommended that one of the following options be instituted to minimize risk of thrombus formation:

1. If counter pulsation is to be continued and synchronised to the CPR effort, then arterial trigger should be selected. If CPR generates sufficient blood pressure, then in most cases, the IABP will pump and may improve perfusion to coronary and carotid arteries. In the event that the CPR cannot generate a consistent and reliable trigger, then additional steps should be taken as follows.

2. A trigger signal generated by the IABP is available through the use of the INTERNAL TRIGGER mode. To select INTERNAL, the INTERNAL TRIGGER key must be depressed TWICE. In most cases the clinician may decrease the assist interval or decrease the volume of the IAB. This trigger will maintain movement of the catheter and therefore reduce the risk of thrombus formation.

   **WARNING:** The use of INTERNAL TRIGGER will produce asynchronies counter pulsation & therefore should never be used in the event that the patient has an ECG or arterial pressure source available. Once the ECG or arterial signal has been re-established, the trigger mode must be changed from INTERNAL to an acceptable patient trigger.

3. If the IABP is not used in one of the above methods & the IABP is turned off, the IAB should be manually inflated. Aspirate with a large Luer lock syringe to check for blood. Inject 10cc of air greater than the total balloon volume (i.e. 50 ml for a 40 ml IAB) into the balloon connector and aspirate it immediately. Manual inflation should be done 4 to 5 times every 30 minutes that counter pulsation is discontinued.
Weaning from the Intra Aortic Balloon Pump

- The time for weaning and the speed for which weaning can be accomplished are dictated by the patient’s haemodynamic status.
- Weaning can be accomplished by decreasing the frequency and/or volume of balloon inflation.
- Weaning by decreasing the frequency is accomplished by decreasing the frequency of assistance from 1 balloon inflation per cardiac cycle to 1:2, 1:3, 1:4 and 1:8.
- Weaning can also be done by decreasing the volume delivered to the balloon. However, do not reduce the volume delivered to the balloon less than 2/3 the capacity of the balloon.

General Recommendations When Weaning

- Monitor the patient’s haemodynamic status to establish a baseline for response and carefully monitor patient during weaning.
- Monitor:
  - ECG - rate and rhythm
  - Blood pressure
  - Urine output
  - Distal perfusion
  - Cardiac output / index

Weaning Criteria

- It is suggested that IABP support be discontinued if the following clinical picture is present:
  - Signs of hypoperfusion due to low cardiac output syndrome are absent.
  - The urine output can be maintained above 30 ml / hr.
  - The need for positive inotropic agents is minimal. The cardiovascular system remains stable in the low dose range.
  - The heart rate is less than 100 beats per minute.
  - Ventricular ectopics are fewer than 6 per minute, not coupled and unifocal.
  - The cardiac index remains equal to or greater than 2 l/min/m² and does not decrease by more than 20%.
✓ The index of LVEDP (PCWP< PADP) does not increase to greater than 20% above pre weaning level
✓ The absence of angina

➢ When the patient no longer needs IAB support, press the OFF key in the PUMP STATUS section of the keypad to stop pumping, then remove the IAB catheter according to protocol
Troubleshooting Helium Loss Conditions

Alarm Criteria

Helium loss is evaluated based on the position of the balloon pressure waveform (BPW) baseline just prior to inflation. This is monitored continually. Depending on the amount of helium loss, the IABP will either attempt to refill or issue an alarm.

Assessment of the BPW

- Shape - should be sharp and squared. The sharper the inflation and deflation curves, the faster the speed of the IAB. If the inflation and/or deflation artefacts are widened, it indicates some compromise of the IABP performance
- Point of monitoring used by the IABP - the position of the BPW just prior to inflation. If this point is consistently below zero despite heart rate and rhythm then there is probably a leak. Or if there are some beats where the baseline is at or slightly above zero and the BPW falls to fall below zero when there is a fast beat, the helium loss alarms are due to incomplete deflation of the IAB

Alarm Code

- BPW baseline monitoring for stability
  - Determines the stability of the baseline. The BPW baseline cannot change more than 2mmHg to be defined as stable
- Helium Refill Criteria
  - Stable BPW baseline: 4 stable BPW baselines below 0.5mmHg and above -10mmHg
  - Unstable baseline: no refill attempt unless 4 stable BPW baselines are seen. If no stable baselines are seen, the fill is not done until the next drain task
- Helium Loss 1 or Unable To Fill
  - Failure to reach 2.5mmHg within 8 refill attempts
  - Alarm then renamed UNABLE TO REFILL
- Helium Loss 2
  - Stable BPW baseline: second refill attempt within 1 minute
  - Unstable baseline: no refill attempt unless 4 stable baselines are seen
- **Helium Loss 3**
  - **Stable BPW baseline:** BPW baseline below -10mmHg for 2 consecutive beats
  - **Unstable BPW baseline:** the ACAT monitors the baseline for 10 seconds. If no stable baseline is found, the pump will monitor for another 10 seconds. If no stable baseline is found, the pump will alarm
  - If at any time the ACAT sees 1 stable BPW baseline, the monitoring period is restarted

<table>
<thead>
<tr>
<th>Alarm</th>
<th>Frequency</th>
<th>Troubleshooting Steps</th>
</tr>
</thead>
</table>
| Large helium loss         | Frequent & persistent            | ✓ Check for blood in tubing
|                           |                                  | ✓ Check for disconnect
|                           |                                  | ✓ Perform leak test                                                                   |
| Large helium loss         | Infrequent                       | ✓ Check for intermittent kinks
|                           |                                  | ✓ Use knee brace to maintain leg position
|                           |                                  | ✓ Reposition patient                                                                 |
| Unable to refill          | Frequent (every 15 minutes or less) | ✓ Check helium supply                                                                 |
|                           |                                  | ✓ Change console - remove pump                                                        |
|                           |                                  | ✓ Report problem to biomed                                                            |
| Unable to refill          | Infrequent                       | ✓ Have biomed check pump after use                                                    |
| Helium loss 2             | Frequent & persistent            | ✓ Place pump in 1:2 ratio                                                             |
|                           |                                  | ✓ If leak persists, perform leak test                                                  |
|                           |                                  | ✓ Repair or remove IAB as indicated                                                   |
| Helium loss 3             | Infrequent                       | ✓ Check timing - move deflation slightly earlier                                       |
|                           |                                  | ✓ Check IAB size                                                                      |
|                           |                                  | ✓ Reduce IAB volume                                                                   |
|                           |                                  | ✓ Perform leak test                                                                   |
|                           |                                  | ✓ Reposition patient                                                                  |
|                           |                                  | ✓ Repair or remove IAB as needed                                                      |
| Combination alarms - helium loss/ high baseline/ high pressure | Frequent or infrequent | ✓ Check for kinks
|                           |                                  | ✓ Check IAB position                                                                 |
|                           |                                  | ✓ Check timing & retime as needed                                                     |
|                           |                                  | ✓ Check trigger, change as                                                             |
To Check IAB Sizing:

- Compare the BPW plateau (inflation portion) against the peak systolic pressure (PDP) of the patient. These should be within +/- 20mmHg of each other. If the BPW plateau is more than 20mmHg above the PDP, the IAB may be too occlusive and prone to helium loss alarms.
- To correct this condition, reduce IAB volume until the BPW plateau and the PDP are within 20mmHg of each other.

To Perform A Leak Test:

- Ensure the patient can tolerate the loss of IABP support for the short periods of time (generally about 1 minute)
- If the patient tolerates this, turn the alarms OFF for 10 minutes
- Stop pumping
- Using a rubber clamp, clamp the DRIVELINE tubing about 15cms from the console, between the bifurcation and the quick connect
- Start pumping
- Observe the BPW baseline. You may want to set the cursor or have a continuous strip printing during the leak test for assessment of changes
- If the BPW falls below zero, the leak is between the pump and the clamp
  - Repair: the most common site of the leak is the driveline tubing under the white collar where it attaches to the IABP connector. Remove the white collar and pull the driveline tubing off of the IABP connector. Cut about 2.5 cm of the driveline tubing and reattach the connector. Return the white collar to its original position
- Perform the leak test again and verify the BPW does not fall below zero. If the leak persists, the leak is in the IAB console and it should be removed
- Check integrity of “O” rings on the IAB connector. If worn or broken, replace the connector
If no leak appears, stop pumping, move the clamp to the driveline tubing closest to the IAB catheter. DO NOT CLAMP THE IAB CATHETER. Repeat the test. If the BPW baseline falls below zero, the leak is between the camp and the pump.

The most common site is the quick connect. Check it for leaks. Repair with adhesive tape or replace the driveline tubing.

If no leaks are seen during the clamping test, an IAB leak should be suspected. IAB removal is recommended since many leaks are detected prior to evidence of blood in the tubing.
Transport Considerations.

Prior to Transfer:

- Notify Medical Retrieval Unit that the patient is on IABP
- Verify that the transport vehicle has an inverter to supply power to the pump
- Inform retrieval that a staff member will be accompanying the patient
- Determine what IABP the receiving hospital uses, if it is not an Arrow pump, be sure to take appropriate adaptors to interface the catheter with their pump with you
- Check IABP battery - the ACAT has a 2 hour battery life when fully charged
- Verify adequate helium supply, consider changing the tank if less than $\frac{1}{4}$ full
- Verify that there is a good tracing on both ECG and arterial pressure waveforms
- Organise paper work as for any transfer
- Ensure that the balloon catheter is secured
- Check pump connection sites to ensure that they are firmly connected

During transport:

- See pictures to gain an idea of the best way to load the patient and the machine into the back of both the ambulance and helicopter.
- For the ambulance, move the patient stretcher up to the back door with the pump on the left side of the trolley. Once the stretcher is loaded but not locked into position, lift the pump into the space
directly behind the observers seat, using the proper handles on the pump. Lock down both the pump and the stretcher. Ensure that the wheel locks and the straps are on the pump.

- Remove the control head from the pump. This is utilised from the lap of the observer.
For helicopter transport
Due to interference from movement during transport, it might be better to trigger the patient through the arterial pressure waveform rather than an ECG trigger.
References:


“Factors That Affect Diastolic Augmentation”. Arrow International. Volume 1, Issue II.


