COUNTERPULSATON APPLIED
An Introduction to Intra-Aortic Balloon Pumping
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## INTRODUCTION TO INTRA-AORTIC BALLOON PUMPING

### 4 HOUR PROGRAM

<table>
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<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>8:00 – 8:10 a.m.</td>
<td>Welcome</td>
</tr>
<tr>
<td>8:10 – 8:30 a.m.</td>
<td>Principals of Intra-Aortic Balloon Counterpulsation</td>
</tr>
<tr>
<td>8:30 – 8:50 a.m.</td>
<td>Complications</td>
</tr>
<tr>
<td>8:50 – 9:00 a.m.</td>
<td>Intra-Aortic Balloon Insertion</td>
</tr>
<tr>
<td>9:00 – 9:45 a.m.</td>
<td>Timing</td>
</tr>
<tr>
<td>9:45 – 10:00 a.m.</td>
<td>Break</td>
</tr>
<tr>
<td>10:00 – 11:15 a.m.</td>
<td>Pump Operation</td>
</tr>
<tr>
<td></td>
<td>• Triggering</td>
</tr>
<tr>
<td></td>
<td>• Troubleshooting (BPW)</td>
</tr>
<tr>
<td>11:15 – 12:00 p.m.</td>
<td>Hands-On</td>
</tr>
<tr>
<td>12:00 – 12:15 p.m.</td>
<td>Evaluation</td>
</tr>
</tbody>
</table>

### 8 HOUR PROGRAM

**Morning**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>8:00 – 8:15 a.m.</td>
<td>Registration</td>
</tr>
<tr>
<td>8:15 – 8:30 a.m.</td>
<td>Welcome</td>
</tr>
<tr>
<td>8:30 – 9:30 a.m.</td>
<td>Physiology and Principles of Counterpulsation</td>
</tr>
<tr>
<td>9:30 – 9:45 a.m.</td>
<td>Indications and Contraindications</td>
</tr>
<tr>
<td>9:45 – 10:00 a.m.</td>
<td>Break</td>
</tr>
<tr>
<td>10:00 – 10:15 a.m.</td>
<td>Complications</td>
</tr>
<tr>
<td>10:15 – 10:45 a.m.</td>
<td>Insertion and Nursing Care</td>
</tr>
<tr>
<td>10:45 – 12:00 p.m.</td>
<td>Arterial Pressure Waveform and Timing</td>
</tr>
</tbody>
</table>

**Afternoon**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
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<tbody>
<tr>
<td>12:00 – 1:00 p.m.</td>
<td>Lunch</td>
</tr>
<tr>
<td>1:00 – 1:30 p.m.</td>
<td>Timing Experience</td>
</tr>
<tr>
<td>1:30 – 2:00 p.m.</td>
<td>Triggering</td>
</tr>
<tr>
<td>2:00 – 2:30 p.m.</td>
<td>Balloon Pressure Waveform and Troubleshooting</td>
</tr>
<tr>
<td>2:30 – 2:45 p.m.</td>
<td>Break</td>
</tr>
<tr>
<td>2:45 – 4:15 p.m.</td>
<td>Hands-On Session</td>
</tr>
<tr>
<td>4:15 – 4:30 p.m.</td>
<td>Evaluation and Post Test</td>
</tr>
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</table>
INTRODUCTION

This program is designed for experienced healthcare professionals directly responsible for the care of patients needing Intra-Aortic Balloon Pump (IABP) therapy. The participants should have a basic understanding of cardiac anatomy, physiology and hemodynamics. Participants should have experience with hemodynamic monitoring and its implications.

Information and instructions given in this manual in no way supersede established medical procedures concerning patient care. Best practice as determined by the medical community is always to be observed. In each case, the user must determine whether the application of the information provided is appropriate to his/her particular clinical setting.

Hands-on time will be provided to allow participants to set up the console and troubleshoot various alarm situations.

Participants are also provided with a competency performance checklist and a post-test to assist in maintaining proficiency.

OBJECTIVES

At the completion of the Arrow® IARP Program from Teleflex®, the participant will be able to:

1. Define two goals of IABP therapy.
2. List three indications for use of the IABP.
3. State three contraindications for use of the IABP.
4. Identify the location of a properly positioned IAB catheter.
5. Correlate the arterial pressure waveform with the cardiac cycle.
6. Describe at least three complications of IAB therapy.
7. Recognize on an arterial waveform properly timed inflation and deflation of the IAB catheter.
8. Discuss the hemodynamic consequences of improperly timed balloon pumping.
9. Identify the characteristics of a normal balloon pressure waveform.
10. Correlate changes in the balloon pressure waveform with hemodynamic changes in the patient.
11. Identify the most appropriate trigger signal selection for a given patient situation.
13. Discuss the clinical intervention for troubleshooting alarms/alerts.
CARDIAC PHYSIOLOGY

The Cardiac Cycle

Contraction of the ventricles propels blood into the systemic or pulmonary circulation and is the result of motion of the cardiac chambers.

There are some basic points to remember about pressures and timing during the cardiac cycle. Fluid (in this case 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 will attempt to equalize. This occurs when the valves between two cardiac chambers are open.

PRINCIPLES OF BLOOD FLOW

- Blood moves forward (from high pressure to low pressure)
- Valves open forward
- Blood moves by pressure gradient

The Intra-Aortic Balloon is a mechanical device making a mechanical change in a mechanical system; thus the mechanical waveform is an important tool in assessing the efficacy of balloon pumping. Its morphology is representative of pressure changes in the vascular system and reflective of the stages of the cardiac cycle.

TOP WAVEFORM:
ECG/Electrical event

BOTTOM WAVEFORM:
Arterial Pressure Waveform/Mechanical event
CARDIAC PHYSIOLOGY

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

DIASTOLIC PHASE

Isovolumetric Relaxation

The relaxation of myocardium begins immediately after 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 which is generally accepted as the beginning of the diastolic phase. During isovolumetric relaxation (IVR) the semilunar valves are closed, but the pressures in the ventricles are greater than those in the atria which prevent the opening of the mitral and tricuspid valves. The ventricles relax, and for a short time, there are no volume changes within the ventricles.

Ventricular Filling

When the ventricular pressures fall below atrial pressures, the mitral and tricuspid valves open. The ventricles then fill rapidly with the blood that has accumulated in the atria. With continued 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

The last event in the diastolic phase is the 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. The contribution to the total ventricular volume from atrial contraction varies between 15–25%.
CARDIAC PHYSIOLOGY

SYSTOLIC PHASES

Isovolumetric Contraction – Pre Ejection Phase
At the start, the ventricles are full and all valves are closed. There are no volume changes taking place at this time until the ventricles generate a pressure greater than the pressures in the aorta and pulmonary artery. This time period has been termed the isovolumetric contraction (IVC) phase or pre-ejection phase. The major purpose of the IVC phase is to build enough pressure to achieve ejection of ventricular contents. This time period of pressure building utilizes much energy. Approximately 90% of myocardial oxygen consumption occurs during the IVC phase. The length of the IVC phase is a major determinant in establishing the oxygen demand.

Rapid Ventricular Ejection
The aortic valve opens at the precise moment the left ventricular pressure exceeds the aortic end diastolic pressure (AEDP). Approximately 75% of stroke volume is ejected during this period. Rapid ventricular ejection continues until the point of maximum ventricular pressure. This point is called peak systolic pressure.

Reduced Ventricular Ejection
After the peak systolic phase, the remaining 25% of stroke volume is ejected.
Systole ends with the onset of myocardial relaxation and the cycle repeats itself. (Closure of the aortic valve.)
CARDIAC PHYSIOLOGY

CARDIAC OUTPUT

Determinants of Cardiac Output

As a mechanical pump, the performance of the heart is typically expressed in terms of cardiac output (CO). The CO is generally expressed in liters per minute.

\[
\text{Cardiac Output} = \text{Stroke Volume} \times \text{Heart Rate}
\]

Normal: 4 – 8 L/min

\[
\text{Stroke Volume} = \frac{\text{CO} \times 1000 \text{ mL}}{\text{HR}}
\]

Normal: SV = 50 – 100 mL

\[
\text{Cardiac Index} = \frac{\text{CO}}{\text{BSA}}
\]

Normal: CI = 2.5 – 4.0 L/min/m²

KEY INFLUENCES ON STROKE VOLUME & HEART RATE

- **PRELOAD**
  - Preload refers to the amount of stretch on the ventricular myocardium prior to contraction.
  - Estimated by the Left Ventricular End Diastolic Pressure (LVEDP)
  - Amount of volume in the ventricle at the end of diastole (LVEDV)

  \[\text{LVEDP} = 4 – 12 \text{ mmHg}\]
  \[\text{PCWP} = 4 – 12 \text{ mmHg}\]
  \[\text{CVP} = 3 – 11 \text{ mmHg}\]

- **STARLING'S LAW OF THE HEART**
  - Increase of volume in the ventricle at the end of diastole resulted in an increase in the volume of blood pumped.
  - The greater the muscle fibers are stretched during diastole, the stronger the next contraction, up to a certain point. The fibers can only stretch to a certain point before they lose their resilience and elasticity, resulting in decreased CO.

  ![Figure 5. Left Ventricular End-Diastolic Pressure](image.png)
CARDIAC PHYSIOLOGY

AFTERLOAD
- Clinically measured using systemic vascular resistance (SVR)
  \[ \text{SVR} = \frac{(\text{MAP} - \text{CVP}) \times 80}{\text{CO}} \]
- Impedance to ventricular ejection
  - Mass of blood
  - AEDP (aortic end-diastolic pressure)
  - Resistance of arterioles

Contractility
- The myocardium’s intrinsic ability to contract independently of the effects of preload or afterload
- Measured indirectly by Ejection Fraction or Ventricular Stroke Work Index

  \[ \text{EF} = 60 – 70\% \]
  \[ \text{RVSWI} = 5 – 10 \text{ g/beat/m}^3 \]
  \[ \text{LVSWI} = 45 – 65 \text{ g/beat/m}^3 \]

MYOCARDIAL OXYGEN BALANCE

Myocardial oxygen balance can be thought of as a scale. On one side there is the oxygen supplied by the coronary artery circulation. On the other side there are all the factors that increase the demand for oxygen.

SUPPLY
- Ninety percent of coronary artery perfusion takes place during the diastolic phase of the cardiac cycle; therefore, it is the diastolic pressure that is the driving force for coronary artery filling. The length of diastolic time is determined by the heart rate. Increased heart rate allows less time for filling of the coronary arteries during diastole.
- It is important to distinguish between oxygen demand, oxygen supply and oxygen consumption. The consumption cannot increase to meet demand if usable supply of oxygen is insufficient (cardiac arrest, unable to use circulated oxygen).

DEMAND
- The variables that increase oxygen demand are preload, afterload, heart rate and contractility. The inflation of the IAB increases diastolic pressure to increase coronary perfusion and potentially open collateral vessels, thereby increasing oxygen supply to the ischemic heart muscle.
- Deflation of the IAB decreases afterload, reducing ventricular resistance. This allows the ventricle to contract more efficiently (improved contractility) and increase stroke volume (cardiac output). This then reduces preload for the next cardiac cycle and reduces overall oxygen consumption.
- The IABP affects both sides of the myocardial oxygen balance.
GENERAL PLACEMENT CONCEPTS

An Intra-Aortic Balloon Catheter is inserted in the femoral artery and passed into the descending thoracic aorta. Once the balloon catheter is passed into the descending aorta, placement must be confirmed by fluoroscopy or chest X-ray. The balloon is situated 1 – 2 cm below the origin of the left subclavian artery and above the renal artery branches. On daily chest X-rays, the tip should be visible between the 2nd and 3rd intercostal space. This placement is critical for proper operation and avoidance of arterial tributary obstruction.

PROPER PLACEMENT

- Too low – the origin of the renal arteries may become obstructed thereby compromising renal perfusion.
- Too high – obstruction of the origin of the left subclavian or even the left carotid artery may result.

CORONARY ARTERY ANATOMY

Coronary arteries receive and circulate the majority of their blood supply during the diastolic phase.

1. Right Coronary Artery (RCA): Supplies the anterior and posterior right ventricle.
2. Left Main (LM): Main branch prior to bifurcation into the left anterior descending and circumflex.
3. Left Anterior Descending (LAD): Supplies the anterior surface of the left ventricle.
4. Circumflex (CX): Supplies the lateral wall to posterior surface of the left ventricle.
5. Posterior Descending (PDA): Supplies the posterior interventricular septum and adjacent areas of the right and left ventricles.

Smaller arteries that come off the main arteries are called marginals. Right Coronary Artery and the Left Circumflex, they are called acute marginal. The branches off the LAD are called Diagonals.
IABP therapy is based on the principle of Counterpulsation, meaning that the action of the balloon inflation and deflation is opposite that of the Cardiac Cycle.

The Intra-Aortic Balloon exerts its effect through volume displacement. At precisely timed intervals, a gas, generally Helium, inflates the balloon occupying a space equal to its volume. This creates an additional "pulse" in the arterial system without additional cardiac work. Conversely, during deflation, the gas is removed from the balloon creating a "potential space". This reduces the pressure in the aorta and allows the heart to eject its contents at a lower pressure.

The IAB Catheter should not totally occlude the aortic lumen during inflation.

- Ideally, the IAB Catheter should be 85 – 90% occlusive.
- Total occlusion could result in aortic wall trauma and damage to red blood cells and platelets.

If an IAB is suspected of being occlusive, do not reduce the IAB volume to less than 2/3 of the balloon’s capacity.

To prevent thrombus formation, pump the balloon at its maximum capacity for five minutes every one to two hours. A smaller IAB volume should be considered.

A smaller IAB volume should be considered.

Table 1

<table>
<thead>
<tr>
<th>IAB SIZE RECOMMENDATIONS</th>
<th>30 CC</th>
<th>40 CC</th>
<th>50 CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>147 – 162 cm</td>
<td>182 – 182 cm</td>
<td>&gt; 182 cm</td>
</tr>
<tr>
<td>4'10&quot; – 5’4&quot;</td>
<td>5’4&quot; – 6’0&quot;</td>
<td>&gt; 6’0&quot;</td>
<td></td>
</tr>
<tr>
<td>BSA</td>
<td>&lt; 1.8 m²</td>
<td>&gt; 1.8 m²</td>
<td></td>
</tr>
</tbody>
</table>

Figure 10.

Figure 11.

REDUCING BALLOON VOLUME

If an IAB is suspected of being occlusive, do not reduce the IAB volume to less than 2/3 of the balloon’s capacity. To prevent thrombus formation, pump the balloon at its maximum capacity for five minutes every one to two hours. A smaller IAB volume should be considered.

COMPLICATIONS: IAB TOO LARGE

- Thrombocytopenia
- Aortic rupture
- Balloon abrasion
- Hemolysis
HEMODYNAMICS

BALLOON INFLATION

Inflation of the balloon should occur at the onset of diastole. At the beginning of diastole, maximum aortic blood volume is available for displacement.

Properly timed inflation will:
• Increase coronary blood flow
• Increase diastolic pressure
• Potential for increased coronary collateral circulation
• Improve systemic perfusion

BALLOON DEFLATION

The balloon remains inflated throughout the diastolic phase. Deflation of the balloon should take place at the onset or just prior to systole. At the beginning of systole, the left ventricle has to generate a pressure greater than the AEDP to achieve ejection. The sudden evacuation of the volume of the balloon will cause a fall in pressure in the aorta.

Properly timed deflation will cause a fall in pressure therefore, the left ventricle will not have to generate as much pressure to achieve ejection thereby reducing oxygen demand.

Properly timed deflation will:
• Decrease afterload
• Shorten IVC phase
• Increase stroke volume
• Enhance forward cardiac output

SIGNS OF AN IMPROVED CLINICAL CONDITION

The alteration of improved coronary circulation and decreased myocardial workload all affect the patient’s clinical status. Many of the clinical signs reflect the benefits of both inflation and deflation of the Intra-Aortic Balloon while some are primarily caused by one action or the other.

<table>
<thead>
<tr>
<th></th>
<th>INFLATION</th>
<th>DEFLATION</th>
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<tbody>
<tr>
<td>Increased cardiac output</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Increased urine output</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Decreased preload</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Decreased pulmonary congestion</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Improved mentation</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Decreased heart rate</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Decreased lactic acidosis</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Increased pulse pressure and pulse rate</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Decreased signs of myocardial ischemia</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Increased coronary blood flow</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Decreased afterload</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Decreased MVO₂ and demand</td>
<td>↓</td>
<td>↓</td>
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TABLE 2
POSSIBLE COMPLICATIONS

HIGH-RISK PATIENTS

Patients at risk of developing complications:
- PVD
- Diabetic
- Female
- History of Smoking
- Shock
- Hypertension
- Obesity

COMPLICATIONS OF BALLOON PUMPING

With insertion, during pumping, and with removal of IAB catheter, complications may include the following:

<table>
<thead>
<tr>
<th>COMPLICATIONS</th>
<th>POTENTIAL CAUSES</th>
<th>SIGNS &amp; SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic rupture (wall damage)</td>
<td>Stripping of the endothelial surface, improper placement of the catheter or unsuspected aortic wall disease</td>
<td>Fluoroscopic changes, Hemodynamic changes</td>
</tr>
<tr>
<td>Aortic dissection</td>
<td>Intimal tear by guidewire or catheter</td>
<td>Resistance during insertion, Fluoroscopic changes, Abdominal pain, Back pain</td>
</tr>
<tr>
<td>Retroperitoneal bleed</td>
<td>Needle passes through posterior wall of femoral artery</td>
<td>Change on Ultrasound, Back Pain, Urges to stool/move bowels, Anxiety, Hemodynamic changes, Change in lab values (Hgb/Hct), Ecchymosis of the flank areas</td>
</tr>
<tr>
<td>Pseudoaneurysm</td>
<td>Needle passes through lateral wall of femoral artery</td>
<td>Change on Ultrasound, Visible bulge at insertion site, Bruising and pulsatile mass above the femoral artery, Increase in thigh girth</td>
</tr>
<tr>
<td>Local Vascular Injury</td>
<td>Multiple sticks at insertion site with leaking of blood into tissue, Applying too much pressure when attempting to achieve hemostasis during removal</td>
<td>Hematoma, Visible bulge at insertion site, Groin and/or thigh hard and tender to touch</td>
</tr>
</tbody>
</table>

INDICATIONS FOR USE

1. Medical Indications
   - Cardiogenic Shock
   - Pre-shock Syndrome
   - Unstable Angina
   - Intractable Ventricular Dysrhythmias
   - Cardiac Contusion

2. Prophylactic Support for:
   - Coronary Angiography
   - Coronary Angioplasty
   - Thrombolytic Therapy
   - High Risk Interventional Procedures (i.e., stents)

3. Mechanical Complications post MI:
   - Valvular Stenosis
   - Valvular Insufficiency–Mitral
   - Ruptured Papillary Muscle
   - Ventricular Septal Defect

4. Surgical Indications
   - Post-operative Myocardial Dysfunction
   - Support for weaning from CPB
   - Cardiac support following correction of anatomical defects
   - Maintenance of graft patency post CABG
   - LV Aneurysm

5. Bridging Device to other mechanical assist:
   - Ventricular Assist Device

6. Support for transport to tertiary care facility

CONTRAINDICATIONS

1. Absolute
   - Aortic Valve Insufficiency
   - Dissecting Aortic Aneurysm

2. Relative
   - End-Stage cardiomyopathies
   - Severe Atherosclerosis
   - End-Stage Terminal Disease
   - Abdominal Aortic Aneurysms, not resected
   - Blood dyscrasias (thrombocytopenia)
### POSSIBLE COMPLICATIONS

<table>
<thead>
<tr>
<th>COMPLICATIONS</th>
<th>POTENTIAL CAUSES</th>
<th>SIGNS &amp; SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EMBOLIC</strong></td>
<td></td>
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</tbody>
</table>
| Air           | Air introduced during catheter/pressure tubing prep | • Shortness of breath  
• Chest pain  
• Alteration in ABGs  
• Symptoms depend on where emboli lodges |
| Thrombus/Plaque | • Pre-existing diseased area disturbed by catheter or guidewire  
• IAB left dormant in the aorta for too long, or pumped at a very low volume then clots are dislodged during inflation or removal of the IAB | • Chest pain  
• ECG changes  
• Neuro changes  
• Extremity pain  
• Loss of pulses |
| IAB LEAK      | • IAB membrane abrasion by repeated contact with plaque or Helium emboli  
• Fractured central lumen | • Blood in Helium driveline tubing  
• Helium loss alarms in absence of kinking, ectopy or loose connections |
| **CATHETER ENTRAPMENT** | • IAB inactive for extended periods of time increasing likelihood of clots  
• Clot formation occurs inside the base of the balloon as a result of compromised balloon integrity | • Increased resistance met while removing IAB and/or sheath  
• Surgical removal should be considered |
| **INFECTION** | • Debilitated patient is exposed to nosocomial organisms in the critical care setting  
• Poor sterile technique with insertion or dressing change | • Pain and redness at insertion site  
• Elevated temperature  
• Changes in CBC |
| **MALPOSITION** | Movement of balloon after insertion; or improper placement | • TTD HIGH:  
• Central changes induced blood flow  
• Altered mentation  
• Loss of Left radial pulse  
• Pulselessness Left arm  
• TTD LOW:  
• Decreased urine output  
• Decreased augmentation  
• Decreased bowel mobility  
• Increased Liver function tests  
• Extremity pain and paresthesia  
• Loss of pulses  
• Pain and coolness of extremity  
• Decreased sensation in affected extremity  
• Increased CPK |
| **COMPROMISED CIRCULATION** | Increased pressure within closed, non-expandable fascial space compromising enclosed tissues | • Pain in extremity  
• Decreased sensation in affected extremity  
• Increased CPK |
| **HEMATOLOGIC** | Increased bleeding due to anticoagulation | • Bleeding  
• Decrease in Hg & Hct |
| **Thrombocytopenia** | Infection and deflation of the balloon may cause destruction of red blood cells and platelets | • Increased bleeding  
• Lab value changes  
• Decrease in platelet count |

### PRE-INSERTION NURSING ASSESSMENT

All hemodynamic and physical assessment data prior to insertion should be noted accurately. The circulation to both legs should be evaluated prior to insertion to determine the best side for insertion and to establish a baseline.

**COMPLETE PRE-INSERTION ASSESSMENT WOULD INCLUDE:**
- Skin color of both legs
- Skin temperature of both legs
- Capillary refill ability of both legs
- Quality of pulses in both legs
- Baseline sensation and movement of both legs
- Ankle/brachial index of both legs
- Pre-insertion hemodynamics
- Complete neuro check
- Patient’s/family’s understanding of procedure

Ankle/Brachial Index = \( \frac{\text{Systolic pressure of dorsalis pedis}}{\text{Systolic pressure of brachial}} \)

The normal range of A/B index is 1.0 – 1.3
- Mild circulatory impairment occurs when the index is 0.80 to 0.99
- Moderate impairment is present with ranges of 0.40 to 0.79
- Severe circulatory impairment falls in the range of less than 0.40
PRE-INSERTION NURSING ASSESSMENT
REFER TO HOSPITAL PROTOCOL AND PROCEDURE MANUAL FOR INSTRUCTIONS

Instructions for the insertion of the IAB catheter are included in every package. These instructions should be reviewed prior to every insertion.

Additional supplies that will be necessary for insertion include:

- Local skin antiseptic
- Local anesthetic
- Suture material
- Sterile drapes, mask, gown, gloves and cap
- Sterile dressing materials and 4 x 4s
- Heparinized saline flush solution and 10 – 20 cc syringe to flush central lumen (refer to hospital protocol)
- Aspirate 3 – 4 mL/cc of blood and flush central lumen carefully with heparinized saline. Using current hospital protocol, connect pressure tubing extension to a prepared standard arterial pressure monitoring assembly which delivers 3 mL/cc of pressurized flush per hour.
- Pressure tubing, transducer and continuous heparin flush solution setup for balloon catheter central lumen.
- Balloon pump console with all necessary patient cables
- ECG electrodes

BALLOON SIZING

The balloon size should be chosen with respect to the patient size and BSA. Ensuring the correct balloon size relative to the patient will result in improved safety and effectiveness of balloon Counterpulsation.

Balloon sizing can be evaluated by monitoring the Balloon Pressure Waveform and the arterial pressure during inflation of the balloon. At full inflation, the plateau pressure should be within ±25 mmHg of the augmented pressure.

<table>
<thead>
<tr>
<th>IAB SIZE RECOMMENDATIONS</th>
<th>30 CC</th>
<th>40 CC</th>
<th>50 CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>147 – 162 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4’10” – 5’4”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>162 – 182 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5’4” – 6’0”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 182 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 6’0”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BSA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1.8 m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 1.8 m²</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5

Figure 12.
INSERTION PROCEDURE CHECKLIST

INTRA-AORTIC BALLOON INSERTION PROCEDURE COMPETENCY CHECKLIST

Name: _____________________________________________________________________________________  Date:______________________

<table>
<thead>
<tr>
<th>SKILL</th>
<th>YES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Balloon Sizing Recommendations</td>
<td></td>
</tr>
<tr>
<td>30 cc 4’10” – 5’4” (147 – 162 cm)</td>
<td></td>
</tr>
<tr>
<td>40 cc 5’4” – 6’ (162 – 182 cm)</td>
<td></td>
</tr>
<tr>
<td>50 cc &gt;6’ (&gt;182 cm)</td>
<td></td>
</tr>
<tr>
<td>2. Sheath Options</td>
<td></td>
</tr>
<tr>
<td>a. Sheath with sideport (requires transducer)</td>
<td></td>
</tr>
<tr>
<td>b. Sheath without sideport</td>
<td></td>
</tr>
<tr>
<td>c. Sheathless (hemostasis device available for post-insertion bleeding)</td>
<td></td>
</tr>
<tr>
<td>3. Interface Fiber Optic IAB Connections to the IABP (AutoCAT 2® System only)</td>
<td></td>
</tr>
<tr>
<td>a. Slide blue fiber optic connection in the IABP</td>
<td></td>
</tr>
<tr>
<td>b. Insert the calibration key (black key)</td>
<td></td>
</tr>
<tr>
<td>c. Verify light bulb change from blue to green</td>
<td></td>
</tr>
<tr>
<td>d. Describe how to do a manual zero</td>
<td></td>
</tr>
<tr>
<td>4. Balloon Preparation</td>
<td></td>
</tr>
<tr>
<td>a. Place IAB guidewire in the field</td>
<td></td>
</tr>
<tr>
<td>b. Attach one-way valve to gas lumen (do not remove until IAB is in position)</td>
<td></td>
</tr>
<tr>
<td>c. Pull vacuum on IAB</td>
<td></td>
</tr>
<tr>
<td>d. Keeping IAB horizontal to the table, remove it from the tray (immediately prior to insertion)</td>
<td></td>
</tr>
<tr>
<td>e. Remove the packing stylet (if present)</td>
<td></td>
</tr>
<tr>
<td>f. Flush IAB central lumen with heparinized NS solution before insertion</td>
<td></td>
</tr>
<tr>
<td>5. AP Source Fiber Optic IAB uses AutoCat 2® System only</td>
<td></td>
</tr>
<tr>
<td>a. To zero fiber optic source manually:</td>
<td></td>
</tr>
<tr>
<td>1. Press AP select to highlight fiber optic</td>
<td></td>
</tr>
<tr>
<td>2. Press soft key under “FOS ZERO”</td>
<td></td>
</tr>
<tr>
<td>b. To calibrate fiber optic source (if sensor was not zeroed prior to insertion and MAP value is erroneous):</td>
<td></td>
</tr>
<tr>
<td>1. Press AP select to highlight fiber optic</td>
<td></td>
</tr>
<tr>
<td>2. Press soft key under “FOS CAL”</td>
<td></td>
</tr>
<tr>
<td>3. Adjust FOS MAP to actual MAP (from another AP source)</td>
<td></td>
</tr>
<tr>
<td>c. To zero fluid transducer:</td>
<td></td>
</tr>
<tr>
<td>1. Press AP select to highlight Xducer</td>
<td></td>
</tr>
<tr>
<td>2. Open stopscrew to air and off to the patient</td>
<td></td>
</tr>
<tr>
<td>3. Press soft key under “TRANSDUCER ZERO” (DO NOT press CAL key)</td>
<td></td>
</tr>
<tr>
<td>d. Close stopscrew</td>
<td></td>
</tr>
<tr>
<td>6. Identify Proper IAB Positioning</td>
<td></td>
</tr>
<tr>
<td>a. 2nd to 3rd intercostal space (antero-lateral) on fluoro/X-ray</td>
<td></td>
</tr>
<tr>
<td>b. Left radial (or short) pulse present</td>
<td></td>
</tr>
<tr>
<td>c. Urine output present (if Foley in place)</td>
<td></td>
</tr>
</tbody>
</table>

NURSING CARE CONSIDERATIONS

REFER TO HOSPITAL PROTOCOL

Nursing care of the patient requiring Intra-Aortic Balloon Pump support demands the same expert skills and assessments like any other critically ill patient. Assessment and evaluation of the patient’s neurologic, respiratory, cardiovascular and renal status are important as well as the gastrointestinal and musculoskeletal systems. Assessment should be carried out with three primary goals in mind:

1. Evaluation of patient response to Counterpulsation in terms of hemodynamic status, control of arrhythmias, systemic perfusion, and relief of symptoms of cardiac ischemia.
2. Observation of early signs of complications from IABP therapy such as limb ischemia, bleeding, infection, thrombus formation, malpositioning of balloon catheter and arterial damage.
3. Ensuring proper functioning of the IABP itself including correct timing, consistent triggering, appropriate troubleshooting of all alarm situations and safe operation.

CARE OF THE CENTRAL LUMEN

The central lumen of the IAB catheter was designed for guidewire insertion and pressure monitoring. It is not advised to use the central lumen for routine blood samples.

1. Use a standard dedicated arterial pressure monitoring setup to monitor arterial pressure via the central lumen.
2. Use of heparinized saline is recommended for maintenance of central lumen unless contraindicated by patient condition, i.e., HIT.
3. Connect pressure tubing extension to a prepared standard arterial pressure monitoring assembly is recommended to maintain line patency.
4. Avoid blood sampling from the central lumen to decrease the formation of thrombosis within the central lumen.
5. If hospital policy or patient situation warrants manipulation or flushing of the central lumen, the pump console should be placed in STANDBY Mode to prevent accidental embolization to the aortic arch.
6. Arterial pressure line setup should be changed in accordance with hospital guidelines.

GENERAL ASSESSMENT GUIDELINES

• Head of bed: 15 – 30 degrees
• Check pulses to lower extremities and pedal pulses
• Check radial or brachial pulses (IAB too high)
• Monitor urine output (IAB too low)
• Monitor skin integrity (potential for skin breakdown due to immobility)
• Family and patient anxiety and stress
NURSING CARE CONSIDERATIONS

WEANING FROM THE INTRA-AORTIC BALLOON PUMP

REFER TO HOSPITAL PROTOCOL

The time for weaning and the speed with which weaning can be accomplished are dictated by the patient’s hemodynamic status.

TWO METHODS OF WEANING (USED INDEPENDENTLY OR IN CONJUNCTION WITH ONE ANOTHER)

1. Decreasing the frequency of balloon inflation. Accomplished by decreasing the frequency of assist ratio from one balloon inflation per cardiac cycle to 1:2, 1:4, and if applicable 1:8.
2. Decreasing the volume delivered to the balloon.
3. Any concerns that the patient may not be tolerating weaning should be directed immediately to the physician.

If an IAB is suspected of being occlusive, do not reduce the IAB volume to less than 2/3 of the balloon’s capacity. To prevent thrombus formation, pump the balloon at its maximum capacity for five minutes every one to two hours. A smaller IAB volume should be considered.

- 30 cc balloon should not be reduced to a volume below 20 cc.
- 40 cc balloon should not be reduced to a volume below 28 cc.
- 50 cc balloon should not be reduced to a volume below 33 cc.

BALLOON REMOVAL

IFU DIRECTIONS

• Successful removal of the IAB depends upon adequate weaning procedures and assessment of the patient, usually over a 12 hour period prior to balloon removal.
• Assess distal circulation several times before and after balloon removal.
• Periodic assessment of distal circulation is recommended, both during and after removal.
• IAB Counterpulsation.
• If distal perfusion has been compromised during Counterpulsation, or if percutaneous removal cannot be performed, surgical removal of percutaneous removal may be indicated.
• Discontinuance or reduction of anticoagulant therapy prior to balloon removal is highly recommended.

PROCEDURE

1. Carefully remove dressing from insertion site. Following standard hospital protocols, prep and drape insertion site for balloon removal. Remove all sutures and ties anchoring catheter to skin.

   Precaution: A high arterial pressure can expel balloon; hold balloon in place until ready to remove it.

2. Turn pump power/drive OFF and disconnect helium drive line from control system.

3. Apply firm digital pressure to femoral artery distal to insertion site. This will help to minimize the potential for distal embolization when catheter is removed.

4. When removing a balloon from a patient, remove balloon and hemostasis sheath introducer or hemostasis device as a unit. Do not remove the Arrow® Intra-Aortic Balloon through a hemostasis sheath introducer or hemostasis device. Once unwrapped, balloon profile will not allow passage through the introducer and attempting removal in this manner may result in arterial tearing, dissection, or balloon damage.

5. Maintaining pressure distal to arterial puncture site, allow free flow of blood to flush puncture site for several seconds. Apply firm pressure proximal to arterial puncture site, and allow retrograde blood flow to flush puncture site for several seconds more.

6. After flushing arterial puncture site thoroughly, apply firm pressure to site for 30 minutes, or until hemostasis has been achieved.

7. Check distal pulses frequently and assess for signs of complications.

8. After use, this product may be a potential biohazard. Handle and dispose of in accordance with accepted medical practice and applicable local, state, and federal laws and regulations.

In cases where a leak in the IAB is suspected, extreme caution must be exercised during removal. If resistance is met during IAB catheter removal, the percutaneous removal procedure should be discontinued and surgical removal via arteriotomy employed.

Post removal care includes:
• Continual assessment of circulation to the cannulated extremity.
• Monitoring and recording of peripheral pulses.
• Circulatory status of the cannulated extremity should be checked per hospital policy.
TRANSPORTING A PATIENT WITH AN IABP TO OFFSITE FACILITY

1. Inform ambulance or air transport company that you are transferring a patient with:
   - IABP
   - Ventilator and other medical or life-supporting devices
   - Number of infusion pumps
   - Be sure transport vehicle or aircraft is large enough to accommodate all equipment
   - Ask if vehicle is equipped with an inverter to supply power to IABP

2. Confirm that bed at accepting facility is ready and determine which IABP the receiving facility is using.

3. Check IABP battery indicator light
   - Amber LED indicates at a minimum of 80% charged

4. Have an IABP Transport Bag with the following suggested items:
   - 60 cc slip-tip syringe
   - Appropriate IAB/IABP adapters
   - Kelly clamp
   - ECG patches
   - Extra helium tank
   - ECG cable and arterial pressure cable
   - IABP flow sheet

5. Secure the IABP in ambulance or aircraft. (See FAA regulations for aircraft.)

6. Verify that balloon catheter is secured.

7. Check that catheter is sutured or securely taped in place

WEIGHT – AERO® AUTOCAT®2 SYSTEM

<table>
<thead>
<tr>
<th></th>
<th>WAVE</th>
<th>NON-WAVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Module</td>
<td>5 lbs</td>
<td>5 lbs</td>
</tr>
<tr>
<td>Pump Console</td>
<td>86.5 lbs</td>
<td>85 lbs</td>
</tr>
<tr>
<td>Total Operational Weight</td>
<td>91.5 lbs</td>
<td>90 lbs</td>
</tr>
</tbody>
</table>

DIMENSIONS

<table>
<thead>
<tr>
<th></th>
<th>SAME FOR BOTH MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>25.5 inches</td>
</tr>
<tr>
<td>Width</td>
<td>13.5 inches</td>
</tr>
<tr>
<td>Depth</td>
<td>21.5 inches</td>
</tr>
</tbody>
</table>

Table 1

AIR TRANSPORT CONSIDERATIONS

Altitude changes

- As altitude increases, the partial pressure of oxygen decreases.
  - Results in reduction of the alveolar partial pressure of oxygen.
    - A PaO2 of 100 mmHg at sea level will decrease to 81 mmHg at 5,000 ft, and 45 mmHg at 15,000 ft.
    - Above 15,000 ft the cabin is pressurized where PaO2 is more normally maintained.
    - Helicopters are usually not pressurized. They must fly within 0 – 10,000 ft where the body can adapt.

- Increased altitude predisposes the patient to hypoxia. Check patient’s ABGs and hemoglobin.
  Oxygen should be administered to:
    - All patients at altitudes over 5,000 ft.
    - All cardiac patients.
    - All patients in shock or impending shock.

  - Watch for an increase in HR, dysrhythmias or change in hemodynamics which may necessitate operator intervention.

ASCENT CHANGES

- It is common for BP to decrease slightly on ascent. The patient may require additional volume or vasopressor support to maintain adequate filling pressures.
  - Altitude increases cause an inversely proportional decrease in barometric pressure (Boyle’s Law).
    - A mass of gas will expand as altitude increases. A gas volume of 1.0 at sea level will expand to 1.4 at 8,000 ft and 2.1 at 18,000 ft. The helium volume in the IAB will increase in size during ascents.
    - Helium has potential to cross the IAB membrane and enter the patient’s blood system if a leak occurs.
    - Always operate IABP with gas alarms active.

  - During ascent, the console will auto vent for altitude changes.
    - AutoCAT® 2/AutoCAT 2WAVE® Intra-Aortic Balloon Pump:
      Possible alarms: If the balloon pressure baseline is >+25 mmHg, a High Baseline alarm will occur. A High Pressure alarm will occur if the plateau of the balloon pressure waveform is over 250 mmHg. If either condition occurs, the pump will go from Pump Status ON to Pump Status OFF. This vents the helium out of the system. Operator then resets alarm and reinitiates pumping by going to Pump Status ON.

DESCENT CHANGES

- Helium volume will shrink during descent. During gradual descents, the console’s beat-to-beat autofill refills the system as the gas volume decreases. During rapid descents, if the pump is required to autofill too many times in 1–2 minutes, the pump will alarm.
  - AutoCAT® 2/AutoCAT 2 WAVE® Intra-Aortic Balloon Pump:
    Possible alarm: Helium Loss. The pump has seen the BPW drop below 10 mmHg. The pump goes from Pump Status ON to Pump Status OFF. This vents the helium out of the system. The operator then resets the alarm and reinitiates pumping by going from Pump Status OFF to Pump Status ON.
TRANSPORTING A PATIENT WITH AN IABP TO OFFSITE FACILITY

FIBEROPTIX® IAB CATHETER PATIENT TRANSPORT CONSIDERATIONS

Managing patients with a fiber-optic balloon catheter during transport is generally the same as when they have a conventional balloon catheter. Some special considerations include:

1. To utilize the fiber optics, the catheter must be connected to a balloon pump that accepts the fiber-optic connection.
2. The fiber-optic sensor should be zeroed prior to insertion to have the most accurate hemodynamic readings. If the sensor was not zeroed and the pressures are in question, manual calibration should be considered.
3. During transport it may be necessary to disconnect the fiber-optic balloon catheter from the pump for a brief time to reposition the patient or position equipment in and out of the vehicle.
   • If the fiber-optic catheter has been zeroed, the fiber-optic connector and calibration key may be disconnected and reconnected without losing the zero information – must be connected to the same console.
4. It is recommended that the fiber-optic cable be taped along the gas drive tubing of the balloon catheter to protect against stretching, pulling or other damage to the fiber-optic cable.
5. Above 10,000 ft fiber-optic pressures may not be accurate or signal may be lost. It is advisable to use an alternative pressure monitoring source.

TIMING ELEMENTS/GOALS OF THERAPY

The precise timing of balloon inflation and deflation is essential to achieve the desired hemodynamic effects.

GOALS OF BALLOON PUMP THERAPY:
1. Increase coronary blood flow.
2. Decrease the workload of the heart.

TIMING ELEMENT TOPICS

• Cardiac cycle relative to the augmented waveform caused by balloon inflation and deflation.
• Landmarks in the arterial pressure waveform that identify proper timing.
• Timing examples from various arterial sites.

ARTERIAL PRESSURE MONITORING SITES & AP TRANSMISSION DELAYS FROM CONVENTIONAL TRANSDUCERS

Central aortic AP is the recommended site.
TIMING ELEMENTS/GOALS OF THERAPY

ARTERIAL PRESSURE WAVEFORM

Landmarks

The IABP is a volume displacement device that affects the cardiovascular system in a mechanical manner. In order to evaluate the proper timing of inflation and deflation, the physical characteristics of the unassisted and assisted arterial pressure waveform must be assessed. Timing of the IABP is always performed using the arterial pressure waveform as the guide.

<table>
<thead>
<tr>
<th>ACRONYM</th>
<th>TITLE</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC</td>
<td>Isovolumetric Contraction</td>
<td>PEP = Pre Ejection Phase</td>
</tr>
<tr>
<td>AVO</td>
<td>Aortic Valve Opens</td>
<td>Beginning of Systole</td>
</tr>
<tr>
<td>DIA</td>
<td>Diastolic Pressure</td>
<td>AEDP = Aortic end diastolic pressure</td>
</tr>
<tr>
<td>SYS</td>
<td>Systolic Pressure</td>
<td>PSP = Peak Systolic Pressure</td>
</tr>
<tr>
<td>DN</td>
<td>Dicrotic Notch</td>
<td>Signifies aortic valve closure and beginning of diastole</td>
</tr>
</tbody>
</table>

The onset of systole first begins with the IVC phase. The IVC phase occurs milliseconds before the upstroke on the arterial pressure waveform. The aortic valve opens when the pressure in the left ventricle (LV) exceeds the pressure in the aorta. Rapid ejection occurs and the ventricle delivers 75% of its stroke volume. The pressure generated is the peak systolic pressure (PSP or SYS). After the Systolic Pressure, flow velocity declines until the pressure in the ventricle falls below the pressure in the aorta, and the aortic valve closes (DN).

ASSISTED ARTERIAL PRESSURE: 1:2 RATIO

<table>
<thead>
<tr>
<th>ACRONYM</th>
<th>TITLE</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUG</td>
<td>Augmentation</td>
<td>Also called Peak Diastolic Pressure (PDP)</td>
</tr>
<tr>
<td>DN</td>
<td>Dicrotic Notch</td>
<td>Signifies aortic valve closure and beginning of diastole</td>
</tr>
</tbody>
</table>

The onset of systole first begins with the IVC phase. The IVC phase occurs milliseconds before the upstroke on the arterial pressure waveform. The aortic valve opens when the pressure in the left ventricle (LV) exceeds the pressure in the aorta. Rapid ejection occurs and the ventricle delivers 75% of its stroke volume. The pressure generated is the peak systolic pressure (PSP or SYS). After the Systolic Pressure, flow velocity declines until the pressure in the ventricle falls below the pressure in the aorta, and the aortic valve closes (DN).
TIMING ELEMENTS/GOALS OF THERAPY

INFLATION TIMING

Inflation goal:
1. Increase myocardial oxygen supply
2. 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 symbol representing aortic valve closure. Inflation should occur just prior to the dicrotic notch. The result of properly timed inflation is a pressure rise, augmentation (AUG), during diastole. The AUG influences the gradient for coronary artery perfusion.

CORRECT INFLATION: JUST PRIOR TO THE DICROTIC NOTCH

The AUG should be higher than the SYS unless:
1. Patient’s stroke volume is significantly higher or lower than the balloon volume.
2. Balloon position too low.
3. Severe cases of hypovolemia.
4. Balloon is too small for patient’s aorta.
5. Low SVR.
6. Improper timing.
7. Catheter partially kinked, in sheath, not unwrapped.
8. IABP delivered volume too low (IABP setting).

DEFLATION TIMING

Deflation goal:
1. Decreased myocardial oxygen demands
2. Increased stroke volume

Accomplishing the goals of deflation requires the assessment of the assisted and unassisted pressure values on the 1:2 assisted arterial pressure waveform.

Correct Deflation: ADIA ≤ DIA
ASYS < SYS

Balloon deflation during the IVC phase of systole causes a reduction in pressure immediately preceding ventricular ejection. This pressure reduction is represented by the assisted diastole (ADIA). For effective afterload reduction, Using Predictive Deflation the ADIA must be lower than the patient’s own unassisted aortic end diastolic pressure (DIA). The following systole (ASYS) 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 SYS. The result of properly timed balloon deflation should be:
1. (ADIA ≤ DIA)
2. (ASYS < SYS)

In R-Wave Deflation, the ADIA may = DIA or may be slightly higher than the angle of deflation, which will still be correct unless the slope of the systolic upstroke changes or the ASYS is severely lower than SYS.
TIMING ELEMENTS/GOALS OF THERAPY

AFTERLOAD REDUCTION
Aside from improper timing, poor afterload reduction may be caused by:

1. Balloon not inflated to full volume causing a decrease in volume displacement.
2. Compliant aortic wall which allows for only small changes in volume.
3. Improper balloon placement.
4. Partial obstruction of gas lumen.

ERRORS IN TIMING

Timing errors can occur in the following manner: inflation, deflation or combination thereof.

**EARLY INFLATION**

- Inflation has prematurely started prior to aortic valve closure (DN)
- Rule #1: Inflate just prior to DN which should result in AUG>SYS

**LATE INFLATION**

- Diastole has already started – the major effect of Late Inflation is suboptimal coronary perfusion
- This is indicated by the presence of the dicrotic notch between the SYS and the AUG

Hemodynamic effect
- Premature closure of aortic valve
- Decreased stroke volume/CO
- Compromised stroke volume adds to the next beat’s preload
- Increased preload causes an increase in left ventricular wall tension, the single most determinant of myocardial oxygen consumption

**Figure 21.**

**Figure 22.**

**Figure 23.**
**ERRORS IN TIMING**

**LATE DEFLATION**

- The balloon remains inflated when ventricular ejection is occurring
- The ventricle is now ejecting against a higher pressure
- Rule #2 ADIA < DIA

**Early Deflation**

- The balloon has deflated during diastole
- Rule #3 ASYS < SYS

**Hemodynamic effect**

- Increased workload to the left ventricle and increased MVO$_2$
- Possible decreased Cardiac Output and increased PCWP

---

**TIMING GUIDELINES**

**Inflation**

Goal: To produce a rapid rise in aortic pressure (optimize AUG), thereby increasing O$_2$ supply to coronary circulation.

Rule: 1. Inflate just prior to DN which should result in AUG > SYS

**Deflation**

Goal: To reduce aortic end diastolic pressure (afterload) thereby decreasing MVO$_2$ while improving the CO (cardiac output).

Rule: 2. ADIA < DIA
3. ASYS < SYS

---

**Figure 24.**

**Figure 25.**

**Figure 26.**
TIMING EXERCISES

The augmented arterial pressure waveform becomes familiar after the operator has practiced identification of pressure landmarks. The evaluation of the pressure waveform should be an orderly process. Use of the “Timing Guidelines” will greatly aid in the diagnosis of proper/improper timing. The speed of evaluation will increase as the operator gains experience and is exposed to patient simulations. To gain mastery, the operator must practice. These timing exercises are included to give the learner the opportunity to develop their own process of analysis and gain familiarity.

1. _______________________________________________________________________________________________________________
   Define Improper Timing
   Explain Hemodynamic Effect

2. _______________________________________________________________________________________________________________
   Define Improper Timing
   Explain Hemodynamic Effect

3. _______________________________________________________________________________________________________________
   Define Improper Timing
   Explain Hemodynamic Effect

4. _______________________________________________________________________________________________________________
   Define Improper Timing
   Explain Hemodynamic Effect

5. _______________________________________________________________________________________________________________
   Define Improper Timing
   Explain Hemodynamic Effect
TIMING EXERCISES

6. Define Improper Timing
   Explain Hemodynamic Effect

7. Define Improper Timing
   Explain Hemodynamic Effect

8. Define Improper Timing
   Explain Hemodynamic Effect

9. Define Improper Timing
   Explain Hemodynamic Effect

10. Define Improper Timing
    Explain Hemodynamic Effect

Bonus Question
ARRHYTHMIA TIMING ON THE IABP

If the patient develops an arrhythmia, conventional timing algorithms may have difficulty maintaining consistent, appropriate inflation/deflation. “Real Timing” (true R-Wave deflation) or “Arrhythmia Timing” modes may result in more efficient deflation timing. Inflation timing is set as usual in these modes; however, deflation of the balloon is automatic once the next systolic cycle is identified. The major benefit is having the full diastolic augmentation thus enhancing perfusion and minimizing the potential negative effects of early and/or late deflation.

WAVE® TECHNOLOGY

Difference between Fiber-Optic Arterial Pressure Signal and Transducer

The Fiber-Optic AP signal produces a high fidelity waveform that transmits the arterial pressure at the speed of light. Since the fiber-optic AP waveform is a real time signal, there is virtually no delay.
WAVE INFLATION TIMING

Windkessel Aortic Valve Equation (WAVE) is exclusive to the AutoCAT 2 WAVE® IABP in AutoPilot™ Mode when the FiberOptix® Signal is present and selected. The fiber optic arterial pressure signal is converted to an aortic flow signal by an algorithm within the pump. The aortic flow waveform is then used to set inflation of the balloon in synchrony with Aortic Valve closure on a beat to beat basis.

This method allows intra-beat timing of inflation and is especially important for patients experiencing arrhythmia, as conventional (predictive) timing algorithms may not maintain consistent and appropriate timing.

- Flow wave calculated from the aortic pressure wave
- Dicrotic notch occurs at peak negative flow
- Dicrotic notch detection occurs at approximately 15% of descending peak flow
- Results in real time, intra-beat inflation timing

Figure 40.

MODES OF OPERATION

AUTOPILOT™ MODE

In AutoPilot™ Mode the console selects the ECG source, AP source, trigger and timing utilizing the Proprietary Best Signal Analysis:

1. Console scans all available ECG leads continuously. If the current ECG lead selected is lost or distorted, the console will select another available lead. If another lead is significantly better for triggering than the current lead, the pump will change leads. If the clinician desires, he/she can change the ECG lead, source, or gain.

2. AP source [FOS]/Transduced/MON AP will be selected by the console however it can be changed by the clinician. If the FiberOptix® Sensor [FOS] arterial pressure is connected, (sensor and calibration key intact), Autopilot™ Mode will default back to FOS as AP source. If FOS is not connected and the user switches between Transduced/MON, the pump will utilize AP source as selected as long as signal is present.

3. Console selects the most appropriate trigger based on patient condition, rhythm, or arrhythmia and rate.

4. All timing settings and adjustments are under control of the console.

OPERATOR MODE

If, at any time, the clinician prefers to take control of trigger selection or timing this can be accomplished by selecting OPERATOR mode.

In Operator mode, the clinician makes all the choices regarding ECG source and lead, AP source, triggering, and timing. Once the initial timing is set, the console will automatically adjust for changes in heart rate +/- 10%.
MODES OF OPERATION

ADJUSTING TIMING (IN OPERATOR MODE)

Timing is established using two separate controls that move the timing markers to the left and right. The inflate and deflate controls are located on the sides of the pump control panel.

INFLATE CONTROL:
Moved to the left to adjust the inflate time to occur earlier and to the right to occur later.
Left = Earlier
Right = Later

DEFLATE CONTROL:
Moved to the left to adjust the deflate time to occur earlier and to the right to occur later.
Left = Earlier
Right = Later

The efficiency of Intra-Aortic Balloon Pumping depends on the accuracy of the inflate and deflate timing settings. It is imperative that the operator fully understand the hemodynamic signs of proper timing and the adverse effects of improper timing.

TRIGGERING

What is Triggering?
• A signal to the IABP computer indicating where the patient’s cardiac cycle begins and ends

Trigger Options
1. R-Wave (ECG) – Preferred option for most cases
2. Arterial Pressure Waveform
3. Pacing Spike

Patient Signal Connections
• Direct connections are always best
• Delays are introduced when a signal connection via monitor to IABP
• Signals may be distorted due to ‘filtering’ by monitoring software
MODES OF OPERATION

TRIGGERS

1. ECG Pattern
   Pattern analyzes the height, width and slope of a positively or negatively deflected QRS complex. The width of the R-Wave must be between 25 – 135 ms. Widened QRS complexes may not be recognized, such as bundle branch blocks. Rejection of pacer spikes is automatic. This is the AutoPilot™ Mode’s trigger of choice when the rhythm is regular, the HR is less than 130 bpm and the QRS complex is normal width.
   AutoPilot™ Mode: HR < 130 and no arrhythmia.

2. ECG Peak
   Peak analyzes the height and slope of a positively or negatively deflected QRS complex. Rejection of pacer spikes is automatic. This is the AutoPilot™ Mode’s choice when the rhythm is regular and the QRS is wide or the HR is greater than 130 bpm. AutoPilot™ Mode will select PEAK. Also select Peak if the rhythm is irregular and ARRHYTHMIA TIMING is turned OFF or if the rhythm is irregular and AutoPilot™ Mode has determined that R-wave deflation is not appropriate for this patient.

3. AFIB
   AFIB analyzes the QRS in the same manner as Peak mode. Deflation cannot be controlled by the operator as the balloon will automatically be deflated whenever an R-Wave is sensed. Rejection of pacer spikes is automatic. This is the AutoPilot™ Mode’s choice when a rhythm is irregular and ARRHYTHMIA TIMING is ON and R-Wave DEFLATE ON has been selected.

4. AP
   Arterial pressure trigger uses the systolic upstroke of an arterial pressure waveform as the trigger signal. It is not recommended for irregular rhythms. AutoPilot™ Mode will choose this trigger when there are no QRS complexes seen or there is artifact/noise on the ECG signal.

5. VPACE
   VPACE utilizes the ventricular spike as the trigger signal. This mode may be used with V or AV paced rhythms. Because the pump will only initiate an inflate/deflate cycle when a ventricular spike is sensed, it is ESSENTIAL that the patient’s rhythm be 100% paced. AutoPilot™ Mode will only choose this trigger if there are no QRS complexes or arterial pressure waveforms seen and pacer spikes are present.

6. APACE
   APACE uses the atrial pacing spike as the trigger signal. This mode can only be used with 100% atrial paced rhythms. AutoPilot™ Mode will select this mode when an ECG or AP is present but not stable and the pacier is more than 100 ms before the R-wave on the ECG.

7. Internal (Operator Mode only)
   The balloon inflates and deflates at a preset rate regardless of the patient’s cardiac activity. This mode is only to be used in situations where there is no cardiac output and no ECG, such as cardiopulmonary bypass. The preset rate is 80 bpm and may be adjusted in increments of 5 bpm with range between 40 and 120 bpm. Selection of this trigger is only available in Operator mode and must be confirmed by an additional keystroke. AutoPilot™ Mode will NEVER choose this trigger.

To access triggers and adjust timing, the pump must be in Operator mode.

1. Press the TRIGGER key.
2. Select the desired trigger mode by pressing the soft key under that trigger.

USE OF THE IABP DURING CARDIAC RESUSCITATION

In the event of a cardiac arrest in a patient while on the IABP, the loss of the ECG and Arterial Pressure wave will result in a loss of the trigger signal to the IABP. This will generally cause a trigger loss alarm and stop Counterpulsation.

If Counterpulsation is to be continued and synchronized to the CPR effort:
   • The Pump should remain on AutoPilot™ Mode in 1:1 assist to optimally support CPR effort.
   • Regardless of the ECG rhythm, disconnect the ECG source and commence CPR. Pump will automatically select AP as the trigger.
   • If the pump is in AutoPilot™ Mode, once sufficient pressure is generated during CPR, AP trigger will automatically be selected and pumping will resume. If AP trigger does not produce a trigger, you may select Operator Mode and use the Internal trigger.
   • If the pump is in OPERATOR Mode, press the Trigger key and select AP.

WARNING: Internal trigger should not be used when the patient has intrinsic cardiac activity. This can cause incorrect timing which may impair patient hemodynamics. Once the ECG or Arterial Pressure signal has been reestablished, the trigger mode must be changed from INTERNAL to an acceptable patient trigger.
**MODES OF OPERATION**

**INITIATION OF PUMPING**

1. **Power On** – Turns power on the pump.
   - AC power – Pump should be plugged directly into AC outlet.
   - Battery power – Amber LED light indicator denotes at least 80% charged.

2. **Patient Connections**
   - **ECG** – Proprietary Best Signal Analysis automatically selects the best quality lead to utilize when in AutoPilot™ Mode.
     - 5 Lead ECG
     - Direct skin lead connection to the pump
     - Pump automatically gains/sizes ECG signal
   - **Monitor**
     - Utilizes monitored ECG signal from alternative monitor source.
     - In use when Skin ECG not available
     - Pump automatically gains signal
     - No option to select lead on IABP. Lead must be changed on the source monitor.
   - **Change Lead/ECG Gain Options**
     - AutoPilot™ Mode will change lead if the selected ECG source becomes lost or unavailable.
     - Press ECG SELECT once. Press key under desired LEAD label. To select an alternate lead II/AVL, press the key under the desired lead again.
     - To switch gain mode press key under desired label. DECREASE/INCREASE GAIN keys can be used with AUTO or MANUAL GAIN. The GAIN change is only valid until lead is changed.

2. **Patient Connections**
   - **Arterial Pressure**
     - BEST OPTION via FiberOptix® Signal
     - FOS will automatically be selected when available and will override the priority of the user.
   - **Helium Driveline**
     - Connect color coded helium driveline to IABP securely and verify appropriate volume on console screen

**CONNECT BLUE SENSOR AND CAL KEY PRIOR TO INSERTION**

- If an alternative AP source selection is desired, the AP FOS must be disconnected from the pump.
  - Connection noted with two audible tones
  - Verify Auto Zero via audible tone, green light bulb, and AP FOS Zeroed message appears.
  - Transduced Central Lumen (Conventional Fluid Filled Method)
  - Select transducer cable
  - Connect to pump
  - Press AP select to highlight transducer
  - Level at phlebostatic axis
  - Zero Transducer – Press AP Select
    - Open transducer to air
    - Press soft key under transducer zero
    - Once zeroed, close transducer, verify waveform
  - Monitor/Phono to phono cable
    - In use when no other AP waveform is connected to the pump or when selected by the user.
  - **AP SELECT**
    - This softkey provides selection for AP SOURCE, SCALE AP ALARM, ZERO and CAL.
    - This key can be used in either AutoPilot™ Mode or Operator mode. If an alternate AP source is selected while the FOS is connected, AutoPilot™ Mode will automatically select FiberOptix® Mode and which will be confirmed by lit LED on screen (AP)
    - To change scale, set AP alarm, zero or calibrate, press AP SELECT once. Press softkey under desired label to select function.
  - **Helium Driveline**
    - Connect color coded helium driveline to IABP securely and verify appropriate volume on console screen
MODES OF OPERATION

3. Pump On – Press green ON button
   • Verify the following Start Up processes before pressing the ON key:
     □ Flashing Heart Icon – upper right corner
     □ Valid Trigger Identified
     □ Correct IAB volume displayed
     □ Adequate helium displayed – lower right corner
   • The first time ON is pressed after power up, the pump will:
     □ Fill the drive with helium
     □ Perform one purge cycle followed by nine mixing beats
     □ This will be repeated twice to optimize the helium concentration in the IAB
     □ Pumping will then continue uninterrupted

FiberOptix® ZERO
The fiber-optic sensor (FOS) will automatically zero if connected to the IABP PRIOR to Insertion
average time: approximately 10 – 15 seconds.
If the FOS does not automatically zero prior to catheter being inserted into patient, perform the following:
1. Press AP select once.
2. Press softkey under FOS for ZERO.
3. Verify green light display and AP FOS Zeroed message appears.

Fiber Optic Mean Arterial Pressure Calibration (FOS MAP CAL)
If the FOS was not zeroed before insertion (Now in situ in patient), the FOS MAP must be adjusted to match the pressure
from a transduced arterial line.
   • Obtain MAP from reliable, alternate AP source (i.e., Center Lumen)
   1. AP select
      • Press FOS MAP CAL
      • Adjust FOS MAP in increments of 5 mmHg to value of known MAP
      • FOS icon will automatically change to color white
      • Light bulb will not go back to green or blue if the CAL is returned to zero

BALLOON PRESSURE WAVEFORM
The Balloon Pressure Waveform (BPW) represents the helium movement between the console and the IAB catheter. It is
displayed as a calibrated, continuous waveform which allows objective assessment of IAB inflation and deflation.

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

BPW Variations due to Heart Rate
The BPW width reflects the duration in which the IAB is inflated and will change with the patient heart rate and rhythm.

Tachycardia
Bradycardia
Irregular Rhythm (AFIB)
MODES OF OPERATION

BPW VARIATIONS DUE TO AORTIC PRESSURE

The balloon pump must overcome the pressure within the aorta to fill the balloon with helium. The BPW height reflects pressure within the aorta when the balloon is inflated and will change with the patient pressures.

Since the balloon material is very compliant, the pressure on either side will be approximately the same. Therefore, the Balloon plateau pressure on (time the IAB is inflated) the BPW should be within ±20–25 mmHg of the AUG pressure on the arterial pressure waveform.

Incorrect Balloon size

A difference of greater than ±20–25 mmHg between the plateau pressure on the BPW and the AUG pressure may indicate incorrect size of the balloon.

Alarms and Alerts

An alarm may cause the IARP to stop pumping. The pump will display a message on the screen to assist in troubleshooting. If the alarm reappears consistently, refer to the Operator’s Manual for further information. The Arrow® IABP support line, 800–447–IABP, may also be utilized for troubleshooting assistance.

Once the condition is corrected, to resume pumping:
1. Press alarm RESET.
2. Press pump ON.
MODES OF OPERATION

CLASS 3 ALERTS
The following Class 3 Alerts inform you of a less serious condition that may not require immediate attention. Class 3 Alerts will cause the AutoCAT®2 Series IABP:

1. Initiate audio alarm
2. Display an alarm message
3. Pumping is not interrupted

AP SIGNAL
- AP FOS Signal Weak
- AP FOS Sensor out of Range
- AP FOS CAL key missing or corrupt
- AP Alarm
  - AP has fallen below set limit

TRIGGER/TIMING
- Operator mode – Timing Error
- Deflate Marker past 100%
- Possible ECG Trigger Detected
  - QRS complex detected while in INTERNAL mode

BATTERY
- Battery Inoperative
- System running on Battery Power
- Available Battery Power less than 20, 10, 5 minutes

HELIUM
- Low Helium Tank Pressure
  - Helium tank is empty or turned off

OTHER
- Weaning Step complete
- Drain Failure
  - Condensate bottle full
  - Drain tubing kinked
  - Drain valve failed to open. Initiate purge cycle by pressing pump OFF then ON to resume pumping. Replace IABP console as needed.

CLASS 4 ALERTS
The following Class 4 Alerts inform you of a less serious condition that may not require immediate attention. Class 4 Alerts will cause the AutoCAT®2 Series IABP to:

1. Display an alarm message
2. Pumping is not interrupted

TRIGGERING/TIMING
- Possible Late Deflation
  - If R-Wave deflation is too late, Press Arrhythmia timing and Press R-Wave deflation OFF. This will disable Automatic R-Wave deflation
  - If in AutoPilot™ Mode, select Operator mode and manually select the Trigger mode and manually adjust timing
- Erratic triggering
  - Check ECG signal and ensure the ECG signal is stable. Replace ECG lead pads as needed to ensure good skin contact
  - Select an alternative ECG lead or Trigger mode
- No ECG Signal Available
  - If in AutoPilot™ Mode, will select AP, no immediate user intervention required, however having no ECG signal limits AutoPilot™ Mode selections so the ECG signal should be re-established when possible
  - No AP Signal Available
    - If in AutoPilot™ Mode, will select ECG, no immediate user intervention required, however having no AP signal limits AutoPilot™ Mode selections for trigger and may result in reduced timing effectiveness so an AP signal should be re-established when possible
- ECG lead fault
  - If in AutoPilot™ Mode, will select alternative ECG lead or AP, no immediate user intervention required.
  - Reconnect ECG leads when possible
  - This indicates that ECG signal is noisy. Ensure ECG signal quality is acceptable and triggering is consistent
- Arrhythmia Timing not Available
  - Arrhythmia Timing not available alarm will be initiated when IABP in AutoPilot™ Mode, compounded by noise on ECG and there is no AP signal. IABP will automatically select Pattern as trigger of choice
  - Check timing. If R-Wave deflation is desired, turn Arrhythmia Timing ON
  - Select Operator mode and select an alternative trigger mode

BATTERY – CLOCK BATTERY NOT CHARGED
- When therapy is complete, contact field service/Biomedical Engineering Department
- Warning: Low battery for static RAM
- When therapy is completed, call field service/Biomedical Engineering Department
**PUMP OPERATIONS**

### SKILL

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### ALARMS

| 1. Verify Alarms On | 1. Verify Alarms On |
| 1. Verify Alarms On | 1. Verify Alarms On |

### HELIUM

| 1. Verify Alarms On | 1. Verify Alarms On |
| 1. Verify Alarms On | 1. Verify Alarms On |

### CONDENSATION BOTTLE

| 1. Empty Condensation Bottle | 1. Empty Condensation Bottle |
| 1. Empty Condensation Bottle | 1. Empty Condensation Bottle |

### BATTERY

| 1. Initiate Battery Operation | 1. Initiate Battery Operation |
| 2. Assess level of battery charge | 2. Assess level of battery charge |

### BALLOON VOLUME

| 1. Adjust Balloon Volume | 1. Adjust Balloon Volume |
| 1. Adjust Balloon Volume | 1. Adjust Balloon Volume |

### AUTOPILOT™ MODE

| PUMP ON | PUMP ON |
| 1. Power cord connection | 1. Power cord connection |
| 1. Power cord connection | 1. Power cord connection |

### PATIENT CONNECTIONS

| 1. ECG cable | 1. ECG cable |
| 2. FiberOptix® Connection | 2. FiberOptix® Connection |
| 3. Transducer Connection | 3. Transducer Connection |
| 4. Balloon gas drive line | 4. Balloon gas drive line |

### INITIATE PUMPING

| 1. Press ON | 1. Press ON |
| 2. AutoPilot™ Mode | 2. AutoPilot™ Mode |

### OPERATOR MODE

| ACTIVATE APPROPRIATE TRIGGER FOR | ACTIVATE APPROPRIATE TRIGGER FOR |
| 1. Clean ECG, QRS Normal, Rate 90 | 1. Clean ECG, QRS Normal, Rate 90 |
| 2. Clean ECG, QRS Wide, Rate 110 | 2. Clean ECG, QRS Wide, Rate 110 |
| 3. Noisy ECG with Expected Interference | 3. Noisy ECG with Expected Interference |
| 4. Irregular Rhythm | 4. Irregular Rhythm |
| 5. CPR | 5. CPR |

### PACEMAKER-FIXED RATE

| 1. Atrial Pacemaker-Fixed Rate | 1. Atrial Pacemaker-Fixed Rate |
| 2. AV Sequential | 2. AV Sequential |

### TIMING

| 1. Assess Inflation and Deflation adjust as necessary | 1. Assess Inflation and Deflation adjust as necessary |
MULTIPLE CHOICE DIRECTIONS

Read each item below, and circle the letter of the correct response(s). More than one response may be correct.

1. Preload is the:
   a. Impedance against which the left ventricle must pump.
   b. Pressure of volume in the ventricle at the end of diastole.
   c. Aortic root pressure.
   d. Peripheral vascular resistance.

2. Afterload is the:
   a. Impedance against which the left ventricle must pump.
   b. Pressure or volume in the ventricle at the end of diastole.
   c. Ability of the myocardial fibers to stretch.
   d. Same as the pulmonary artery wedge pressure.

3. The major physiological effects of Counterpulsation include:
   a. Increased coronary artery perfusion, increased preload, decreased afterload, and decreased myocardial oxygen consumption.
   b. Increased coronary artery perfusion, increased preload, increased afterload, and decreased myocardial oxygen consumption.
   c. Increased coronary artery perfusion, decreased preload, decreased afterload, and increased myocardial oxygen consumption.
   d. Increased coronary artery perfusion, decreased preload, decreased afterload, and decreased myocardial oxygen consumption.

4. Coronary artery perfusion occurs predominantly during:
   a. Ventricular systole.
   b. Isovolumetric ventricular contraction.
   c. Reduced ventricular ejection.
   d. Ventricular diastole.

5. During isovolumetric contraction:
   a. Mitral valve is open.
   b. Coronary artery perfusion occurs.
   c. 90% of myocardial oxygen consumption occurs.
   d. Aortic valve is open.
6. Contraindications to balloon pumping include:
   a. Aortic valve insufficiency.
   b. Mitral valve incompetence.
   c. Dissecting aortic aneurysm.
   d. Dissecting thoracic aneurysm.
   e. Pre-infarction angina.
   f. Coronary artery disease.

7. List four medical or surgical indications for using the balloon pump.
   a. __________________________
   b. __________________________
   c. __________________________
   d. __________________________

8. List two possible complications of IAB insertion or pumping.
   a. __________________________
   b. __________________________

9. Insertion of the Intra-Aortic Balloon Pump should be halted immediately if the patient complains of:
   a. Numbness in the affected leg.
   b. Back pain.
   c. Pressure at the insertion site.
   d. Chest pain.

10. The Intra-Aortic Balloon Pump ________________ at the onset of diastole.
    (Inflates/Deflates)

11. The Intra-Aortic Balloon Pump ________________ at the onset of systole.
    (Inflates/Deflates)

12. The most commonly used tracing for triggering the balloon pump to inflate and deflate is the __________________________

13. The only tracing representing the mechanical events in the heart used to accurately time balloon inflation and deflation is the __________________________

14. When timing the Intra-Aortic Balloon Pump, the assist interval to use is:
   a. 1:1
   b. 1:2
   c. 1:4
   d. 1:8

15. The dicrotic notch on the arterial waveform reflects:
   a. Systolic ejection.
   b. Isovolumetric contraction.
   c. Aortic valve opening.
   d. Aortic valve closure.

16. Some of the desirable effects that can be expected from proper timing are:
   a. Decrease in afterload.
   b. Decrease in ppcwp.
   c. Increase in preload.
   d. Increase in lsv.
   e. Increase in co.
   f. Increase in heart rate.
   g. Increase in systemic pulsatile pressure.

**Matching Directions**
Place the letter from the diagram below next to their correct descriptions at the left.

17. Arterial Pressure Tracing

   1. Peak systole (patient).
   2. Patient aortic end diastole.
   3. Balloon aortic end diastole.
   4. Dicrotic notch.
   5. Peak diastole.
   6. Assisted systole.
18. Identify timing alterations in the arterial pressure tracing below and indicate their detrimental hemodynamic effects.

Timing = 
Hemodynamic Effect = 

19. Identify timing alterations in the arterial pressure tracing below and indicate their detrimental hemodynamic effects.

Timing = 
Hemodynamic Effect = 

20. Late inflation of the balloon can result in:
   a. Premature augmentation.
   b. Increased augmentation.
   c. Decreased augmentation.
   d. Increased coronary perfusion.

21. Late deflation of the balloon can result in:
   a. Increased myocardial oxygen consumption.
   b. Premature closure of the aortic valve.
   c. Decreased afterload.
   d. Increased afterload.

22. Label the parts of the balloon pressure waveform:

23. A rounded balloon pressure waveform can indicate:
   a. Helium leak.
   b. High pressure.
   c. Balloon occluding the aorta.
   d. Hypovolemia.

24. Which of the following is most likely to cause a high pressure alarm:
   a. Hypertension.
   b. Increased ectopy.
   c. Kinked balloon catheter.
   d. Hypotension.

25. The width of the balloon pressure waveform should correspond to:
   a. Heart rate.
   b. Length of diastole.
   c. Length of systole.
   d. Arterial pressure.
True or False Directions

Label statements True or False:

26. _____ The dicrotic notch is the landmark used to set balloon deflation.

27. _____ Deflation is timed to occur during the period of isovolumetric contraction.

28. _____ The balloon should be large enough to occlude the aorta, when fully inflated.

29. _____ The most commonly used trigger mode is the arterial pressure mode.

30. _____ The internal trigger mode is acceptable to use for a patient in a normal sinus rhythm.

31. _____ Pacing spikes are automatically rejected in ECG trigger modes.

32. _____ The pacing trigger modes can be used for a patient in a 50% paced rhythm.

33. _____ After percutaneous balloon removal, firm pressure is held at the femoral site for 15 minutes.

34. _____ The patient on the IABP is allowed to have the head of the bed up no more than 90 degrees and can flex the leg of insertion.

35. _____ Blood in the clear plastic tubing of the balloon catheter indicates a hole in the balloon itself.

36. _____ When the console alarms for “high pressure” or “kinked line,” the balloon continues to inflate and deflate.

REVIEW INFORMATION

Timing Exercises

1. Timing Assessment: Inflation optimal – Deflation optimal
   Hemodynamic Effect: Timing is set for maximum benefit

2. Timing Assessment: Inflation optimal – Deflation late
   Hemodynamic Effect: Balloon inflated during systole which increase oxygen demands and afterload

3. Timing Assessment: Inflation late – Deflation optimal
   Hemodynamic Effect: Little increase in CPP

4. Timing Assessment: Inflation early – Deflation early
   Hemodynamic Effect: Decreases CO by early valve closure and has poor afterload reduction

5. Timing Assessment: Inflation optimal – Deflation early
   Hemodynamic Effect: Poor afterload Reduction

   Hemodynamic Effect: Premature closure of the aortic valve causes decreased CO increase preload

7. Timing Assessment: This is a 1:1 assist interval; therefore, cannot assess timing accurately

8. Timing Assessment: Inflation late – Deflation late
   Hemodynamic Effect: Little increase in CPP and increased

   Hemodynamic Effect: Greatly decreased CO by premature aortic valve closure and increased afterload

10. Timing Assessment: Inflation late – Deflation early
    Hemodynamic Effect: Little increase in CPP and poor afterload reduction

11. There has been a heart rate change. The original rate was 100 which slowed to 80. Deflation on the fourth complex is early after which it is corrected. This is an example of the automatic timing circuits readjusting to a rate change without operator intervention. The compensation is automatic, occurs in one beat and is accurate for heart rate changes of ±20%.
SELF-ASSESSMENT TEST ANSWERS

1. B
2. A
3. D
4. D
5. C
6. A, C, D
7. Med/Surg Indications: Cardiogenic shock; threatening extension of MI; unstable angina; and during procedures such as angiography or angioplasty; inability to wean from bypass; etc.
8. Complications: Dissection of aorta, emboli, limb ischemia
9. B
10. inflates
11. deflates
12. ECG or R-wave
13. Arterial waveform
14. B
15. D
16. A, B, E, G
17. 11 B 40 F
   20 A 50 C
   30 D 60 E
18. A  Early inflation
    B  Decreased CO; premature closure of aortic valve
19. A  Late deflation
    B  Increased MVO2, increased afterload
20. C
21. A or D
22. 7146/352
23. B or C
24. C
25. B or A
26. F
27. T
28. F
29. F
30. F
31. T
32. F
33. F
34. F
35. T
36. F
37. T
38. F
39. F
40. F
41. T
42. F
43. F
44. F
45. T
46. F
47. F
48. F
49. F
50. F
51. T
52. F
53. F
54. F
55. T
56. F

INTRA-AORTIC BALLOON PUMPING
REFERENCE LIST
For complete list, please refer to the Intra-Aortic Balloon Pump Operations Manual.

NURSING CARE

TRANSPORT
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