

Counterpulsation Applied

An Introduction to Intra-Aortic Balloon Pumping

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Document Specification

When making reference to or requesting additional copies of this document, please note the following Part Number: ABT-TG, Revision 5/05

U.S. Patent No. 6,258,035

Caution: U.S. Federal Law limits this device to sale by or on order of a physician.

Refer to operating manual for current warnings, indications, contraindications, precautions, and instructions for use.

Introduction to Intra-Aortic Balloon Pumping—4 Hour Program

8:00 – 8:10	Welcome, Registration	9:45 – 10:00	Break
8:10 – 8:30	Principles of Intra-Aortic Balloon Counterpulsation	10:00 – 11:15	Pump Operation -Triggering -Troubleshooting (BPW)
8:30 – 8:50	Complications	11:15 – 12:00	Hands-On
8:50 – 9:00	Intra-Aortic Balloon Insertion	12:00 – 12:15	Evaluation
9:00 – 9:45	Timing		

8 Hour Program
Program Schedule

Introduction to Intra-Aortic Balloon Pumping—8 Hour Program

Morning		Afternoon	
8:00 – 8:15	Registration	12:00 – 1:00	Lunch
8:15 – 8:30	Welcome	1:00 – 1:30	Timing Exercises
8:30 – 9:30	Physiology and Principles of Counterpulsation	1:30 – 2:00	Triggering
9:30 – 9:45	Indications and Contraindications	2:00 – 2:30	Balloon Pressure Waveform and Troubleshooting
9:45 – 10:00	Break	2:30 – 2:45	Break
10:00 – 10:15	Complications	2:45 – 4:15	Hands-On Session
10:15 – 10:45	Insertion and Nursing Care	4:15 – 4:30	Evaluation and Post Test
10:45 – 12:00	Arterial Pressure Waveform and Timing		

Introduction to Intra-Aortic Balloon Pumping

This program is designed for experienced health care 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.

3. Participant Behavioral Objectives

Introduction to Intra-Aortic Balloon Pumping

At the completion of the Arrow International IABP program, the participant will be able to:

1. Define two expected outcomes of IABP therapy.
2. List three indications for utilization of the IABP.
3. State three contraindications for use of the IABP.
4. Describe the location of a properly positioned IAB catheter.
5. Describe the hemodynamic benefits of properly timed balloon pumping.
6. Correlate the arterial pressure waveform with the cardiac cycle.
7. Describe the procedure for insertion and removal of a percutaneously inserted IAB catheter.
8. Outline specific nursing care measures for patients receiving balloon pump therapy.
9. Describe at least three complications of IAB therapy.
10. List three clinical signs that indicate improved left ventricular function during IAB therapy.
11. Recognize on an arterial waveform properly timed inflation and deflation of the IAB catheter.
12. State the signs of improperly timed inflation and deflation of the IAB catheter.
13. Discuss the hemodynamic consequences of improperly timed balloon pumping.
14. Identify the characteristics of a normal balloon pressure waveform.
15. Correlate changes in the balloon pressure waveform with hemodynamic changes in the patient.
16. Distinguish the most appropriate trigger signal selection for a given patient situation.
17. Demonstrate proper set-up procedure for the Intra-Aortic Balloon Pump.
18. Discuss correct operator intervention for troubleshooting alarms/alerts.

I. Anatomy

A. Chambers

B. Valves

II. Blood flow control

A. Blood flows forward

B. Heart valves open forward

C. Blood moves by pressure gradients

III. 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. This coordinated succession of cardiac events must be understood in order to grasp the concept of the interaction of the IABP with cardiac physiology.

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 change until they become approximately the same. This occurs when the valves between two cardiac chambers are open. When valves between two chambers are closed, the pressure changes that may occur do so independently of each chamber.

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)

The cardiac cycle is divided into two major phases: diastole and systole. The periods of diastole and systole can be further subdivided into several different mechanical periods. The subdivisions addressed will be those that directly relate to physiology as applied to IABP therapy.

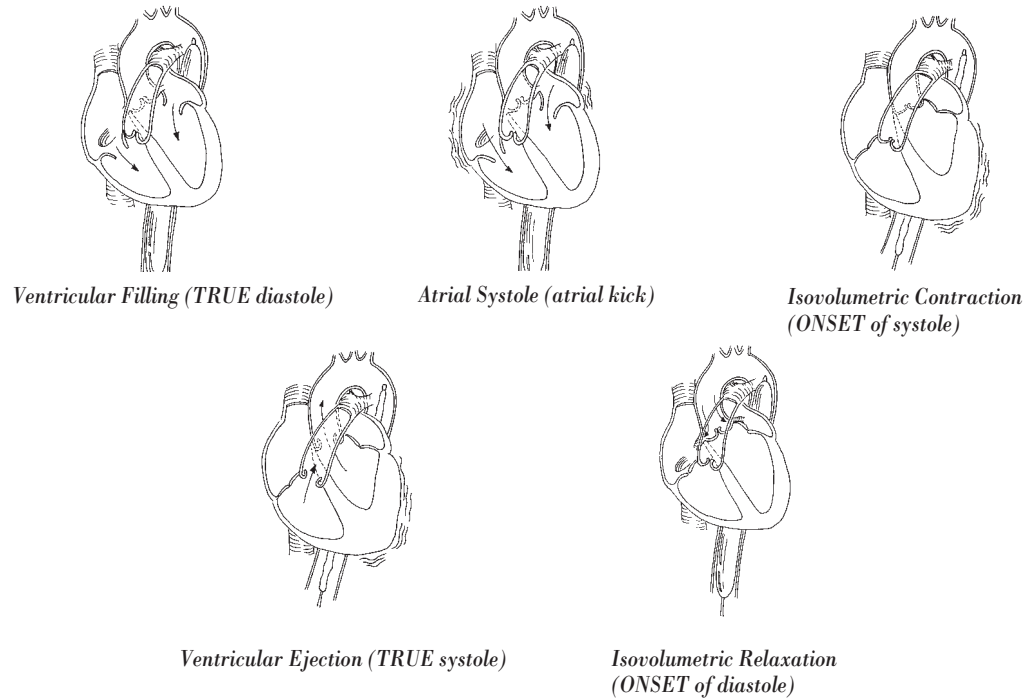


Figure 1.

Diastolic Events

Isovolumetric Relaxation

The onset of diastole brings relaxation of the myocardium. 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.

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)

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. The ventricles continue to relax which causes a further drop in pressure and an increasing gradient of pressure from atria to ventricles. The increasing gradient causes rapid inflow of blood to the ventricles. 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

Relatively late in the diastolic phase, the atria undergo depolarization, 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. The contribution to the total ventricular volume from atrial contraction varies between 15-25%. This variance is influenced greatly by the venous return and the heart rate (a lesser contribution with higher heart rates). Atrial contraction may contribute upwards of 50% of cardiac output in mitral/tricuspid stenosis.

At the end of this period, the ventricles depolarize. Diastole ends with the onset of ventricular contraction.

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 higher than the pressure in the atria, and this causes the closure of the mitral and tricuspid valves. The aortic and pulmonic valves remain closed until the ventricles generate a pressure higher than the pressures in the aorta and pulmonary artery.

During this brief time, both the atrio-ventricular valves and the semilunar valves are all 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. The major purpose of the IVC phase is to build enough pressure to achieve ejection of ventricular contents. The IVC period corresponds to the ascending limb on the ventricular curve of Figure 2.

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 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 the semilunar valves.

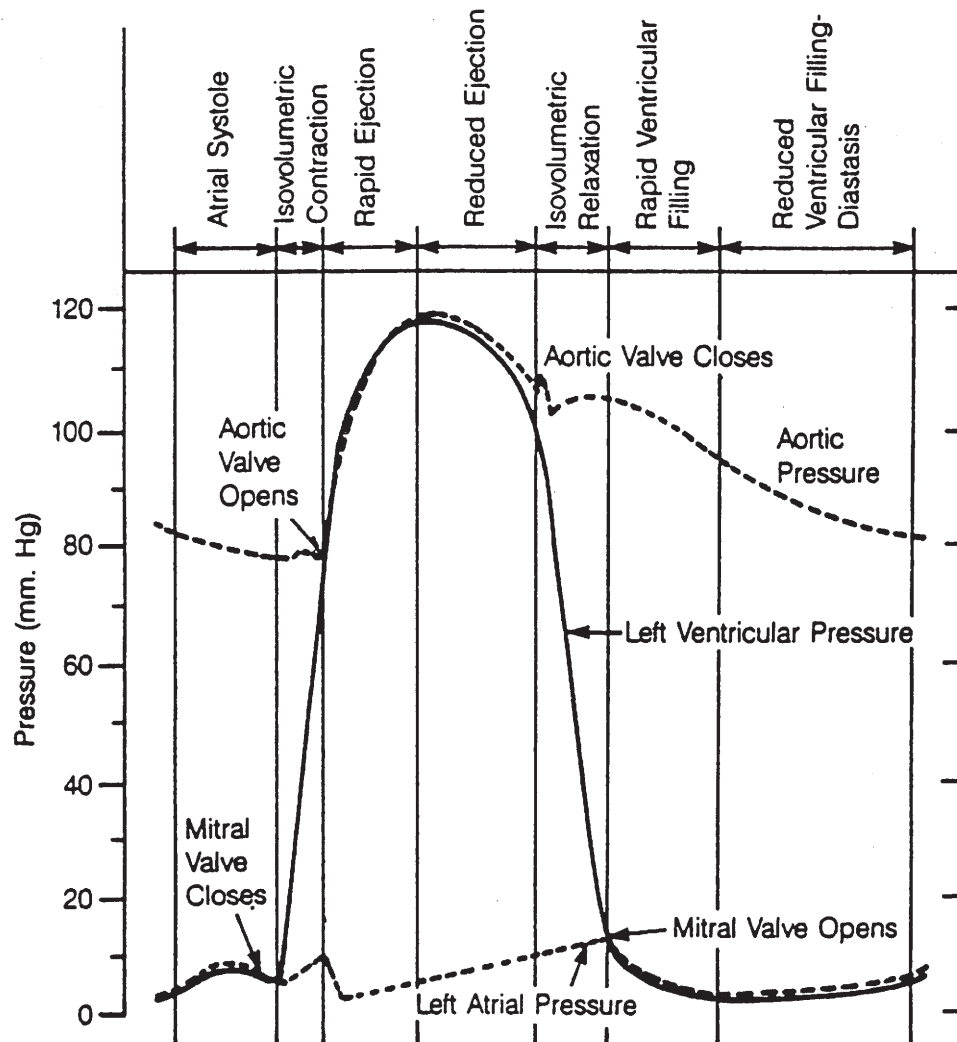


Figure 2. Arterial Pressure Waveform.

Rapid Ventricular Ejection

The opening of the aortic and pulmonic valves signifies the onset of the rapid ejection 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 become 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 in Figure 2.

Rapid ventricular ejection continues until the point of maximum ventricular pressure. This point is called peak systolic pressure.

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)

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 phase of systole. The reduced ejection period is seen on the descending limb of the arterial pressure waveform in Figure 2.

Systole ends with the onset of myocardial relaxation and the cycle repeats itself. (Closure of the aortic valve.)

Determinants of Cardiac Output

The heart functions as a mechanical pump within a dynamic vascular system. The performance of the heart is typically expressed in terms of cardiac output (CO). See Figure 3. The CO is expressed in liters per minute (normal: 4-8 L/min) and is obtained by multiplying the amount ejected with each contraction Stroke Volume (SV) by the number of times per minute the contraction occurs (HR). The SV is influenced by the intrinsic state of the vascular system and myocardium as shown in Figure 3. The HR 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 SV is insufficient, the HR must increase to maintain CO.

Measurements of Cardiac Effectiveness

Factors that Affect Stroke Volume

$$\text{Cardiac Output} = \text{HR} \times \text{SV}$$

$$\text{Stroke Volume} = \frac{\text{CO} \times 1000\text{ml}}{\text{HR}}$$

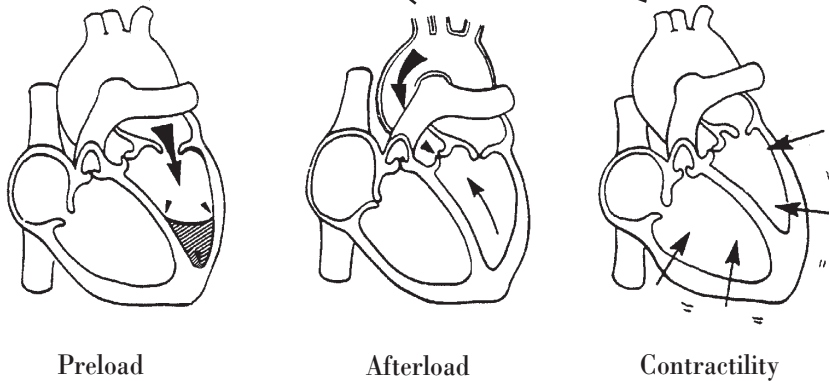
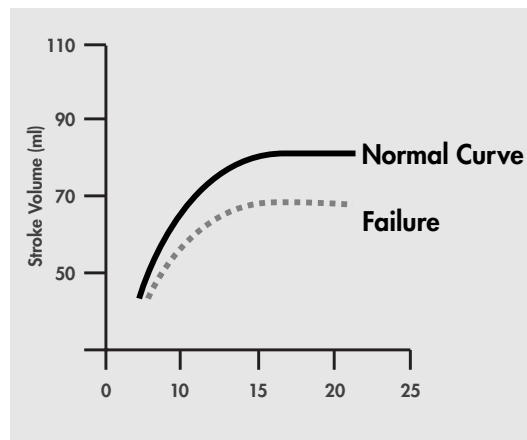


Figure 3. Determinants of Cardiac Output.

$$\text{Cardiac Index} = \frac{\text{CO}}{\text{BSA}}$$

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)



Left Ventricular End-Diastolic Pressure (mmHg)

Figure 4. Starling Curve. The Starling curve shows the relationship of CO and preload pressures.

Preload

Preload refers to the amount of stretch on the ventricular myocardium prior to contraction. Early in the 1900's, Frank and Starling observed that an increase of volume in the ventricle at the end of diastole resulted in an increase in the volume of blood pumped. This property is known as Starling's Law of the Heart. (See Figure 4)

Frank/Starling law

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.

The left ventricular end diastolic pressure (LVEDP) is used as an indication of ventricular volume. Preload has also been termed "filling pressure" and is clinically measured by the pulmonary capillary wedge pressure.

- a. LVEDP = left ventricular end diastolic pressure

- b. Indirectly measured by PCWP, LAP, RAP
 1. normal PCWP < 12mm Hg

 2. normal RAP 1-5mm Hg

The most important concept to keep in mind regarding Starling's law of the heart 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 ventricular chamber has occurred resulting in a decreased CO. The goal of the IAB in such a disease state is to decrease or "optimize" preload by ensuring a filling pressure high enough to obtain the highest CO on the Starling curve but not so high as to cause pulmonary congestion. In addition, preload is a component of MVO₂, so as PCWP increases, MVO₂ increases.

d. Pharmacological intervention

1. decreases preload
 - a. diuretics
 - b. nitroglycerin (vasodilation)

2. increases preload
 - a. fluids
 - b. vasoconstriction

Normal Adult Cardiac Measurements

- | | |
|---|--|
| 1. CO = 4–8 L/min | 7. LA = ≤ 12mmHg |
| 2. CI = 2.5–3.5 L/min/m ² | 8. RA = 1–7mmHg |
| 3. SV = 70ml | 9. RV = 20–25/5–8mmHg |
| 4. PCWP = ≤ 12mmHg | 10. PA = 20–25/10–12mmHg |
| 5. SVR = 900–1200 dynes/sec/cm ⁻⁵ | 11. LV Failure = CI ≤ 2.2 L/min/m ² |
| 6. Ejection Fraction (EF) = 60%–75% of end diastolic volume | 12. Shock = CI ≤ 1.8 L/min/m ² |

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)

Afterload

Afterload is the impedance to ventricular ejection. This impedance takes several forms (see Figure 5). The first impedance to ejection is the mass of blood that must be moved. The hematocrit 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 to ejection is the aortic end diastolic pressure. If the AEDP is 80mm Hg, then the left ventricle must generate 81mm Hg to open the aortic valve to achieve some forward blood flow. 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 the SV falls.

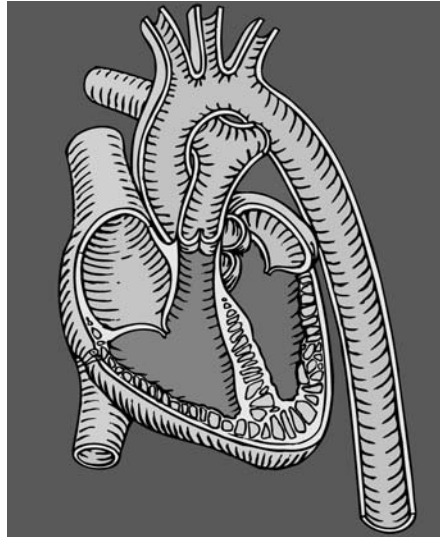


Figure 5. Afterload or Resistance to Ejection.

Clinically, afterload is measured using the diastolic blood pressure or systemic vascular resistance (SVR). The SVR is calculated by the following formula:

$$SVR = [(MAP-RAP) / CO] \times 80$$

MAP = Mean Arterial Pressure

RAP = Right Atrial Pressure

The normal SVR value falls within the range of 900-1200 dynes/sec/cm⁵. The objective in afterload manipulation is to maintain the SVR within the low normal range thereby minimizing the work of the heart.

Pharmacological Interventions

1. decreases afterload—vasodilators

- a. Nipride
- b. ACE inhibitors

2. increases afterload—vasoconstrictors

- a. Levophed
- b. Neosynephrine

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)

Contractility

Contractility is the myocardium's intrinsic ability to contract independently of the effects of preload or 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, which is calculated from a left ventriculogram obtained during cardiac catheterization. The normal ejection fraction is 65-75%. Preload/Afterload may increase/decrease contractility.

Many factors affect contractility as listed in the table below. An increase in contractility will increase the force of contraction, stroke volume, MVO_2 and delivered O_2 to the ventricles. Therefore, generally, the myocardial supply/demand ratio improves.

Left Ventricular Stroke Work Index (LVSWI) is another index of contractility. It may be trended as an indication of the performance of the left ventricle. It is the work involved in moving the blood in the left ventricle with each heartbeat against aortic impedance.

The formula for calculating LVSWI:

$$(\text{MAP} - \text{PCWP}) \times \text{SVI} \times 0.0136$$

SVI (Stroke Volume Index) is expressed as ml/m^2 per beat and is determined by $\frac{\text{CI}}{\text{HR}}$

Work is converted to pressure by the factor 0.0136.

Normal values for LVSWI range from 38 to $80\text{g}/\text{m}^2$ per beat, however the range varies depending upon the monitor manufacturer. With initiation of balloon pumping, one would expect to trend an increase in LVSWI and an improvement in the Starling Curve (moving up and to the left).

Increases Contractility

Inotropic Agents
Dopamine
Dobutamine
Isoproterenol
Epinephrine
Norepinephrine
Amrinone
Digitalis
Calcium

Exercise

Sympathetic Stimulation

Endogenous Catecholamines

Decreases Contractility

Acidosis

Hypoxia

Hyperkalemia

Parasympathetic Stimulation

Pharmacologic Agents

Beta Blockers

Calcium Channel Blockers

Disopyramide

Barbiturates

Alcohol

Procainamide

Thyroid Hormone

Myocardial Ischemia/Infarction

Myocardial Stunning

4. Anatomy and Physiology as Related to Counterpulsation Therapy (continued)

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 (see Figure 6).

Supply	Demand
1. Coronary artery anatomy	1. HR
2. Diastolic pressure	2. LV wall tension
3. Diastolic time	(afterload and preload)
4. O ₂ Extraction	3. Contractility
a. HGB	
b. PaO ₂	

Table 1. Myocardial Oxygen Supply and Demand.

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. In normal circumstances, the coronary perfusion pressure (CPP) is approximately 65mm Hg, but in severely diseased states, coronary blood flow can become tremendously impaired necessitating higher perfusion pressures to supply the same amount of blood flow. 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.

Under normal circumstances, the myocardium extracts 60-75% of its oxygen from the blood. It is difficult to extract more oxygen than this, but the myocardium can increase its oxygen consumption several-fold during periods of stress.

How then, if most of the oxygen is extracted from arterial blood, can the myocardium increase the amount of delivered oxygen to meet the metabolic needs?

Oxygen delivery is improved by increasing blood flow through the coronary arteries by a process called autoregulation. The limiting factor of increased oxygen delivery in diseased hearts is the inability to dilate coronary arteries further to meet the demands of increased flow and supply. It is important to distinguish between oxygen demand, oxygen supply and oxygen consumption. The consumption cannot increase to meet demand if supply of oxygen is insufficient.

5. Myocardial Oxygen Balance (continued)

Coronary Artery Anatomy

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

1. Right Main: Supplies the anterior and posterior right ventricle.
2. Left Main: Main branch prior to bifurcation into the left anterior descending and circumflex. Referred to as a “widows maker.”
3. Left Anterior Descending (LAD): Supplies the anterior surface of the left ventricle.
4. Circumflex: Supplies the lateral wall to posterior surface of the left ventricle.
5. Posterior Descending: Supplies the posterior interventricular septum and adjacent areas of the right and left ventricles.

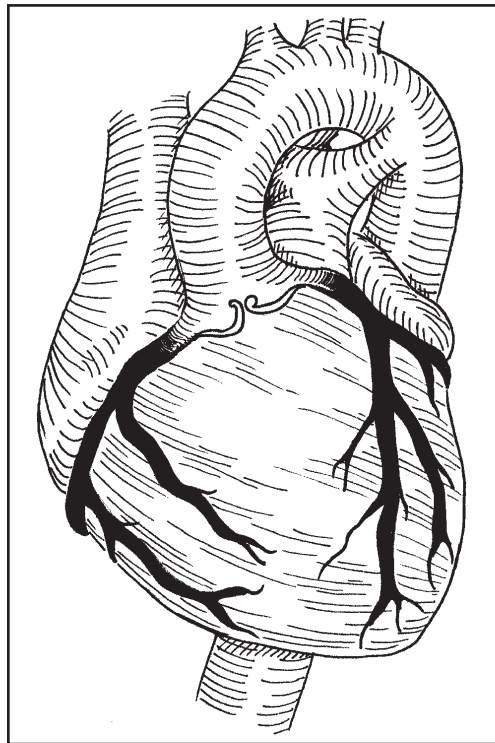


Figure 6. Anterior Coronary Artery

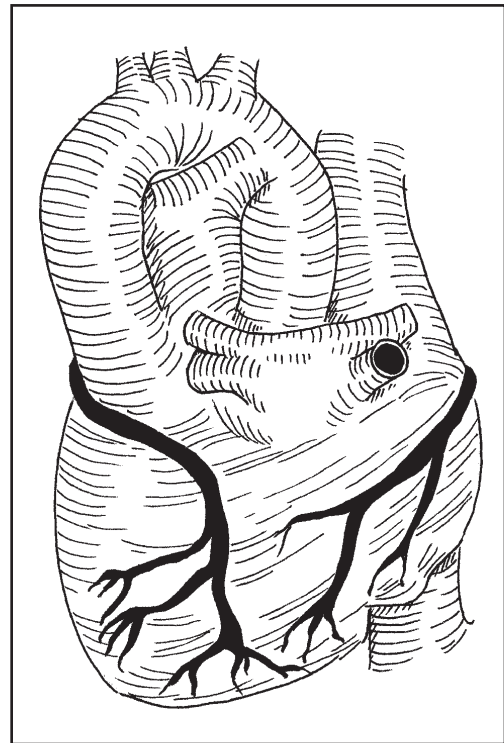


Figure 7. Posterior Coronary Artery

A. Coronary artery perfusion

1. 90% occurs during diastole

2. Diastolic blood pressure is driving force for coronary perfusion pressure (CPP)

Demand

The variables that increase oxygen demands are several:

1. Heart Rate
2. LV wall tension (afterload)
3. Contractility

The Law of Laplace

The Law of Laplace describes the interaction of preload and afterload and their effects on myocardial oxygen consumption (MVO₂). The Law of Laplace is a formula used to calculate the tension or stress in the myocardial wall during the IVC phase of systole.

$$T = \frac{Pr}{2h}$$

- T = myocardial wall tension
P = intraventricular pressure
r = intraventricular radius
h = ventricular wall thickness

Clinically stated:

1. An increase in the pressure generated by the ventricle will increase the wall tension (afterload).
2. A rise in LVEDV or LVEDP will increase the wall tension (preload).
3. Ventricular wall tension is inversely proportional to the wall thickness; therefore, a thinning of the ventricular wall will increase wall tension.

Heart Rate

It is easily seen that an increased heart rate will increase MVO₂ as each contraction utilizes oxygen. The increase in oxygen consumption can be serious especially in the patient unable to maintain CO by increases in SV. An already compromised myocardium cannot sustain an increase in HR without some liability.

Contractility

Although the physiologic basis of contractility is not completely understood, it is known that an increase in contractility increases MVO₂. Increases in contractility compound the oxygen demands further by increasing the pressure generation of the ventricle.

5. Myocardial Oxygen Balance (continued)

Principles of Intra-Aortic Balloon Counterpulsation

General Concepts

Placement

A flexible catheter with a balloon mounted on the end is inserted in the femoral artery and passed into the descending thoracic aorta. The Arrow International Intra-Aortic Balloon material was chosen for its durability. Once the balloon catheter is passed into the descending aorta, placement must be confirmed by fluoroscopy or chest X-ray. As shown in Figure 8, the balloon is situated 1 – 2cm below the origin of the left subclavian artery and above the renal artery branches. On daily CXR, 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. If the balloon is placed too low, then the origin of the renal arteries could become obstructed thereby compromising renal perfusion. If the catheter is placed too high, obstruction of the origin of the left subclavian or even the left carotid artery could result.

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

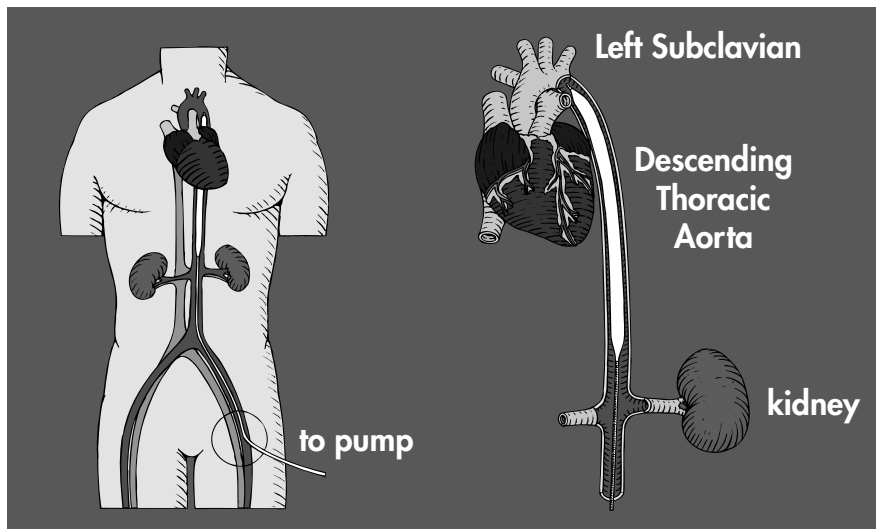


Figure 8. Correct Placement of the Intra-Aortic Balloon.

6. Principles of Intra-Aortic Balloon Counterpulsation (continued)

Volume Displacement

The intra-aortic balloon exerts its effect by volume displacement and pressure changes caused by rapidly shuttling helium gas in and out of the balloon chamber. This principle is known as counterpulsation. At a precisely timed interval, the gas enters the balloon chamber within the aorta. As the gas is shuttled into the balloon, it occupies a space within the aorta equal to its volume. The usual adult balloon volume is 40cc (although it can range from 30-50cc). The sudden occupation of space by the gas upon 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 intra-aortic balloon, the chain of events is in the reverse. A sudden 40cc fall in aortic volume causes a sudden decrease in aortic pressure within that localized area. In response to the local fall in pressure, the blood in adjacent areas moves to normalize the pressure within the aortic cavity as a whole.

Displacement of blood volume (both away from the balloon on inflation and toward the balloon on deflation) is the mechanism by which the IABP alters the hemodynamic state. In order to obtain beneficial hemodynamic changes the inflation and deflation of the balloon must occur at optimum times in the cardiac cycle.

Balloon Inflation: Hemodynamics

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. Figure 9 shows inflation of the balloon.

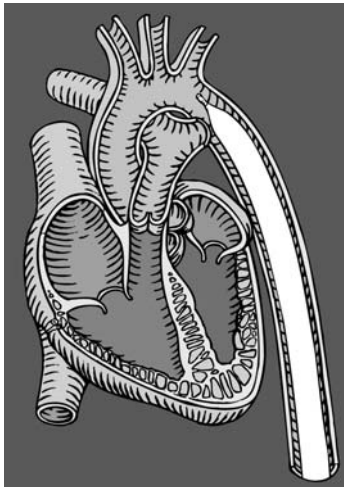


Figure 9. Intra-Aortic Balloon Inflation.

Benefits of Accurately Timed Inflation

1. Coronary artery blood flow and pressure are increased. Increased perfusion may increase the oxygen delivered to the myocardium.
2. Increased diastolic pressure also increases the perfusion to distal organs and tissues; i.e.: increased urine output, cerebral perfusion.
3. Coronary collateral circulation is potentially increased from the increased CPP.
4. Systemic perfusion pressure is increased.

Balloon Deflation: Hemodynamics

The balloon remains inflated throughout the diastolic phase. Deflation of the balloon should take place at the onset of systole during the IVC phase. 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 40cc volume 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. The IVC phase is shortened, thereby decreasing the oxygen demands of the myocardium. Since the left ventricle will be ejecting against a lower pressure, the peak pressure generated during systole will be less. Figure 10 shows deflation of the balloon catheter.

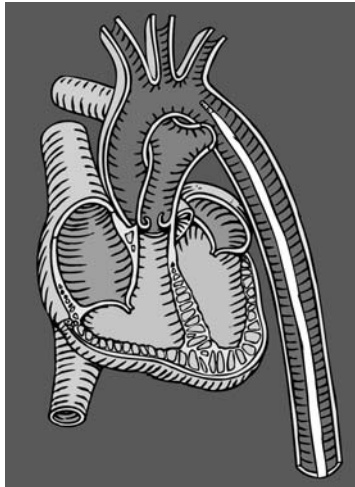


Figure 10. Intra-Aortic Balloon Deflation.

Benefits of Accurately Timed Deflation

1. The pressure that the LV must generate is less throughout the systolic phase. Therefore, afterload is reduced which decreases myocardial oxygen demands.
2. The IVC phase is shortened which decreases oxygen demands.
3. Reduced afterload allows the LV to empty more effectively so SV is increased. In addition, preload is reduced if elevated.
4. Enhanced forward CO also decreases the amount of blood shunted from left to right in cases of intraventricular septal defects and incompetent mitral valve.

Clinical Correlates of IAB Pumping

What You Should See as 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 2 shows the clinical signs of improvement by the IABP with the primary cause indicated.

Table 2. Correlation between Clinical Status and the Effects of Balloon Inflation and Deflation

	Inflation	Deflation
Decreased signs of myocardial ischemia: angina, ST segment changes, ventricular arrhythmias	XX	XX
Increased coronary blood flow	XX	
Decreased afterload	X	XX
Decreased MVO ₂ and demand	X	XX
Increased cardiac output	X	XX
Increased urine output	X	XX
Decreased preload (PCWP & CVP)	X	XX
Decreased pulmonary congestion, improved arterial oxygenation, improved breath sounds, clearing CXR	X	XX
Improved mentation	XX	X
Decreased heart rate	XX	XX
Decreased lactic acidosis	X	XX
Increased pulse rate and increased pulse pressure	XX	X

6. Principles of Intra-Aortic Balloon Counterpulsation (continued)

Indications For Use

A. Medical Indications

1. Cardiogenic Shock
2. Pre-shock Syndrome
3. Threatening Extension of MI
4. Unstable Angina
5. Intractable Ventricular Dysrhythmias
6. Septic Shock Syndrome
7. Cardiac Contusion
8. Prophylactic Support for:
 - a. Coronary Angiography
 - b. Coronary Angioplasty
 - c. Thrombolysis
 - d. High Risk Interventional Procedures (i.e. stents)
9. Bridging Device to other mechanical assist:
 - a. Ventricular Assist Device
10. Support During Transport
11. Cardiac support for hemodynamically challenged patients with mechanical defects PRIOR to correction
 - a. Valvular Stenosis
 - b. Valvular Insufficiency–Mitral
 - c. Ruptured Papillary Muscle
 - d. Ventricular Septal Defect
 - e. LV Aneurysm

7. Indications for the Intra-Aortic Balloon Pump (continued)

B. Surgical Indications

1. Post Surgical Myocardial Dysfunction
2. Support for weaning from CPB
3. Cardiac support following correction of anatomical defects
4. Maintenance of graft patency post CABG
5. Pulsatile flow during CPB

Contraindications

A. Absolute

1. Aortic Valve Insufficiency
2. Dissecting Aortic Aneurysm

B. Relative

1. End-Stage Cardiomyopathies—unless bridging to VAD
2. Severe Atherosclerosis
3. End-Stage Terminal Disease
4. Abdominal Aortic Aneurysms, not resected.
5. Blood dyscrasias (thrombocytopenia)

Complications of Balloon Pumping

Patients at highest risk of developing complications:

PVD	Smoking
Female	Obesity
Diabetic	Shock
Systemic Hypertension	SVR

A. Aortic Wall

1. Dissection
2. Rupture
3. Local Vascular Injury

B. Emboli

1. Thrombus
2. Plaque
3. Air

C. IAB Rupture

1. Helium Embolus
2. Catheter Entrapment

D. Infection

8. Complications of the Intra-Aortic Balloon Pump (continued)

E. Obstruction

1. Malposition

a. Too high - obstruction of left subclavian, carotids

b. Too low - obstruction of renal and mesenteric arteries

2. Compromised circulation due to catheter

a. Ischemia

b. Compartment Syndrome

F. Hematologic

1. Bleeding

2. Thrombocytopenia

Introduction

Nursing care of the patient requiring intra-aortic balloon pump support demands the same expert skills and assessments as any 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.

IAB Catheter Insertion

The Balloon Catheter

Use of the percutaneously inserted balloon catheter has broadened the application of the IABP. The percutaneous technique requires only 5 to 10 minutes for insertion in an uncomplicated case. Insertion of the catheter can be performed by any physician skilled in catheterization techniques.

Pre-Insertion Nursing Assessment

All hemodynamic and physical assessment data prior to insertion should be noted accurately. 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 prior to insertion, to determine the best side for insertion and to establish a baseline.

A complete pre-insertion assessment would include:

1. skin color of both legs
2. skin temperature of both legs
3. capillary refill ability of both legs
4. quality of pulses in both legs
5. baseline sensation and movement of both legs
6. ankle/brachial index of both legs
7. pre-insertion hemodynamics including CO, CI, PCWP, CVP, SVR, PA, LVSWI
8. complete neuro check
9. patient's/family understanding of procedure

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

The normal range of A/B index is .80 to 1.00. Mild circulatory impairment occurs when the index is .60 to .80. Moderate impairment is present with ranges of .40 to .60. Severe circulatory impairment falls in that range less than .40. It is important to remember that A/B ratios are an objective means of evaluating peripheral circulation, and trends rather than absolute numbers should be monitored.

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

Instructions for the insertion of the IAB catheter are included in every package. These instructions should be reviewed prior to every insertion. It is especially important that the nurse or assistant remembers to maintain the catheter in its package until absolutely ready to insert the balloon and to completely draw the vacuum before insertion to ensure that the balloon clears the sheath. Additional supplies that will be necessary for insertion include:

1. Betadine
2. Lidocaine with syringe for topical anesthetic
3. Suture material
4. Sterile drapes, mask, gown, gloves and cap
5. Sterile dressing materials and 4 X 4's
6. Heparinized saline flush solution and 10-20cc syringe to flush central lumen
7. Pressure tubing, transducer and continuous heparin flush solution set-up for balloon catheter central lumen.
8. Balloon pump console with all necessary patient cables (slave, direct or combination of both)
9. ECG Electrodes

Refer to your hospital's Policy and Procedure Manual and the detailed insertion instructions included with every balloon catheter for instructions on insertion.

Balloon Sizing

The balloon size should be chosen with respect to the patient size. This will result in improved safety and effectiveness of balloon counterpulsation.

Generally, the balloon is chosen by the patient's height and possibly aortic diameter, so that the balloon is positioned above the renal vasculature.

The following represents sizing recommendations:

<u>Patient Height</u>	<u>IAB Volume</u>	<u>Body Surface Area</u>
4'10"-5'4" (147-162 cm)	30cc	less than 1.8m ²
5'4"-6'0" (162-182 cm)	40cc	greater than 1.8m ²
> 6'0" (182 cm) or aortic diameter > 20mm	50cc	greater than 1.8m ²

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 +/-25mm Hg of the PDP (or augmented pressure value).

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

Arrow International Intra-Aortic Balloon Catheter Selection

All are double lumen and pre-wrapped.

RediGuard®

- Stainless steel braiding around a polyurethane central lumen
- Cardiothane™ 2 balloon material
- ArmorGlide® hydrophilic coating
 - 50cc 9Fr. Intra-Aortic Balloon
 - (1) 6" introducer sheath, with or without sideport
 - (2) .025 175cm guidewires
 - 30cc 7Fr. and 40cc 8Fr. Intra-Aortic Balloon
 - (2) 6" introducer sheaths, with and without sideport
 - (2) .025 175cm guidewires

NarrowFlex®

- Nitinol central lumen
- Cardiothane™ 2 balloon material
- Kink resistant and pushable
- (2) 6" introducer sheaths, with and without sideport
- (2) .030 175cm guidewires
- 30cc and 40cc 8Fr. Intra-Aortic Balloon
- pre-mounted hemostasis device

Ultra8®

- thin walled stainless steel central lumen
- Cardiothane™ 2 balloon material
- ArmorGlide® hydrophilic coating
- (2) 6" introducer sheaths, with and without sideport
- (2) .025 175cm guidewires
- 30cc and 40cc 8Fr. Intra-Aortic Balloon
- fits through an 8Fr. Sheath
- pre-mounted hemostasis device

UltraFlex™ Series

- thin walled stainless steel central lumen
- Cardiothane™ 2 balloon material
- Kink resistant and pushable
- (2) 6" PTFE introducer sheaths, with and without sideport
- (2) .025 175cm guidewires
- 30cc and 40cc 7.5Fr. Intra-Aortic Balloon, uses an 8Fr. Sheath
- 50cc 9Fr. Intra-Aortic Balloon, uses a 9Fr. Sheath
- pre-mounted hemostasis device

FiberOptix™ Series

- Ultra8® and UltraFlex™ 7.5 catheters are available with Fiber Optic LightWAVE™ Sensors embedded in the tip for use with AutoCAT®2 WAVE™ pump consoles
- Available in 30cc and 40cc balloon volumes for both styles, 50cc only in UltraFlex™

IAB Insertion

A. Percutaneous Insertion

- Sheathed
- Sheathless

Preparation of IAB for insertion

- attach the one-way valve to the IAB connector
- connect the 60cc syringe to the one-way valve
- apply full vacuum
- do not remove one-way valve until IAB is fully inserted into the patient
- flush through central lumen with heparinized saline just prior to insertion
- do not remove IAB from tray until time to insert into patient
- if IAB is to be inserted through a sheath, remove pre-mounted hemostasis device if present

After IAB is positioned in the patient

- aspirate blood from central lumen and gently flush with approximately 3cc heparinized saline
- immediately hook-up pressurized heparinized saline flush system to central lumen
- remove one-way valve and connect IAB to pump
- suture at both the sheath hub and catheter site

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

ARROW INTERNATIONAL

Intra-Aortic Balloon Insertion Procedure Competency Checklist

Name: _____ Date: _____

SKILL	YES
1. Balloon Sizing Recommendations	
30cc 4' 10" – 5' 4"	
40cc 5' 4" – 6'	
50cc > 6'	
2. Sheath Options	
A. Sheaths with side-port	
B. Sheaths without side-port	
C. Sheathless (hemostasis device available for post insertion bleeding)	
3. Interface Fiberoptic IAB connections to the IABP (AutoCAT®2 WAVE™ only)	
A. Slide blue fiberoptic connection in the IABP	
B. Insert calibration key (black key)	
C. Verify light bulb change from blue to green	
D. Describe how to do a manual zero	
4. Balloon Preparation	
A. Place IAB guidewire on the field	
B. Attach one-way valve to Gas lumen (do not remove until IAB is in position)	
C. Pull vacuum on IAB	
D. Remove IAB from the tray (immediately prior to insertion)	
E. Remove the packing stylet (if present)	
F. Flush IAB central lumen with heparinized NS solution before insertion	
5. Arterial Pressure Source (Fiber optic IAB uses AutoCAT®2 WAVE™ only)	
A. To zero Fiberoptic source manually:	
a) Press AP select to highlight fiber optic	
b) Press soft key under "FOS ZERO"	
B. To calibrate Fiberoptic source, if FOS was not zero'd prior to insertion and MAP value is erroneous:	
a) Press AP select to highlight fiber optic	
b) Press soft key under "FOS CAL"	
c) Adjust FOS MAP to actual MAP (from another AP source)	
C. To zero Fluid Transducer:	
a) Press AP select to highlight Xducer	
b) Open stopcock to air and off to patient	
c) Press soft key under "TRANSDUCER ZERO" (DO NOT press CAL key)	
d) Close stopcock	
6. Identify proper IAB positioning	
A. 2nd to 3rd Intercostal Space (anterior ribs) on Fluoro/X-ray	
B. Left radial (or ulner) pulse present	
C. Urine output present (if Foley in place)	

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

Nursing Care Considerations

A. Care of the Central Lumen

The central lumen of the IAB catheter was designed for guidewire insertion and pressure monitoring. Use of the central lumen for blood samples should be discouraged.

1. Use a standard arterial pressure monitoring set-up to monitor pressure through the central lumen.
2. Use of heparin in the flush bag should be in accordance with standard hospital guidelines.
3. A 3cc/hour continuous flush is recommended to maintain line patency.
4. Aspirate and discard 3cc of blood prior to connecting the flush tubing.
5. If unable to aspirate blood from the central lumen consider the line clotted. Attach a standard dead end plug and DO NOT attempt to use the central lumen during the course of therapy.
6. Avoid flushing and blood sampling from the central lumen to decrease the risk of embolization or formation of thrombus. If hospital policy or patient situation warrants manipulation of the central lumen, the pump console should be placed in STANDBY to prevent accidental embolization to the aortic arch.
7. Ensure that the pressure monitoring set-up and tubing are free of air bubbles.
8. The use of in-line filters may dampen the arterial pressure waveform and, therefore, should not be used.
9. Arterial pressure line set-up should be changed in accordance with hospital guidelines.

B. Potential for Inadequate Circulation

Pulse checks to lower extremities

Pulse checks to upper extremities—IAB too high

Monitor urine output—IAB too low

C. Potential for infection R/T invasive lines

D. Potential for skin breakdown R/T immobility

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

E. Potential for impaired gas exchange R/T atelectasis

F. Potential for injury R/T hematological abnormalities

G. Family and patient anxiety and stress

H. Control of arrhythmias

INTRA-AORTIC BALLOON PUMP FLOW SHEET

Date: _____ Insertion Site: _____ FR: _____ CC: _____

PARAMETERS

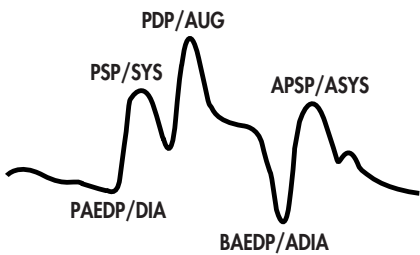
Time												
Heart Rate												
Rhythm												
Mode (AutoPilot™/Operator)												
Trigger												
Assist Ratio												
IAB Volume												
Systole												
Diastole												
MAP												
Asst Systole												
AUG/PDP												
Asst Diastole												
Asst MAP												

CIRCULATION ASSESSMENT

LT Radial Pulse												
DP Pulse												
PT Pulse												
Insertion Limb												
Color L/R												
Temp L/R												
Sensation L/R												
Calf Circumference												
Ankle/Brachial Index												

LEGEND: PULSES **PS** = PALPABLE STRONG **PD** = PALPABLE DIMINISHED **D** = DOPPLER **○** = ABSENT
COLOR/SENSATION **N** = NORMAL **D** = DIMINISHED **C** = CYANOTIC **M** = MOTTLED
LIMB TEMP **W** = WARM **C** = COOL **N** = NUMB **○** = ABSENT

INITIALS	SIGNATURE	INITIALS	SIGNATURE



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DATE:	TIME:	MODE:	TRIGGER:
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DATE:	TIME:	MODE:	TRIGGER:
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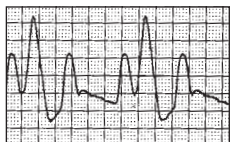
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EARLY INFLATION



LATE INFLATION



EARLY DEFLATION



LATE DEFLATION

Weaning from the Intra-Aortic Balloon Pump

The time for weaning and the speed with which weaning can be accomplished are dictated by the patient's hemodynamic status. Those patients requiring the IABP because of profound cardiogenic shock will probably wean more slowly than those needing balloon assistance for instability due to low cardiac output syndrome following cardiac surgery.

There are two methods of weaning which may be used independently or in conjunction with one another. 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 one balloon inflation per cardiac cycle to 1:2, 1:3, 1:4, and 1:8. Weaning can also be accomplished by decreasing the volume delivered to the balloon.

Any concerns that the patient may not be tolerating weaning should be directed immediately to the physician.

Do not reduce the volume delivered to the balloon less than 2/3 the capacity of the balloon, i.e. a 40cc balloon should not have the volume reduced to less than 28cc.

General recommendations when weaning:

1. Monitor the patient's hemodynamic data to establish a baseline for analysis of response to weaning, and carefully monitor the patient during weaning.
2. Throughout the weaning period, monitor the patient's vital signs including but not limited to:
 - ECG
 - Heart rate
 - Blood Pressure
 - Urine output
 - Mentation
 - Distal perfusion
 - Cardiac output/index

It is suggested that IABP support may be discontinued if the following clinical picture is present:

1. Signs of hypoperfusion due to low cardiac output syndrome are absent.
2. The urine output can be maintained above 30ml per hour.
3. The need for positive inotropic agents is minimal. The cardiovascular system remains stable in the low dose range.
4. The heart rate is less than 100 beats per minute.
5. Ventricular ectopic beats are fewer than 6 per minute, not coupled and unifocal.
6. The cardiac index remains equal to or greater than 2 l/min/m² and does not decrease by more than 20%.
7. The index of LVEDP (PCWP, PADP) does not increase to greater than 20% above pre-weaning level.
8. Absence of angina.

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

The inability to meet the above weaning criteria shows an intolerance to the withdrawal of mechanical support. The operator should return to the previous step in the weaning process and the physician notified in the event of weaning intolerance. A slow patient weaning protocol can be successful in those cases where IABP support has been prolonged or where the cardiovascular reserve is small.

3. When the patient no longer requires IABP support, press the OFF key in the PUMP STATUS section of the keypad to stop pumping, then remove the IAB according to your hospital policies and procedures.
4. After each use, clean and disinfect the IABP and its accessories and perform the Operational Checkout Procedure, according to the operator's manual.

For specific recommendations for weaning the patient on the Arrow IABP pump, refer to your operator's manual.

Removal of the Balloon Catheter

Removal of a percutaneously inserted balloon catheter can be done quickly and safely without an operative procedure.

The procedure for removal of a percutaneous balloon is as follows:

1. Explain to the patient and family the nature of the procedure and what to expect.
2. Remove all anchoring ties and sutures.
3. Disconnect the balloon from the console. (Note: the patient's blood pressure collapses the balloon membrane, eliminating the necessity to aspirate the balloon with a syringe. However, in some situations it is standard practice to reattach the one-way valve and aspirate with a 60cc syringe. Should blood be aspirated into the tigon tubing during this procedure, a radiographic examination of the IAB should be done to rule out entrapment.)
4. Remove the cuff from the sheath connector. While holding the sheath with one hand, the balloon catheter is slowly withdrawn with the other hand until resistance is met. This resistance means the balloon material is entering the end of the sheath.

ANY UNDUE RESISTANCE TO COMPLETE WITHDRAWAL SHOULD BE IMMEDIATELY NOTED AND SURGICAL REMOVAL SHOULD BE CONSIDERED.

5. Apply firm pressure to the femoral artery immediately below the insertion site.
6. Remove the balloon and sheath simultaneously.
NEVER ATTEMPT TO WITHDRAW THE BALLOON BACK THROUGH THE SHEATH. THIS PRACTICE CAN SEVERELY DAMAGE AND FRAGMENT THE BALLOON MATERIAL.
7. Allow proximal bleeding for 1-2 seconds to encourage extravascular loss of thromboembolic material.
8. Apply firm digital pressure to the femoral artery immediately above the insertion site. Release pressure below the insertion site to encourage backbleeding for 1-2 seconds.
9. Apply firm pressure to the insertion site to provide hemostasis (30-40 minutes or more if heparinized), and then apply a pressure dressing. A 5 to 10 pound sandbag can be used as per hospital policy. Follow hospital policy guidelines for sterile wound care.

In cases where a leak in the IAB is known or suspected, extreme caution must be exercised during removal. If resistance is met during step 4 (above), the percutaneous removal procedure should be discontinued and surgical removal via arteriotomy employed.

Post removal care includes the continual assessment of circulation to the cannulated leg. Monitoring and recording of peripheral pulses and the circulatory status of the cannulated extremity should be done every hour for the first 24 hours post-removal. The patient should not be allowed to flex the hip greater than 30 degrees for several hours to ensure a solid, organized clot. The patient should also avoid the Valsalva maneuver for the first 24 hours. Coughing exercises should not be done too vigorously and the insertion area splinted during coughing.

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

Transporting a Patient with an IABP

1. Inform ambulance or air transport company that you are transferring a patient with:
 - a. IABP
 - b. Ventilator
 - c. Number of Infusion Pumps
 - d. Be sure transport vehicle or aircraft is large enough to accommodate all equipment
 - e. Ask if vehicle is equipped with an inverter to supply power to IABP
2. Confirm that bed at accepting facility is ready.
3. Verify clean ECG skin and AP transducer signals on IABP screen.
4. Check IABP battery—On the KAAT II PLUS®, the Message on screen should read “Charging Battery HI” or “Charging Battery.” Do not use IABP for transport if message reads “Charging Battery LO.” On the ACAT®1, AutoCAT®1 and AutoCAT®2 Series of pumps, “Battery Charged” LED should be lit. On the TransAct®, the indicator light “DC ON” indicates that the system is running and the power is being supplied by the internal battery. The battery status is displayed on the screen as a bar graph; a complete bar indicates the battery is fully charged. The bar graph will display percent of battery charge.
5. Verify adequate helium supply.
6. Determine what IABP the receiving facility uses. If it is not an Arrow International pump, be sure to take appropriate adapters to interface the patient’s IAB to receiving IABP.
7. Know the route you will be taking to exit the hospital, and be sure the elevator and hallways are large enough to accommodate all the equipment and personnel required.
8. If transport infusion pumps are required, be sure the hospital or ambulance has the number of pumps needed.
9. Have an IABP transport bag with the following suggested items:
 - 60cc slip-tip syringe
 - appropriate IAB/IABP adapters
 - scissors and Kelly clamp
 - ECG patches
 - extra helium tank
 - IABP Operator’s Manual
 - ECG cable and arterial pressure cable
 - IABP flowsheet
10. Properly secure the IABP in ambulance or aircraft. (See FAA regulations for aircraft.)
11. It is helpful to run through a “mock transport” at periodic intervals in order to identify any potential problems that may arise.

Reference:

Mertlich, G. & Quaal, S.J.: “Air Transport of the Patient Requiring Intra-Aortic Balloon Pumping”
Critical Care Nursing Clinics of Nursing Clinics of North America—Vol. 1 No. 3 September 1989.

Air Transport with an Arrow International IABP

Helicopters

- Altitude usually less than 10,000 ft.
- Cabin usually not pressurized

Fixed Wing Aircraft

- Altitude between 12,000 and 50,000 ft.
- Pressurized cabin

Pressure and Gas Changes in Flight

- Barometric pressure decreases as altitude increases, causing the volume of helium to expand.
- The TransAct®, KAAT II PLUS®, ACAT® Series, AutoCAT® 1 and AutoCAT® 2 WAVE™ Series IABPs contain a pressure transducer inside the helium gas shuttle circuit. This transducer senses the above mentioned changes in barometric pressure and gas expansion and contraction, causing activation of alarms. These alarms will result in venting the system and referencing the transducer to current atmospheric pressure. The IABP can then be re-purged with the appropriate helium volume and pressure. The TransAct® and AutoCAT® 1 Series of IABPs will automatically adjust for these changes.

Procedures During Flight for all IABP consoles:

1. Maintain alarms in “ON” position at all times.
2. Balloon gas volume expansion and contraction may result in alarm conditions (“High Baseline” or “Kinked Line” during ascent and “Helium Loss” or “Gas Loss” during descent.)
3. Both alarms result in the pump going to “OFF” position and venting the system.
4. Observe alarm condition on the screen/strip. The screen of the IABP console should be placed for continual visual observation of pump performance as well as allow access for adjustments, if required.
5. Press “Reset,” then “Pump On.”

9. Nursing Care of the Intra-Aortic Balloon Pump Patient (continued)

Introduction

The precise timing of balloon inflation and deflation is essential to achieve the hemodynamic effects that increase coronary blood flow and decrease the workload of the heart. This section relates the cardiac cycle to the waveform changes caused by balloon inflation and deflation. The landmarks that will identify proper timing are discussed. Timing examples from various arterial sites are discussed to inform the reader of the inherent time delays from the different locations used for monitoring. Timing exercises will allow the reader to practice timing skills.

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 operates in a similar manner: moved to the left for earlier deflation, to the right for later deflation.

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.

Even if your IABP adjusts and sets timing automatically, timing assessment should be done per hospital policy.

10. Elements of Timing (continued)

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 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.

Before one may appreciate the changes that occur with balloon inflation and deflation, an assessment of the arterial pressure morphology is necessary.

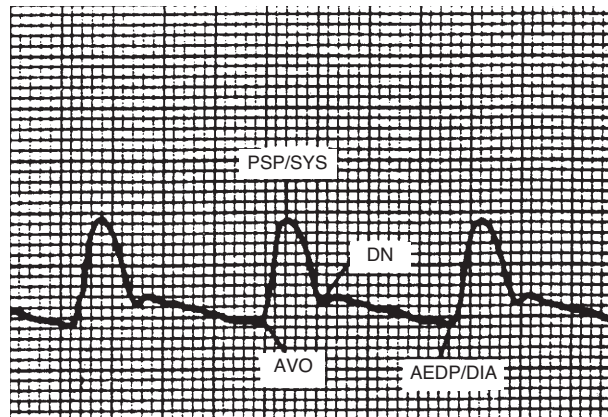


Figure 11. Arterial Pressure Waveform Landmarks.

AVO = Aortic valve opens. Beginning of systole.

AEDP = Aortic end diastolic pressure (DIA or diastolic pressure).

PSP = Peak systolic pressure (SYS or systolic pressure) 65-75% of stroke volume has been delivered.

DN = Dicrotic notch. Signifies aortic valve closure and diastole. The last 25-35% of stroke volume is delivered by this point.

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 LV exceeds the pressure in the aorta. Rapid ejection occurs and the ventricle delivers 65-75% of its stroke volume. The pressure generated is the peak systolic pressure (PSP or SYS). After the Peak Systolic Pressure, flow velocity declines until the pressure in the ventricle falls below the pressure in the aorta, and the aortic valve closes (DN). The blood in the aorta flows to the periphery in the runoff phase. The cycle then repeats itself.

The important landmarks of the arterial pressure waveform are shown in Figure 11. Identification is necessary for proper timing of inflation and deflation. When intra-aortic balloon pumping is begun, the assist interval is set on 1:2 (the IAB inflates and deflates every other systole). This is done so that landmarks can be identified and the effects of inflation and deflation can be compared to the baseline hemodynamic status.

Inflation Timing

Inflation goal:	Inflation effect achieved by:
Increase myocardial oxygen supply	Increasing CPP
Increase systemic perfusion pressure	Increasing systemic pulse pressure/rate

To accomplish the goals of inflation, the balloon must be inflated at the onset of diastole. The dirotic notch is the landmark for this on the arterial pressure waveform and inflation should occur just prior to this point. The result of properly timed inflation is a pressure rise, peak diastolic pressure (PDP) or augmentation (AUG), during diastole. The PDP/AUG influences the gradient for coronary artery perfusion. While it may not only be a reflection of timing, the PDP/AUG should be higher than the PSP/SYS unless:

1. the patient's stroke volume is significantly higher or lower than the balloon volume
2. balloon is positioned 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

The reference point for absolute timing is the aortic root. It is not possible in the critical care unit to monitor the aortic root pressure, therefore we measure the pressure in the descending aorta via the central lumen of the balloon. Because the monitoring site is not the aortic root, there are time delays between the actual physiological events and the monitoring of those events. Propagation of a pressure wave takes much the same pattern as a ripple in a pond.

There is a larger transmission delay in the fluid filled transducer system than with the fiber optic AP sensor. This may result in timing waveform differences between AP monitoring sites.

10. Elements of Timing (continued)

What does this mean in terms of setting IABP timing?

Inflation timing should be set to occur 40-50 milliseconds (msec) early to compensate for the delay. Forty msec is the same as one very small block on the horizontal axis on standard ECG paper. Therefore, the inflation point should be set to occur one small block ahead of the DN on the ECG paper. Correct inflation timing is illustrated in Figure 12.

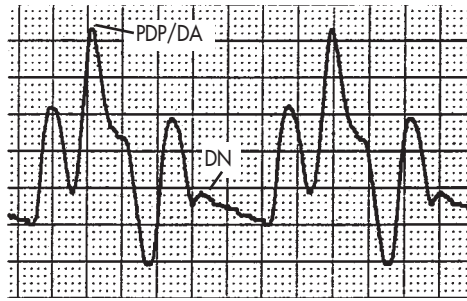


Figure 12. Correct Inflation Timing.

DN = Dicrotic Notch. Symbolizes the beginning of diastole.

PDP = Peak Diastolic Pressure. Also called diastolic augmentation (DA).

When using the radial artery as the monitoring point for cardiovascular pressures, the time delay will be approximately the same as for the central lumen pressure line. The increased amount of blood volume involved when transducing a femoral arterial site necessitates an increase in time delay to 120 msec (3 small blocks).

Deflation Timing

Deflation goal:	Deflation effect achieved by:
Decreased myocardial oxygen demands	Afterload reduction
Increased stroke volume	Decreasing aortic pressure

Accomplishing the goals of deflation requires the assessment of several pressures on the 1:2 assisted arterial pressure waveform. Deflation timing does not have the benefit of absolute landmarks but entails assessment of pressure responses.

Balloon deflation during the IVC phase of systole causes a fall in pressure immediately preceding ventricular ejection. This fall is represented by the balloon aortic end diastolic pressure (BAEDP) or assisted diastole (ADIA). (See Figure 13.) For effective afterload reduction, the BAEDP/ADIA must be lower than the patient's own unassisted aortic end diastolic pressure (AEDP). 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/SYS. The result of properly timed balloon deflation should be:

1. BAEDP < AEDP (ADIA < DIA)
2. Assisted PSP < PSP (ASYS < SYS)

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

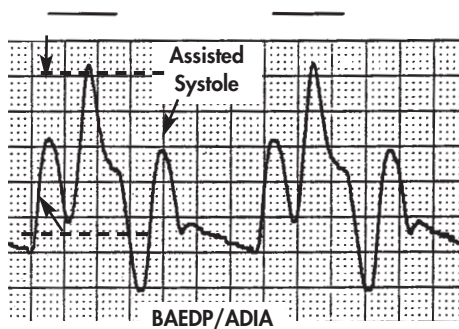


Figure 13. Correct Deflation Timing.

BAEDP/ADIA	Balloon aortic end diastolic pressure or assisted diastole. Fall in end diastolic pressure caused by balloon deflation.
Assisted Systole (ASYS)	The systole following a balloon inflate/deflate cycle. (Reduced peak systolic pressure)

Errors in Timing

Inflation or deflation timing errors can be made in two ways: too early or too late. Two of these errors, early inflation and late deflation, are considered potentially risky to the patient. Late inflation and early deflation are considered suboptimal, as the patient may not receive the full benefits of IAB pumping. Although not risky in themselves, late inflation and early deflation may cause further deterioration of myocardial status due to the lack of benefit.



Figure 14. Early Inflation.

The IAB has inflated before the aortic valve has closed (during systole) causing premature closure of the aortic valve and reduction of SV. The hemodynamically unstable patient cannot afford to lose any forward CO and an impediment of only 10% may cause deterioration.

Figure 14 shows early inflation. Assess the position of the DN by the assisted systole. One can see that inflation occurs too far before (early) the DN.

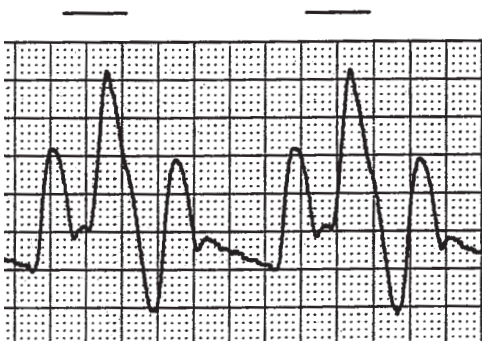


Figure 15. Late Inflation.

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 volume available for displacement, resulting in a lower pressure increase. The major effect of late inflation is a suboptimal increase in coronary perfusion. Many times the PDP/AUG is the same as PSP/SYS as well as the DN being visible. See Figure 15.

Figure 15 shows late inflation. Assess the position of the DN by the assisted systole. One can actually see the DN where it should not be seen. Inflation occurs after (late) the DN.

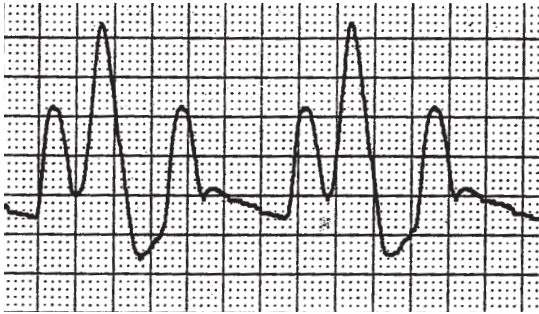
Early Deflation

Figure 16. Early Deflation.

When properly timed, 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. By the time the aortic valve opens, pressure in the aorta has equilibrated back to baseline so that the ventricle is ejecting against the same pressure as it was without the balloon. (The equilibrating aortic pressure, at heart rates less than 90, can be seen as a shelf just prior to the assisted systole.) The net effect is that afterload reduction is not present, and the workload of the heart is therefore not decreased. See Figure 16.

Figure 16 shows early deflation. In the evaluation of the pressure landmarks, there is no reduction in the assisted systolic pressure (no afterload reduction effects).

$$\text{PSP} = \text{ASSISTED PSP (SYS} = \text{ASYS)}$$

Late Deflation

Figure 17. Late Deflation.

During late deflation, the balloon is inflated (or partially so) at the beginning of ventricular ejection. The left ventricle now has to force its contents 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 SV. The hallmark of this timing error is a BAEDP/ADIA that is higher than AEDP/DIA as seen in Figure 17.

Figure 17 shows late deflation. In the evaluation of the pressure landmarks there is an increase in the BAEDP/ADIA.

$$\begin{aligned} \text{BAEDP} &> \text{AEDP} \\ \text{ADIA} &> \text{DIA} \end{aligned}$$

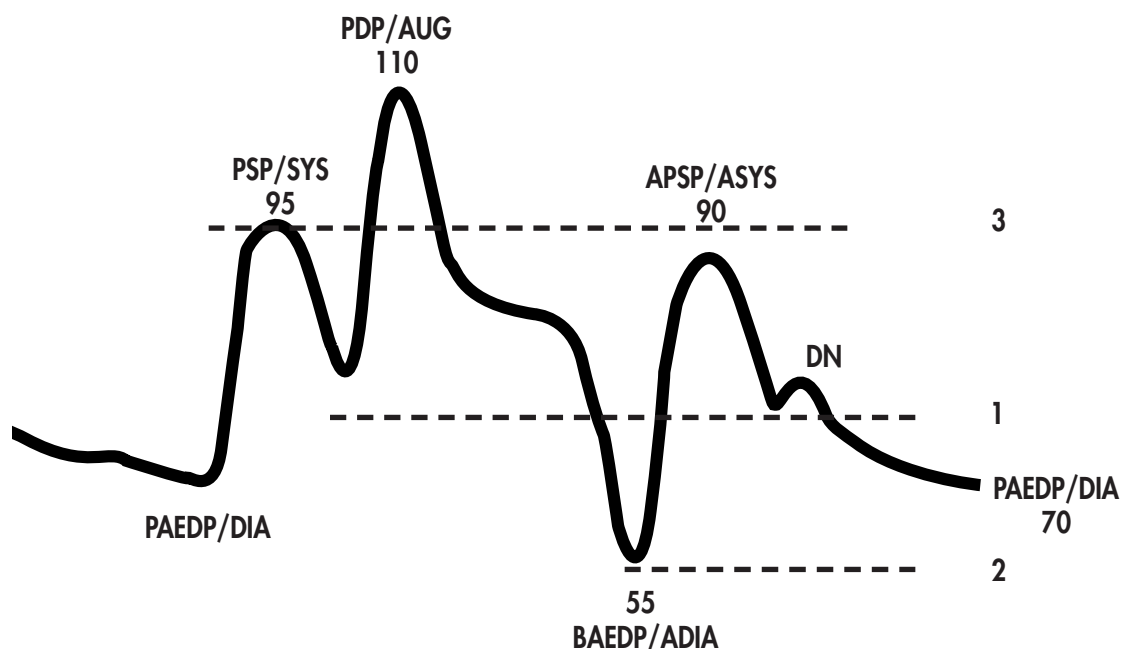


Figure 18.

The Timing Three

1. Inflation

Just Prior to the Dicrotic Notch (DN)

If > 40ms before—EARLY INFLATION

If dicrotic notch exposed—LATE INFLATION

2. Deflation:

BAEDP < PAEDP ADIA < DIA

BAEDP = Balloon Aortic End Diastolic Pressure (ADIA)

PAEDP = Patient Aortic End Diastolic Pressure (DIA)

If BAEDP/ADIA is higher—LATE DEFLATION may be occurring

3. Deflation:

Assisted Systole (APSP/ASYS) < Peak Systole (PSP/SYS)

SYS/PSP = Peak Systolic Pressure

ASYS/APSP = Assisted Peak Systolic Pressure

If both pressures are equal—EARLY DEFLATION can be suspected or afterload reduction not required

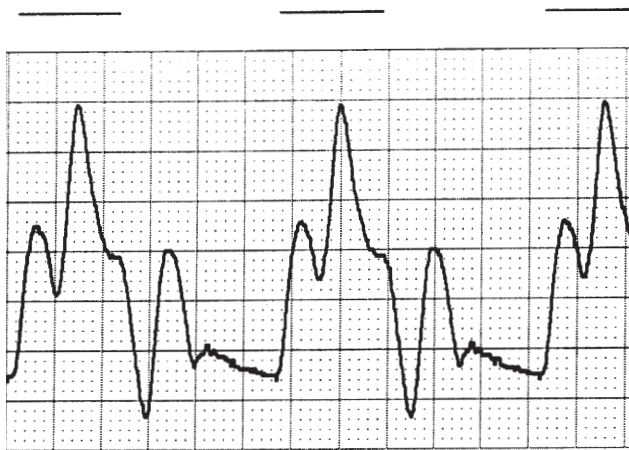
Timing Exercises

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 Three” 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 situations. To gain mastery, the operator must PRACTICE, PRACTICE, PRACTICE. These timing exercises are included to give the learner the opportunity to develop their own process of analysis and gain familiarity.



1. Improper Timing

Hemodynamic Effect



2. Improper Timing

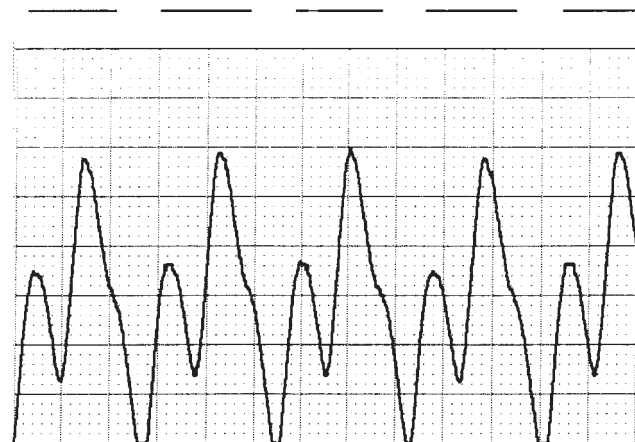
Hemodynamic Effect

10. Elements of Timing (continued)



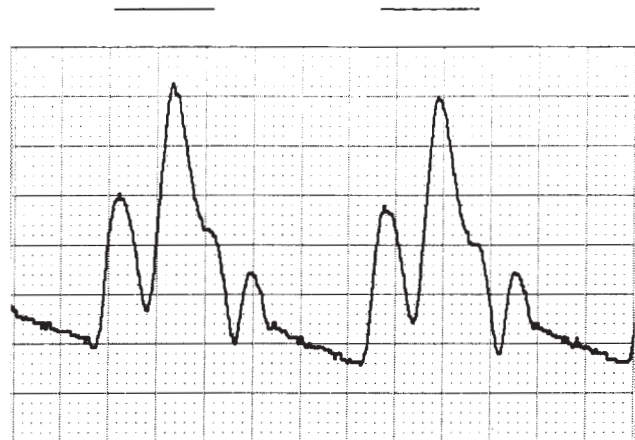
3. Improper Timing

Hemodynamic Effect



4. Improper Timing

Hemodynamic Effect



5. Improper Timing

Hemodynamic Effect

10. Elements of Timing (continued)



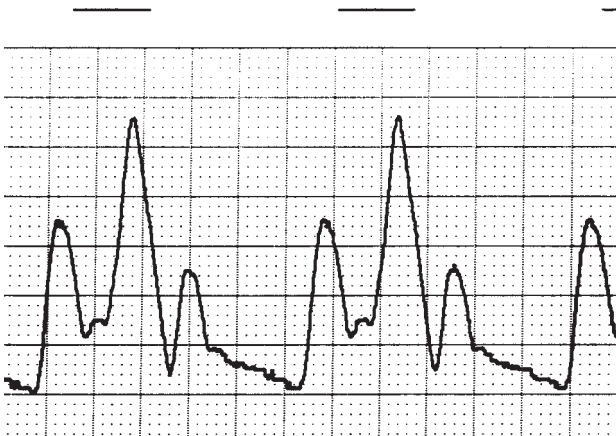
6. Improper Timing

Hemodynamic Effect



7. Improper Timing

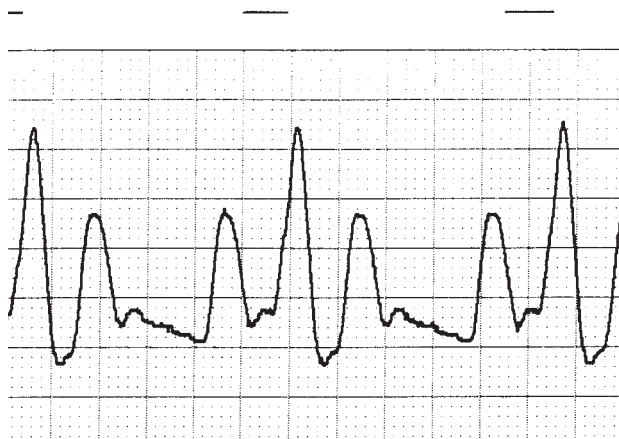
Hemodynamic Effect



8. Improper Timing

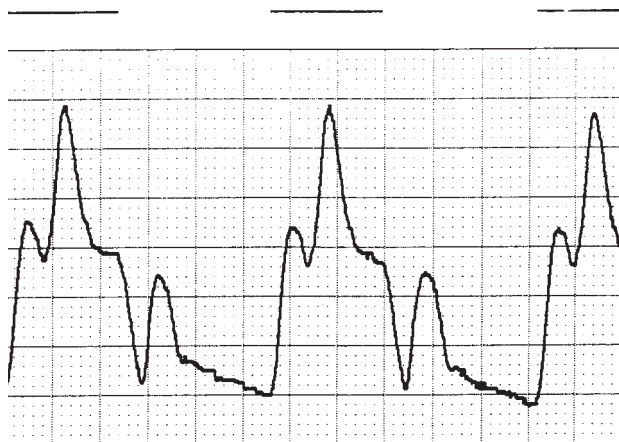
Hemodynamic Effect

10. Elements of Timing (continued)



9. Improper Timing

Hemodynamic Effect



10. Improper Timing

Hemodynamic Effect



Bonus Question: Any guesses on what is happening here?

Answers to Timing Exercises

- | | |
|---|---|
| <p>1. Timing Assessment: Inflation optimal
Deflation early</p> <p>Hemodynamic Effect: Poor afterload reduction</p> | <p>7. Timing Assessment: Inflation late
Deflation optimal</p> <p>Hemodynamic Effect: Little increase in CPP</p> |
| <p>2. Timing Assessment: Inflation early
Deflation optimal</p> <p>Hemodynamic Effect: Premature closure of the aortic valve causes decreased CO, increase preload</p> | <p>8. Timing Assessment: Inflation late
Deflation late</p> <p>Hemodynamic Effect: Little increase in CPP and increased afterload</p> |
| <p>3. Timing Assessment: Inflation optimal
Deflation optimal</p> <p>Hemodynamic Effect: Timing is set for maximum benefit.</p> | <p>9. Timing Assessment: Inflation late
Deflation early</p> <p>Hemodynamic Effect: Little increase in CPP and poor afterload reduction.</p> |
| <p>4. Timing Assessment: This is a 1:1 assist interval, therefore, cannot assess timing accurately.</p> | <p>10. Timing Assessment: Inflation early
Deflation late</p> <p>Hemodynamic Effect: Greatly decreased CO by premature aortic valve closure and increased afterload. Oxygen demands greatly increased, increase preload.</p> |
| <p>5. Timing Assessment: Inflation optimal
Deflation late</p> <p>Hemodynamic Effect: Balloon inflated during systole which increases oxygen demands and afterload</p> | <p>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 $\pm 20\%$.</p> |
| <p>6. Timing Assessment: Inflation early
Deflation early</p> <p>Hemodynamic Effect: Decreases CO by early valve closure and has poor afterload reduction.</p> | |

10. Elements of Timing (continued)

Arrhythmia Timing on the IABP

If the patient develops an irregular rhythm 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 period of diastole augmented to enhance perfusion and minimizing the potential negative effects of early and/or late deflation.

For the ACAT® 1 PLUS series and KAAT II PLUS® consoles, to initiate "Real Timing", the clinician can select AFIB trigger to initiate true R wave deflation.

To disengage "Real Timing", select Peak trigger and manually set deflation point.

For AutoCAT® 2 Series "AFIB" is selected automatically in AutoPilot™ mode and is indicated by the "Arrhythmia Timing" message and AFIB in trigger area.

To disengage "Arrhythmia Timing", or AFIB, press Arrhythmia Timing (LED will go off) or select Operator Mode and Peak Trigger.

For the AutoCAT® console, "Arrhythmia Timing" is automatically engaged in both the AutoPILOT™ and OPERATOR modes when an irregular cardiac cycle is identified and is indicated by the message "AFIB TIMING".

To disengage "Arrhythmia Timing", hold the AFIB OFF key for 2 seconds. The message "AFIB TIMING OFF" will be displayed. Deflation must be set by the clinician.

For the TransAct® console, "Arrhythmia Timing" is automatically engaged when using the R-wave trigger and an irregular cardiac cycle is identified.

To disengage "Arrhythmia Timing", select Peaks trigger and manually set deflation point.

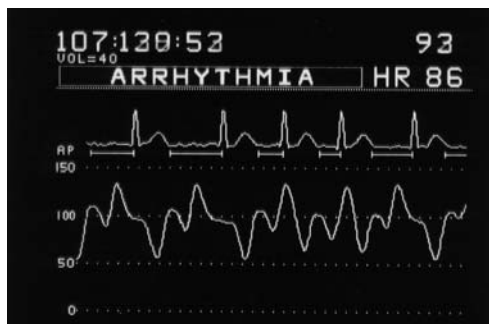


Figure 19. R-Wave Trigger

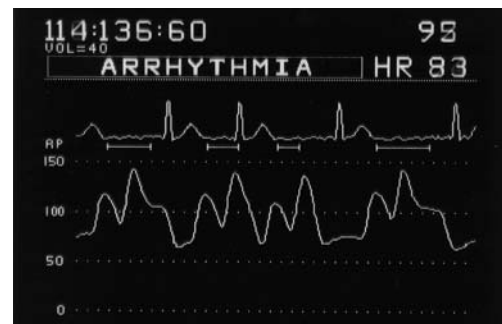
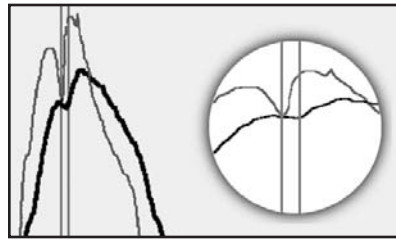
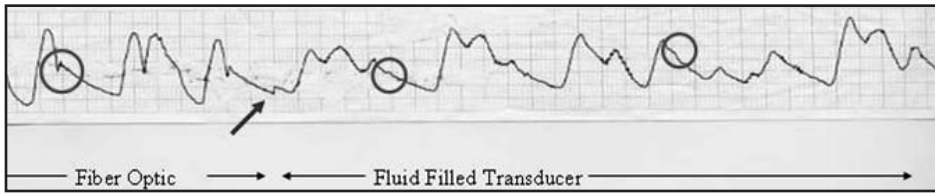


Figure 20. Peaks Trigger

Difference between Fiber Optic Arterial Pressure Signal and Transducer



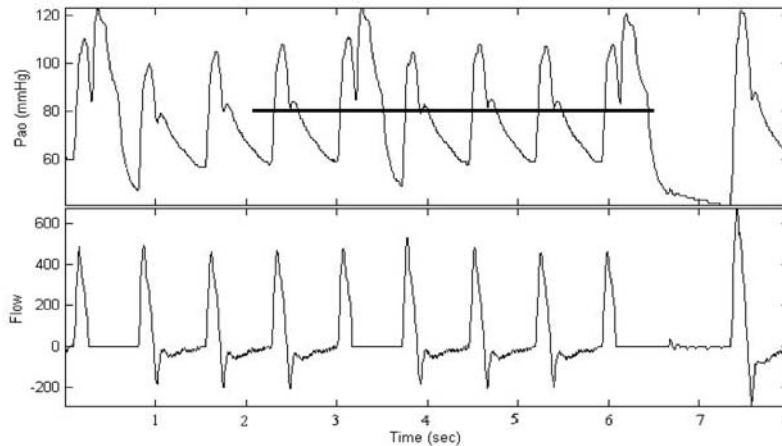
33msec delay



The Fiber Optic AP Signal produces a high fidelity waveform that is available to the IABP earlier than fluid filled AP signals. When the inflation timing is correct on the fiber optic arterial pressure waveform it may look early on the fluid filled line because of the transmission delay in fluid systems. Since the fiber optic AP waveform is a real time signal, there is virtually no delay.

WAVE™ Inflation Timing

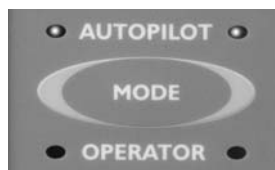
Windkessel Aortic Valve Equation (WAVE™) is exclusive to the AutoCAT®2 WAVE™ IABP in AutoPilot™ mode when the Fiber Optic signal is selected. The fiber optic arterial pressure signal is converted to an aortic flow signal by the pump. The aortic flow waveform is then used to set inflation of the balloon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



Compare inflation to the most unassisted beat Dicrotic Notch.

10. Elements of Timing (continued)

The AutoCAT®2 Series IABP offers two distinct modes of operation:



AutoPilot™ MODE

In AutoPilot™ mode the console selects the ECG source, AP source, trigger, and timing.

1. Console scans all available ECG leads continuously. If the current lead selected is lost or noisy, 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 is selected by the console but can be changed by the clinician. On the AutoCAT®2 WAVE™, if the Fiber Optic sensor is connected and available, it will always be selected since it has the most optimal waveform and allows for WAVE timing to be selected.
3. Console selects the available trigger modes based on patient condition and signal availability.
4. All timing settings and adjustments are under control of the console.

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

OPERATOR MODE

This is the mode of operating common to all other models of intra-aortic balloon pumps. The clinician makes all the choices regarding ECG source and lead, AP source, triggering, and timing.

1. Once the initial timing is set, the console will automatically adjust for changes in heart rate.



AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

Trigger Modes

It is necessary to establish a reliable trigger signal before balloon pumping can begin. The computer in the IAB console needs a stimulus to cycle the pneumatic system which inflates and deflates the balloon. The trigger signal tells the computer that another cardiac cycle has begun. In most cases it is preferable to use the R wave of the ECG as the trigger signal. Back-up options are the arterial pressure waveform and pacer spikes.

AutoPilot™ automatically selects the best available trigger. If control of the trigger mode is desired, select Operator mode.

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 25-135msec. Widened QRS complexes may not be recognized, such as bundle branch blocks. Rejection of pacer spikes is automatic. This is AutoPilot™'s trigger of choice when the rhythm is regular, the HR is less than 130bpm and the QRS complex is normal width.

AutoPilot™: HR < 130 and no arrhythmia.

ECG Peak

Peak analyzes the height and slope of a positively or negatively deflected QRS complex. Rejection of pacer spikes is automatic. This is AutoPilot™'s choice when the rhythm is regular and the QRS is wide or the HR is greater than 130bpm. It will also select Peak if the rhythm is irregular and ARRHYTHMIA TIMING is turned OFF.

AutoPilot™: HR > 130 and/or arrhythmia with arrhythmia timing off.

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 AutoPilot™'s choice when a rhythm is irregular and ARRHYTHMIA TIMING is ON.

AutoPilot™: Any HR with arrhythmia and arrhythmia timing on.

AP

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

AutoPilot™: Noisy or no ECG present.

VSPACE

VSPACE 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 is 100% paced. AutoPilot™ will only choose this trigger if there are no QRS complexes or arterial pressure waveforms seen but pacer spikes are present.

AutoPilot™: Single or dual pacer spikes with no ECG/AP.

APACE

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

AutoPilot™: Single pacer with R wave > 100msec after pacer.

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 but may be adjusted in increments of 5 between 40 and 120 bpm. Selection of this trigger is only available in Operator mode and must be confirmed by an additional keystroke. AutoPilot™ will NEVER choose this trigger.

To access trigger modes the pump must be in Operator mode.

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



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 wave will result in a loss of the trigger signal to the IABP. This will generally cause a TRIGGER LOSS alarm and stop counterpulsation. It is strongly recommended that one of the following options be instituted to minimize patient risk of thrombus formation.

1. If counterpulsation is to be continued and synchronized to the CPR effort, then ARTERIAL TRIGGER should be selected*. If the 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 in Operator Mode. To select INTERNAL, the INTERNAL TRIGGER key must be depressed TWICE. This is done to prevent inadvertent selection of INTERNAL. In most cases, clinicians may decrease the assist interval or decrease the volume of the IAB. This trigger will maintain movement of the IAB and therefore reduce the risk of thrombus formation.

WARNING: The use of INTERNAL TRIGGER will produce asynchronous counterpulsation and 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 reestablished, 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 and the IABP is turned OFF, the IAB should be manually inflated. Aspirate with a large Luer-slip syringe to check for blood. Inject volume of air of the total balloon volume capacity (i.e. 40cc for a 40cc IAB) into balloon at quick connector and aspirate it immediately. Manual inflation should be done 4 to 5 times every 5 to 10 minutes that counterpulsation is discontinued.

NOTE: Some clinicians have reported the successful use of the ECG TRIGGER by placing an ECG electrode close to the CPR site. The mechanical motion of the ECG Electrode may produce enough voltage on the ECG waveform to be used. If this maneuver is attempted, the PEAK TRIGGER mode should be used.

***Reference:**

Osborn CS, Quaal SJ. Maximizing cardiopulmonary resuscitation in patients with intra-aortic balloon pumps. *Critical Care Nurse*. 18(2):25-27, April 1998.
Quaal SJ. *Comprehensive Intra-Aortic Balloon Counterpulsation*. 2nd Edition. Mosby Publishing, p.131. 1993.

1. Power ON

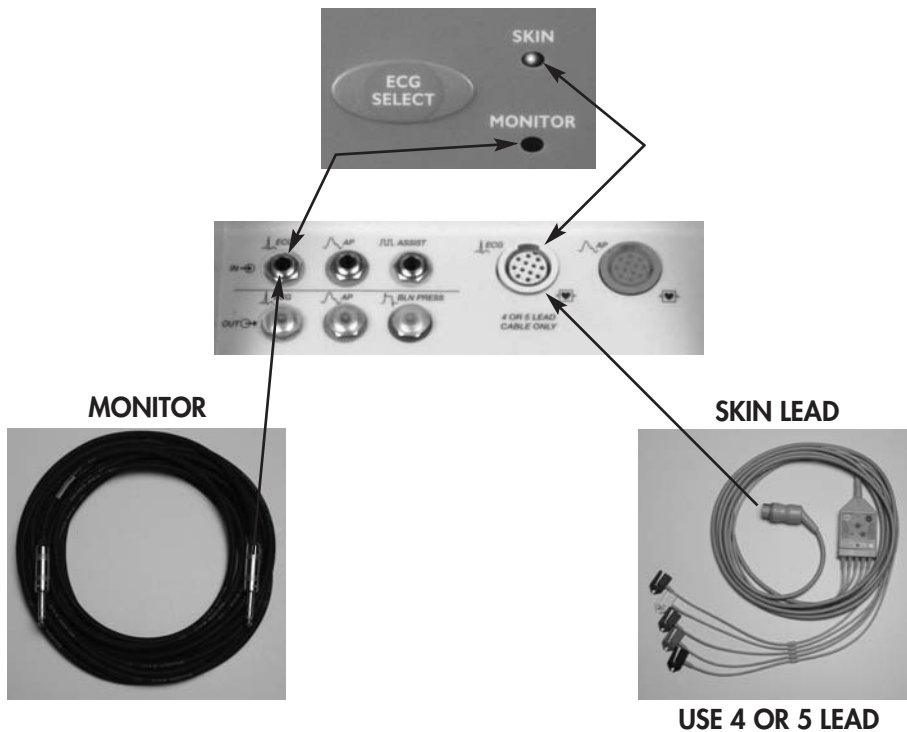
- a. Applies power to the system.

Pump should be plugged into an AC outlet. The green indicator LED below the power switch denotes AC power is being received by the pump. The amber indicator LED denotes that the battery is at least 80% charged.



2. Patient Connections

ECG



11. AutoCAT®2 Series Operation (continued)

ECG Cables

a. Skin Lead Cable

1. In use when SKIN selected on keypad, next to ECG Select.
2. Must use either a 4 or 5 lead cable.
3. For 4-lead cable, the lead choices are I, II or III.
4. For 5-lead cable AutoPilot™ will select either I, II, III or V. AVR, AVL and AVF may be selected by the clinician.
5. Lead selected is highlighted in white and displayed in upper left corner of LCD screen.

b. Phono to Phono Cable (Monitor Cable)

1. In use when MONITOR selected on keypad.
2. Actual lead choice is made on the bedside monitor.

ECG SELECT

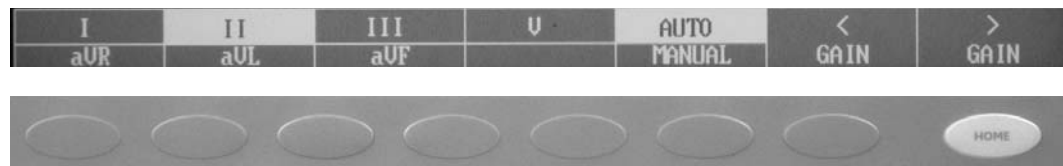
- a. ECG SELECT provides selection for LEAD, input source, gain mode and level.
- b. This key can be used in either AutoPilot™ or Operator mode. If in AutoPilot™ mode, a manually selected lead is unavailable or less optimal than another available choice, AutoPilot™ will override the manual selection.



1. To change input source press ECG SELECT twice.
2. To change lead, press ECG SELECT once. Press key under desired LEAD label. To select the 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. If AUTO is selected, the GAIN change is only valid until lead is changed.

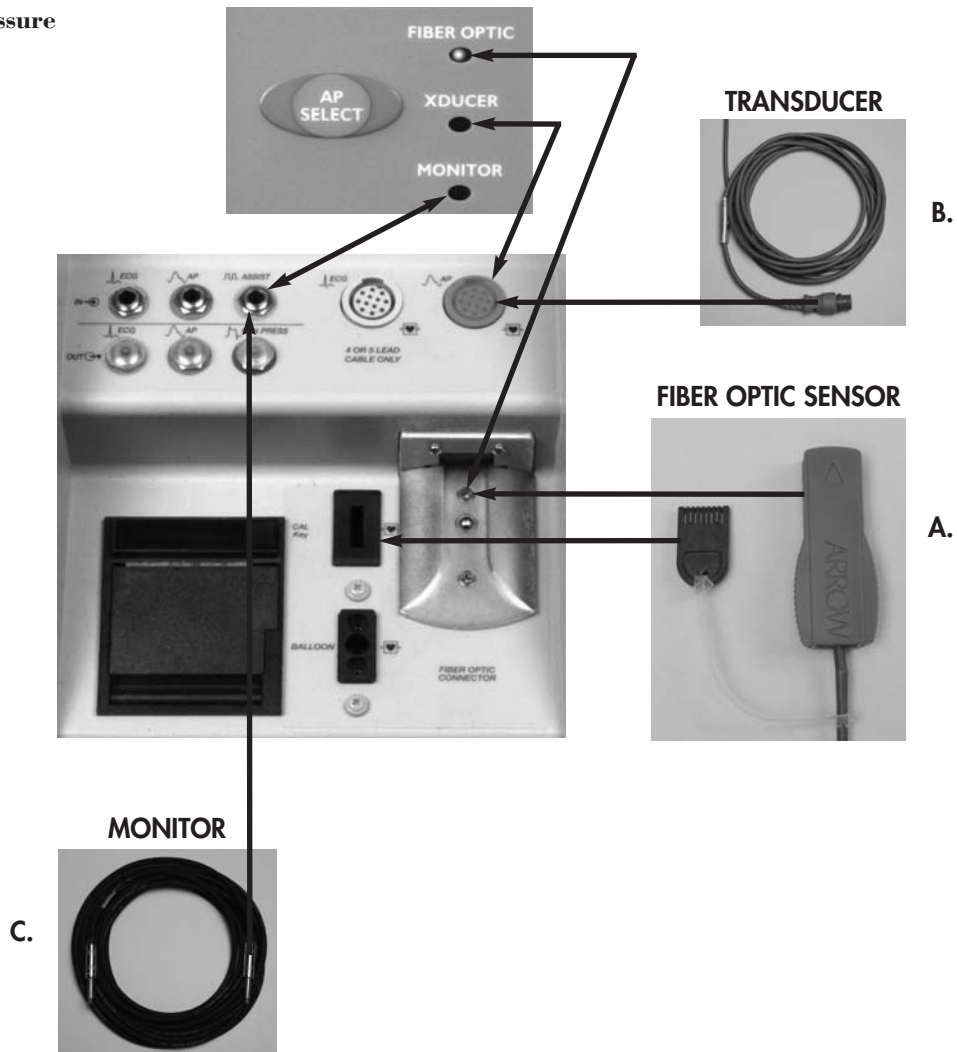
SELECT LEAD OR PRESS ECG SELECT AGAIN TO SELECT MONITOR

5 lead ECG cable



Note: It is highly recommended to use ECG skin leads when AP fiber optic is selected.

Arterial Pressure



AP Cables

A. Fiber Optic Cable

1. Exclusive to the AutoCAT®2 WAVE™ IABP.
2. In use when FIBER OPTIC is selected on the keypad.

B. Transducer Cable

1. In use when XDUCER is selected on the keypad.

C. Monitor Cable

1. In use when MONITOR is selected on the keypad.

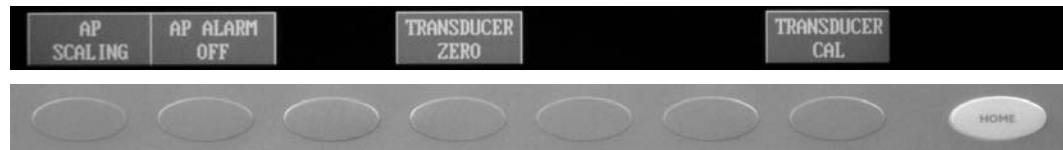
11. AutoCAT®2 Series Operation (continued)

AP SELECT

- a. AP SELECT provides selection for AP SOURCE, SCALE, AP ALARM, ZERO and CAL.
- b. This key can be used in either AutoPilot™ or Operator mode. If you select an alternate AP source while the fiber optic sensor is connected to the pump, AutoPilot™ will return to FIBER OPTIC after one minute.



1. To change input source press AP SELECT twice.
2. To change scale, set AP alarm, zero or calibrate, press AP SELECT once. Press key under desired label to select function.



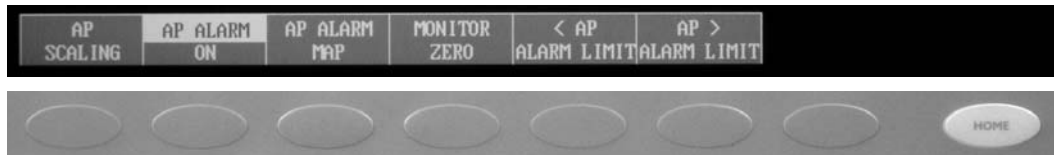
AP SCALING

- AUTO is the preset.
- To set scale manually press AP SCALING once.
- Press AP SCALING AUTO to select MANUAL scaling.
- Press MANUAL SCALES.
- Press soft key under desired scale.



AP ALARM

- Press AP ALARM OFF key. This will toggle the alarm system to ON.
- Select AP parameter for alarm: MAP or AUG.
- Preset MAP limit is 70mm Hg. Preset AUG limit is 100mm Hg.
- Verify alarm limit. Alarm limit can be adjusted in 5mmHg increments.

**FiberOptix™ ZERO and MAP CAL**

- The fiber optic sensor will zero automatically if it is connected to the pump prior to insertion (average time: approximately 15 seconds).
- To zero manually, connect FOS sensor and CAL key then press FOS ZERO before the catheter is inserted into the patient.
- The FOS icon (light bulb) will turn green after the ZERO is complete.
- If the fiber optic sensor was not zeroed before insertion, the MAP value may be adjusted to match the pressure from a transduced arterial line.
 - Select FOS CAL.
 - Use either the <FOS MAP or >FOS MAP to adjust the MAP value in the hemodynamic section of the display screen to the desired value. The MAP can be adjusted in increments of 5mmHg. The waveform is adjusted as the <> keys are pressed.
 - If the adjustment was made in error, press the CANCEL key.
 - If the FOS MAP value is changed, the FOS icon will change to white.



11. AutoCAT®2 Series Operation (continued)

ZERO Transducer

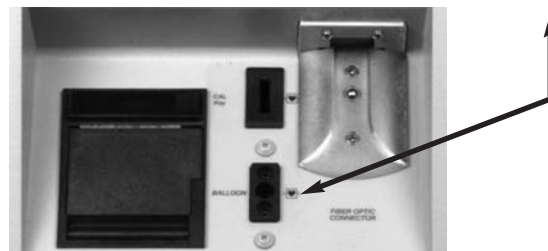
- Verify level of the transducer to the patient's phlebostatic axis; open transducer to air.
- Press AP SELECT key once, then press soft key under XDUCER ZERO.
- Close transducer; observe for return of arterial pressure waveform.

(Note: Transduced AP does NOT need to be zeroed to use as a trigger source.)

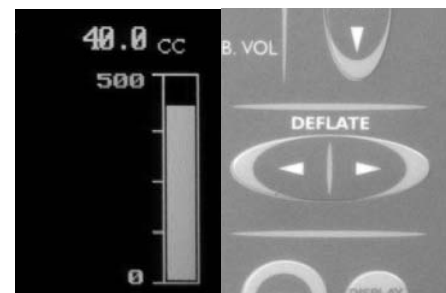
Balloon

- a. Push balloon connector in firmly, right side up or upside down – it does not matter.

- 30cc IAB - white connector
- 40cc IAB - blue connector
- 50cc IAB - orange connector



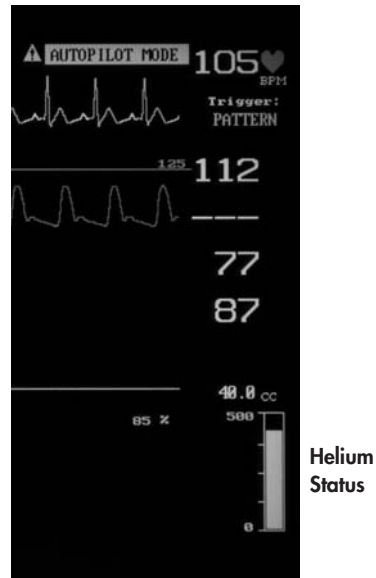
- b. Balloon volume is displayed above the helium bar display.



3. Pump ON

Verify:

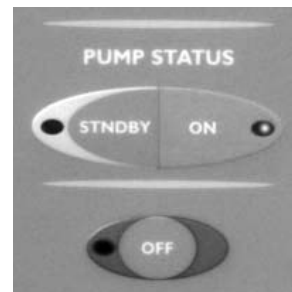
- The console can not pump without a trigger. Trigger acceptance is indicated by the white overlay on the ECG, flashing heart symbol and accurate Heart Rate.
- Trigger mode displayed below HR.
- Helium gauge to ensure adequate amount of helium to fill the drive system.



Initiate Pumping

Press PUMP ON

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 two times to optimize helium concentration. Pumping will continue uninterrupted.

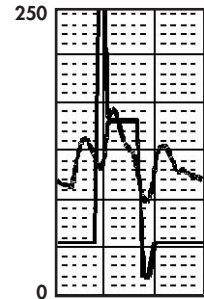


11. AutoCAT®2 Series Operation (continued)

Balloon Pressure Waveform

1. Description

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 counterpulsation.

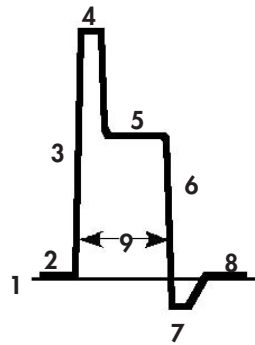


2. BPW Height

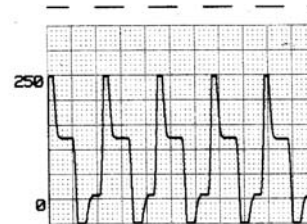
Reflects the pressure in the aorta, therefore the plateau pressure on the BPW should be within $\pm 25\text{mmHg}$ of the AUG pressure.

3. BPW Width

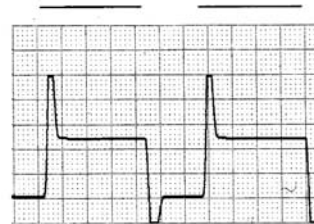
It is approximately the duration in which the balloon is inflated.



- 1 Zero Baseline
- 2 Balloon Pressure Baseline
- 3 Rapid Inflation
- 4 Peak Inflation Artifact
- 5 Plateau Pressure
- 6 Rapid Deflation
- 7 Deflation Artifact
- 8 Return to Baseline
- 9 Duration of Balloon Cycle



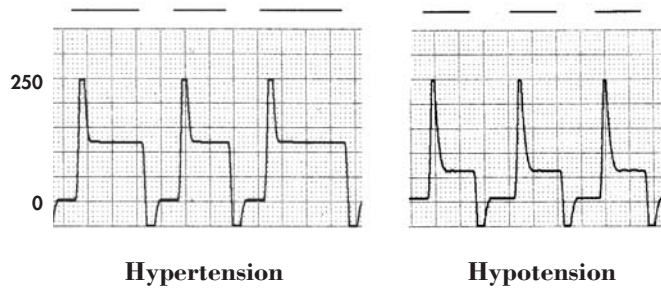
Tachycardia



Bradycardia



Irregular Rhythm (AFIB)



Alarms and Alerts

An alarm may cause the pump 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, can also be utilized for troubleshooting assistance.

Class 1 Alarms (Automatic Response)

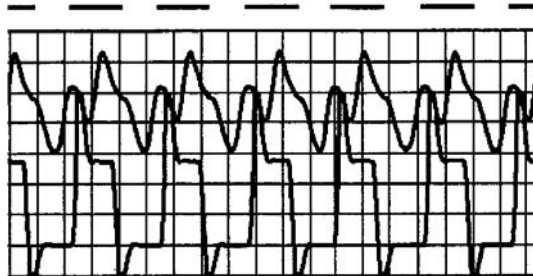
The following Class 1 alarms cause the AutoCAT®2 Series IABPs to:

1. Stop pumping (PUMP OFF key illuminates)
2. Deflate the balloon
3. Open vent valve
4. Initiate the audio alarm
5. Display an alarm message
6. Freeze the waveform display
7. Print approximately the last 10 seconds of BPW and AP on the strip chart recorder

Once the condition is corrected, to resume pumping:

1. Press alarm RESET.
2. Press pump ON.

Unable to Refill

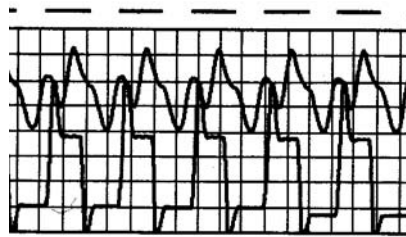


AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

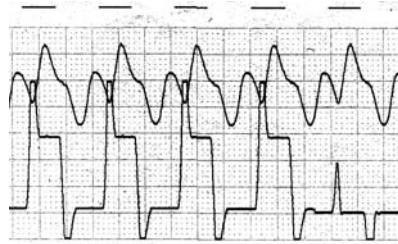
Operation Mode	Possible Cause(s)	Corrective Action
AutoPilot™ Operator	Low Helium tank pressure	Check HE tank. Change as needed.
	Fill/Drain valves malfunction	Change IABP console; call field service.
	Insufficient deflation time	Check timing. If deflation time is very short, i.e. there is no visible BPW baseline, select Operator mode.
Operator	Incorrect timing	Verify Operator mode. Adjust timing until BPW baseline is visible during IAB deflation. If problem persists, select 1:2 assist ratio. Change IABP console.

Possible Helium Loss



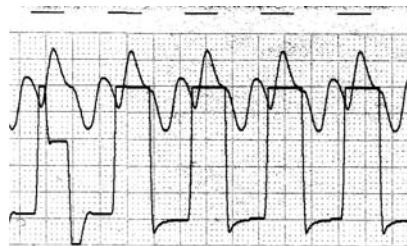
Operation Mode	Possible Cause(s)	Corrective Action
AutoPilot™ Operator	Leak in Tubing or Connections	Perform Leak test and repair tubing as needed.
	Kinked Catheter	Assess for kink and straighten out catheter.
	IAB has not fully exited the sheath	Verify IAB has exited the sheath.
	Balloon connector not properly seated	Disconnect and reconnect the IAB connector.
	Blood in catheter tubing	Remove balloon immediately and insert a new IAB catheter. Disconnect driveline tubing and clamp prior to IAB removal.
	Erratic triggering or arrhythmias	Reduce IAB volume. Select Operator mode and select PEAK trigger. Verify timing.
Operator only	Very late deflation or early inflation	Change to 1:2 assist. If alarm condition does not occur, return to 1:1 and adjust timing so BPW baseline may be observed. NOTE: If HE loss continues in 1:2 assist, perform leak test.
	Erratic triggering or arrhythmias	Change to PEAK trigger mode. Adjust deflation earlier.

Large Helium Leak



Operation Mode	Possible Cause(s)	Corrective Action
AutoPilot™ Operator	<p>IAB tubing disconnected from console</p> <p>Gas line tubing and IAB catheter not tightly connected at catheter bifurcation</p> <p>Leak at IAB connection or in Tygon tubing between console and catheter insertion point</p> <p>Other helium leak. Check for blood in tubing. If blood is observed, remove and replace IAB. If no blood is observed, perform leak test.</p>	<p>Check all IAB connections for leak. Reconnect and/or tighten as needed.</p> <p>Tighten connection.</p> <p>Verify tight connections at all drive line tubing connection points.</p> <p>Perform leak test. Replace or repair IAB as needed.</p>

High Pressure



Operation Mode	Possible Cause(s)	Corrective Action
AutoPilot™ Operator	<p>Kinked IAB Driveline</p> <p>IAB has not exited the sheath</p> <p>Partially wrapped IAB</p> <p>Balloon too large for the aorta</p>	<p>Check tubing for kinks. Find and straighten kink.</p> <p>Verify IAB is out of sheath. Reposition IAB as needed.</p> <p>Notify physician: aspirate IAB, if no blood is present inject air into the balloon and aspirate and remove syringe from IAB connector.</p> <p>Check BPW/AP relationship. Decrease IAB volume as indicated.</p>

AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

High Baseline



Operation Mode	Possible Cause(s)	Corrective Action
AutoPilot™ Operator	Kinked catheter	Assess for kink and straighten out catheter.
	IAB has not exited the sheath	Verify IAB is out of sheath. Reposition IAB as needed.
	Partially wrapped balloon	Notify physician: aspirate IAB, if no blood is present inject air into the balloon and aspirate and remove syringe from IAB connector.
	Improper IAB position	Verify IAB position and reposition as needed.
	Drive System malfunction	Change console. Call Arrow International for service.

Purge Failure



Operation Mode	Possible Cause(s)	Corrective Action
AutoPilot™ Operator	No trigger or reliable trigger signal is lost	Check patient. Verify trigger bands are present on ECG. Verify flashing heart and HR corresponds to patient. Select Operator mode and choose appropriate trigger mode.
	Helium tank not open or inserted properly	Check helium tank. Change as needed.
	Helium tank empty	Replace HE tank.
	Prior alarms not reset	Verify alarms are reset. Reset alarms as needed.
	IAB not connected	Check IAB connections. Attach IAB connector.
	Drive System malfunction	Change console. Call Arrow International for service.

11. AutoCAT®2 Series Operation (continued)

Problem	Operation Mode	Possible Cause(s)	Corrective Action
System Error 1-6	AutoPilot™ Operator		Press alarm RESET. Press pump ON to resume pumping. If this does not correct the problem then turn power OFF then ON. If alarm persists, change IABP console. Call field service.
System Error 7 Key board controller failure Does not interrupt pumping	AutoPilot™ Operator	Umbilical cable disconnected at control head or at console Control head hardware failure	Check umbilical cable connections. Reconnect as needed. If alarm persists, power pump OFF then ON. Change control heads or IABP console. Call field service.
System Error 8 (AutoCAT®2 WAVE™ only) Does not interrupt pumping	AutoPilot™ Operator	FiberOptix™ hardware failure	1. Select alternate AP Source. 2. Change console. 3. Power console OFF then ON. 4. Call field service.

Class 2 Alarms (Automatic Response)

The following Class 2 alarms cause the AutoCAT®2 Series IABPs to:

1. Stop pumping (PUMP STANDBY key illuminates, system not vented)
2. Deflate the balloon
3. Initiate the audio alarm
4. Display alarm message

NOTE: Trigger loss alarms will automatically reset and pumping resumes when trigger is established.

Problem	Operation Mode	Possible Cause(s)	Corrective Action
Standby Alarm Disabled	AutoPilot™ Operator	Standby alarm disabled indefinitely	Press pump OFF. Press pump ON to resume counterpulsation.
Standby longer than 3 MIN	AutoPilot™ Operator	Pump in standby for longer than 3 minutes	<ul style="list-style-type: none"> • Press RESET to clear alarm (alarm will be re-issued in 3 minutes). • Press pump OFF. • Press pump ON to resume counterpulsation. • Press pump STANDBY twice to place pump in standby mode indefinitely.

AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

Problem	Operation Mode	Possible Cause(s)	Corrective Action	
ECG Trigger Loss	Operator only	No ECG waveform	<ul style="list-style-type: none"> • Check patient condition/rhythm. • Check electrode placement and change if necessary. • Check ECG cable connections; reconnect as needed. • Check external monitor and IABP input. • Check/change ECG lead. Check/change ECG source. 	
		Waveform erratic or noisy	Reapply electrodes. Consider using Manual gain.	
		Low waveform amplitude or biphasic QRS complexes	Select another lead (if using external monitor, change lead on monitor). Increase size using gain controls.	
		Inappropriate trigger mode selected	Select another trigger mode and reset timing as needed.	
Pressure Trigger Loss	Operator only	No pressure waveform displayed	<ul style="list-style-type: none"> • Check patient condition. • Check all connections. • Verify correct AP Select source is selected. • Check pressure transducer, IAB catheter and connections for loose connections, repair/tighten if necessary. • Select another trigger mode. • Re-zero AP source. 	
		FiberOptix™ AP sensor (AutoCAT®2 WAVE™ only)	AP sensor cable disconnected	Check connections and reconnect as needed.
		AP sensor cable broken	Replace IAB. Select an alternate AP source.	
		CAL key not inserted or corrupted	Insert CAL. Change IAB catheter. Use alternate AP source.	

11. AutoCAT®2 Series Operation (continued)

Problem	Operation Mode	Possible Cause(s)	Corrective Action
Pressure Trigger Loss (continued)		FiberOptix™ connector needs to be replaced	Replace FiberOptix™ connection. Call field service.
		FiberOptix™ electronics failure	Replace console. Use an alternate AP source. Call field service.
		FiberOptix™ electronic temperature out of range	Replace console. Use an alternate AP source. Call field service.
		Altitude above 10,000 ft.	Use an alternate AP source.
ECG Lead Fault Detected	Operator only	Poor electrode connection	Re-apply electrodes.
		Loose connections	Check ECG cable connections; repair/reconnect as needed. Replace ECG cable.
		3 lead cable detected	Use 4 or 5 lead ECG cable only
		Phono to Nicolay cable detected	Use a Phono to Phono cable for slaving
Trigger Loss	AutoPilot™ only	No ECG/AP/PACER trigger can be found	Check patient condition. Switch to Operator mode. Check ECG/AP sources and change as needed.
		Very small ECG signal	Use ECG gain to increase ECG size.

AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

Class 3 Alerts

The following Class 3 (information only) alerts inform you of a less serious condition. Verify the condition, but immediate action may not be required. Class 3 alerts cause the AutoCAT®2 Series IABPs to:

1. Initiate the audio alarm.
2. Display an alarm message.
3. Pumping is **NOT** interrupted.

Problem	Operation Mode	Possible Cause(s)	Corrective Action
AP FOS Signal Weak	AutoPilot™ Operator	AP sensor failure	Cable is broken. Replace IAB. Select an alternate AP source.
		AP sensor dirty	Replace FiberOptix™ sensor contact.
		AP sensor partially connected	Disconnect AP FiberOptix™ sensor. Verify "click" is heard when sensor is connected.
AP FOS Sensor Out of Range	AutoPilot™ Operator	Electronics operating temperature too high or too low	Select an alternate AP source.
		Altitude above 10,000 ft.	Change altitude. Select an alternate AP source.
AP FOS Cal key Missing or Corrupted	AutoPilot™ Operator	AP FiberOptix™ key not plugged into receptacle	Reconnect CAL key
		AP FiberOptix™ CAL key damaged	Replace IAB. Select an alternate AP source.
Drain Failure	AutoPilot™ Operator	Condensate bottle full	Empty condensation bottle.
		Drain tubing kinked	Straighten drain tubing.
		Drain valve failed to open or system purge not performed	Initiate purge cycle by pressing pump OFF then STANDBY, wait 5 seconds for purge, then press pump ON to resume pumping. Replace IABP console. Call field service.
Deflate Marker beyond 100%	Operator only	Deflation set beyond the R wave	Check deflation timing. Set deflation earlier as needed.
Timing Error	Operator	Insufficient time to inflate/deflate IAB	Check timing; adjust as needed.

11. AutoCAT®2 Series Operation (continued)

Problem	Operation Mode	Possible Cause(s)	Corrective Action
Warning: Battery Inoperative	AutoPilot™ Operator	The AutoCAT®2 will not run in battery mode	Do not disconnect the AutoCAT®2 from AC power source. Check circuit breaker position located in helium compartment.
		Circuit breaker turned OFF	Turn on circuit breaker.
Available Battery Power Less than 20, 10, 5 Minutes	AutoPilot™ Operator	Battery voltage low	Change to AC power as soon as possible to recharge batteries.
System Running on Battery Power	AutoPilot™ Operator	AC power disconnected	Check AC power source. Reconnect the IABP to AC power.
		AC power failure	Arrange for alternate AC power source if failure is expected to exceed 90 minutes. If AC power is connected but not available, change IABP console. Call field service.
Possible ECG Trigger Detected	Operator	QRS complex detected while in INTERNAL mode	Verify ECG is present. Change to ECG or AP trigger mode.
Weaning Step Complete	AutoPilot™ Operator	Weaning time has expired	Evaluate patient hemodynamics and set parameters for next weaning step. If weaning is complete, remove IAB.
Arterial Pressure Alarm	AutoPilot™ Operator	AP has fallen below set limit	Check patient hemodynamics. Check for AP disconnect.
Low Helium Tank Pressure	AutoPilot™ Operator	HE tank is empty	Change HE tank.
		HE tank is OFF	Open HE tank.

AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

Class 4 Alerts

The following Class 4 (information only) alerts inform you of a less serious condition. Verify the condition, but immediate action may not be required. Class 4 alerts cause the AutoCAT®2 Series IABPs to:

1. Display an alarm message.
2. Pumping is **NOT** interrupted.

Problem	Operation Mode	Possible Cause(s)	Corrective Action
Possible Late Deflation	AutoPilot™	Electromechanical delay is less than 100msec, with IAB deflation > 250msec.	Check deflation timing. If deflation is too late and patient hemodynamics are compromised, select Operator mode and manually adjust timing.
Erratic Triggering	AutoPilot™	ECCG connected from bedside monitor. Signal delay is longer than 35msec.	Consider using direct patient connection with 4 or 5 lead ECCG cable.
		Multiple lead switches within 1 minute and no AP signal available	Check ECCG signal quality. Change ECCG electrodes. Change ECCG lead. Adjust Auto gain or select Manual gain. Select Operator mode.
No ECCG Signal Available	AutoPilot™	Multiple trigger switches between AP and Pacer within 1 minute	Check patient condition. Select Operator mode. Select appropriate trigger mode.
		ECCG signal is not available; IABP is triggering on AP or pacer signal	Check ECCG connections. Reconnect ECCG cable or leads. Attach another ECCG source from patient or monitor.
No AP Signal Available	AutoPilot™	AP signal is not available; IABP is triggering on ECCG or pacer signal.	Check AP connections. Reconnect AP cable. Attach another AP source from patient or monitor.
ECCG Lead Fault	AutoPilot™	ECCG electrode disconnected	ECCG lead or cable disconnected but pump is pumping in an alternate trigger mode. Check ECCG lead contact. Check ECCG cable/lead connections. Reconnect ECCG cable/lead. Replace ECCG electrodes.
		3 lead cable detected	Use 4 or 5 lead ECCG cables only.
		Phono to Nicolay cable detected	Use Phono to Phono cable for slaving.

11. AutoCAT®2 Series Operation (continued)

Problem	Operation Mode	Possible Cause(s)	Corrective Action
Arrhythmia Timing not Available	AutoPilot™	Arrhythmia detected but AFIB trigger cannot be selected	R wave deflation cannot be implemented due to user selection or patient condition. Check timing. If R wave deflation is desired, turn Arrhythmia Timing ON. Select Operator mode. Select AFIB trigger mode. Check timing.
Warning: Dead Clock Battery	AutoPilot™ Operator	Internal clock battery malfunction	Call field service. Pump can remain on patient.
Warning: Low Battery for Static RAM	AutoPilot™ Operator	Internal Static RAM battery malfunction	Call field service. Pump can remain on patient.

WARNING:

Do not pump the balloon at a decreased volume that is less than 2/3 of the balloon's capacity. If the balloon volume must be reduced to less than 2/3 of its capacity to achieve a normal waveform, a smaller balloon should be considered.

11. AutoCAT®2 Series Operation (continued)

Performance Checklist for Arrow International AutoCAT®2 Series IABP

Name: _____

Instructor: _____ Date: _____

Skill	Observed	Completed with Assistance	Completed without Assistance
AUTOPILOT™ MODE			
Initial Set-up			
1. Establish Power			
a. Plug Power Cord to Wall Outlet	_____	_____	_____
b. Press Power On Switch	_____	_____	_____
2. Connect Patient ECG			
a. Skin Cable	_____	_____	_____
b. Phono-Phono Cable (Slave)	_____	_____	_____
3. Verify Trigger Acceptance			
a. Assist Marker on ECG	_____	_____	_____
b. Flashing Heart and Heart Rate	_____	_____	_____
4. Connect Arterial Pressure			
a. Transducer Cable	_____	_____	_____
b. Phono-Phono Cable (Slave)	_____	_____	_____
c. FOS (if available)	_____	_____	_____
5. Connect IAB Catheter			
a. Verify IABP Volume Setting	_____	_____	_____
6. Initiate Pumping	_____	_____	_____
7. Change Assist Interval (Starts in 1:1)	_____	_____	_____
Recorder			
1. Record Timing Strip	_____	_____	_____
2. Change Recorder Paper	_____	_____	_____
ECG			
1. Adjust ECG Gain	_____	_____	_____
2. Change ECG Source	_____	_____	_____
Arterial Pressure			
1. Zero FOS	_____	_____	_____
2. Zero Arterial Pressure Transducer	_____	_____	_____
3. Change AP Scale	_____	_____	_____
4. Set AP Alarm (optional)	_____	_____	_____
Assess Balloon Pressure Waveform Characteristics	_____	_____	_____

AutoCAT®2 Series Triggering and Operation

11. AutoCAT®2 Series Operation (continued)

Skill	Observed	Completed with Assistance	Completed without Assistance
Assess Patient Response			
1. Assess Diastolic Augmentation	_____	_____	_____
2. Assess Pressures/Timing			
a. SYS	_____	_____	_____
b. ASYS	_____	_____	_____
c. DIA	_____	_____	_____
d. ADIA	_____	_____	_____
3. Assess IAB Sizing	_____	_____	_____
Alarms			
Verify Alarms On	_____	_____	_____
Helium			
1. Assess Helium Tank Level on Screen	_____	_____	_____
2. Change Helium Tank	_____	_____	_____
Empty Condensation Bottle			
Initiate Battery Operation			
Adjust Balloon Volume			
OPERATOR MODE			
Activate Appropriate Trigger For:			
1. Clear ECG, QRS Normal, Rate 90	_____	_____	_____
2. Clear ECG, QRS Wide, Rate 110	_____	_____	_____
3. Noisy ECG with Excessive Interference	_____	_____	_____
4. AV Sequential Pacemaker-Fixed Rate	_____	_____	_____
5. Atrial Pacemaker-Fixed Rate	_____	_____	_____
6. Irregular Rhythm	_____	_____	_____
7. CPR	_____	_____	_____
Timing			
Assess Inflation and Deflation adjust as necessary	_____	_____	_____



*Figure 21. Arrow International
KAAT II PLUS® IABP*

12. IABP Operation (continued)



*Figure 22. The Arrow International
ACAT® Series Intra-Aortic Balloon Pump.*

Triggering Modes

It is necessary to establish a reliable trigger signal before balloon pumping can begin. The computer in the IAB console needs a stimulus to cycle the pneumatic system which inflates and deflates the balloon. The trigger signal tells the computer that another cardiac cycle has begun. In most cases it is preferable to use the R wave of the ECG as the trigger signal. However, the operator also has the option of using pacing spikes or the arterial pressure waveform as the trigger signal. The seven trigger modes on the Arrow International IAB console are explained below:

ECG Pattern

This is the pre-set trigger mode on the Arrow International IAB console. The computer 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 msec. Widened QRS complexes may not be recognized, such as bundle branch blocks. Rejection of pacer spikes and artifact is automatic.

ECG Peak

The computer analyzes the height and slope of a positively or negatively deflected QRS complex. This may be the trigger mode of choice for wide complex rhythms such as partially paced or bundle branch blocks. Rejection of pacing spikes is automatic. Preferred trigger for HR >140.

A-FIB

The computer analyzes the QRS complex in the same manner as in the peak mode. Deflation of the balloon cannot be controlled by the operator as the balloon will automatically be deflated whenever an R wave is sensed. This may be the trigger mode of choice for rhythms with varying R to R intervals. Rejection of pacing spikes is automatic.

V Pace

The computer uses the ventricular spike as the trigger signal. This mode can be used with ventricular or AV paced rhythms. Because the balloon will inflate and deflate only when a ventricular pacing spike is sensed, it is ESSENTIAL that the patient's rhythm is 100% paced.

A Pace

The computer uses the atrial pacing spike as the trigger signal. This mode can only be used with 100% atrial paced rhythms.

NOTE: FOR PACER TRIGGER MODES, IT IS BEST TO USE THE ECG SKIN CABLE. FOR THE KAAT II PLUS YOU MUST USE EITHER THE SKIN CABLE OR THE PHONO-NICOLAY CABLE (SKIN BEING BEST) TO TRIGGER ON PACER SPIKES.

* For ACAT® Series, a 5 Lead ECG cable can also be used. ACAT®1 PLUS enables use of Phono -to- Phono cable for pacer triggers.

12. IABP Operation (continued)

Arterial Pressure

The computer uses the systolic upstroke of an arterial pressure waveform as the trigger signal. This mode is available as an option for clinical situations where an ECG is unavailable or distorted—i.e.: cardiac arrest, bathing or lead changes, in OR where artifact obscures ECG.

Internal

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 (cardiac arrest, cardiopulmonary bypass). Selection of this trigger mode must be confirmed by an additional keystroke.

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 wave will result in a loss of the trigger signal to the IABP. This will generally cause a TRIGGER LOSS alarm and stop counterpulsation. It is strongly recommended that one of the following options be instituted to minimize patient risk of thrombus formation.

1. If counterpulsation is to be continued and synchronized to the CPR effort, then ARTERIAL TRIGGER should be selected*. If the 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. This is done to prevent inadvertent selection of INTERNAL. In most cases, clinicians may decrease the assist interval or decrease the volume of the IAB. This trigger will maintain movement of the IAB and therefore reduce the risk of thrombus formation.

WARNING: The use of INTERNAL TRIGGER will produce asynchronous counterpulsation and 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 reestablished, 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 and the IABP is turned OFF, the IAB should be manually inflated. Aspirate with a large Luer-slip syringe to check for blood. Inject volume of air of the total balloon volume capacity (i.e. 40cc for a 40cc IAB) into balloon at quick connector and aspirate it immediately. Manual inflation should be done 4 to 5 times every 5 to 10 minutes that counterpulsation is discontinued.

NOTE: Some clinicians have reported the successful use of the ECG TRIGGER by placing an ECG electrode close to the CPR site. The mechanical motion of the ECG Electrode may produce enough voltage on the ECG waveform to be used. If this maneuver is attempted, the PEAK TRIGGER mode should be used.

***Reference:**

Osborn CS, Quaal SJ. Maximizing cardiopulmonary resuscitation in patients with intra-aortic balloon pumps. *Critical Care Nurse*. 18(2):25-27, April 1998.
Quaal SJ. Comprehensive Intra-Aortic Balloon Counterpulsation. 2nd Edition. Mosby Publishing, p.131. 1993.

Initiation of Balloon Pumping

1. Power

- Plug in power cord
- Turn on power switch located in recessed area just below direct patient connections.

2. Helium

- Verify helium supply

3. ECG

- Connect ECG signal using either the Skin Lead cable or the Phono-to-phono cable (Phono-to-Nicolay for KAAT II PLUS®)
- Select appropriate source for ACAT® 1 PLUS and lead for KAAT II PLUS®
- Verify gain is correct, adjust if needed.
- Verify trigger recognition, indicated by the following:
 - Presence of white bands on ECG tracing
 - Flashing red heart next to HR on display screen
 - Flashing LED on selected trigger mode

4. Arterial Pressure

- Connect AP signal using either the Transducer cable or the Phono-to-phono cable
- If using ACAT® 1 PLUS, select appropriate source
- If using Transducer cable, zero arterial line
- Select appropriate AP display scale

5. Purge

- Plug the balloon connector into the pump located next to the power switch
- Press STNDBY on keypad for an automatic 4 beat purge cycle

6. Pump

- Press ON when purge cycle is complete
- Fine tune timing
- Go to 1:1 assist ratio
- Assess balloon sizing

Preset Parameters

ECG - Skin Lead II

AP - For ACAT® 1 PLUS AP from transducer. For KAAT II PLUS® AP automatically selected based on which cable is connected.

Trigger – Pattern

Assist Ratio – 1:2

Timing – safe

IAB Volume – full volume

Alarms – ON

Arrow International 24 Hour Intra-Aortic Balloon Product Hotline:

1-800-447-IABP (4227)

International/Worldwide: 617-389-8628

12. IABP Operation (continued)

What Is It?

During a cycle of inflation/deflation, helium is rapidly moved in and out of the balloon. The environment within the balloon and the surrounding forces that affect balloon behavior all contribute to a predictable pattern of gas flow and pressure. The Arrow International IABP console has an in-line transducer that relays the pattern of gas pressure during the inflate/deflate cycle. The gas pressure characteristics are converted into a waveform that is reflective of the behavior of the gas. This transduced waveform can tell us much about the interaction of the balloon within the patient's aorta. A thorough understanding of the balloon pressure waveform is also important for efficient troubleshooting of the console as most of the alarm states are based on this gas surveillance system.

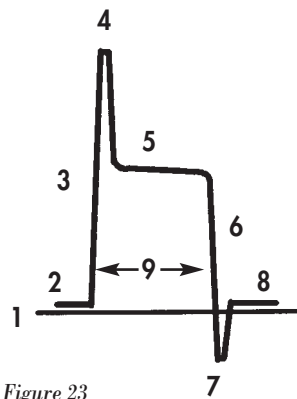


Figure 23

Figure 26. 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 (return to baseline)
8. Return to Baseline
9. Duration of Balloon Cycle

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 a 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.

Figure 26 shows the normal shape of the balloon pressure waveform (BPW). The BPW is shown in blue below the arterial pressure tracing on the balloon pump console. Two very important points to be made about the shape of the BPW are:

1. The width of the BPW corresponds to the duration of balloon inflation during the cardiac cycle.
2. 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.

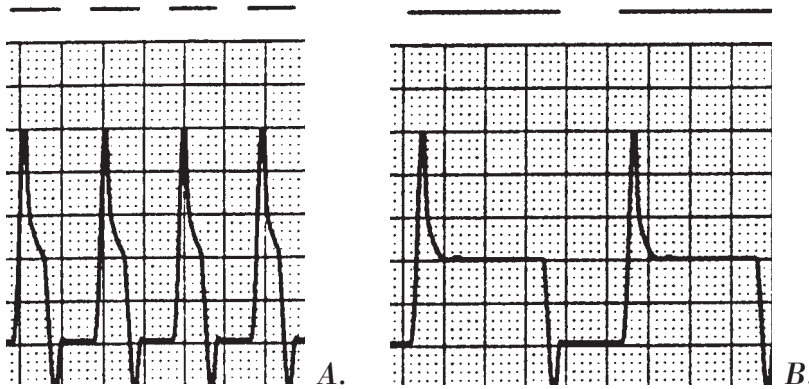


Figure 24. Effects of heart rate on Balloon Pressure Waveform. A shows the changes due to tachycardia and B shows the effects of bradycardia.

Variations of Normal

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

Variations Due to Heart Rate

Since the balloon remains inflated only during the diastolic phase, it would be expected that heart rates and rhythms with longer diastolic phases would have a wider balloon pressure waveform. (Please see Fig. 24)

Changing Balloon Pressure Waveform Width Due to an Irregular Diastolic Phase.

If the heart rate is erratic, such as in atrial fibrillation or there are frequent premature complexes, the balloon pressure waveform will have varying widths as seen in Figure 25.

The normal variant shapes 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, then check the accuracy of timing as this finding is not appropriate. If the BPW width is erratic, and the patient rhythm is very regular, check to see if the trigger stimulus is clear and appropriate.

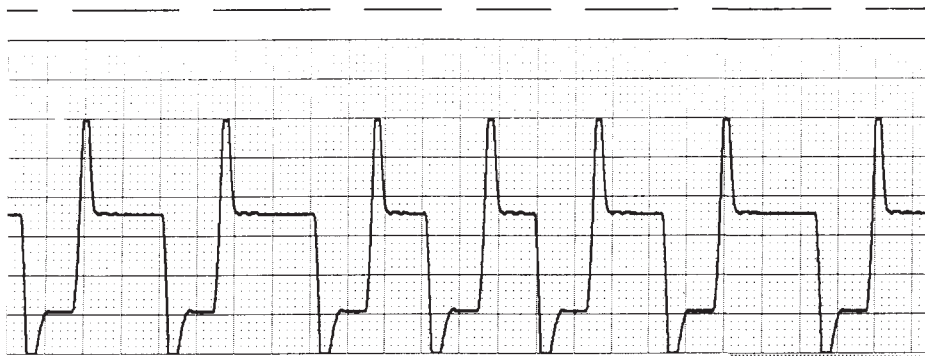
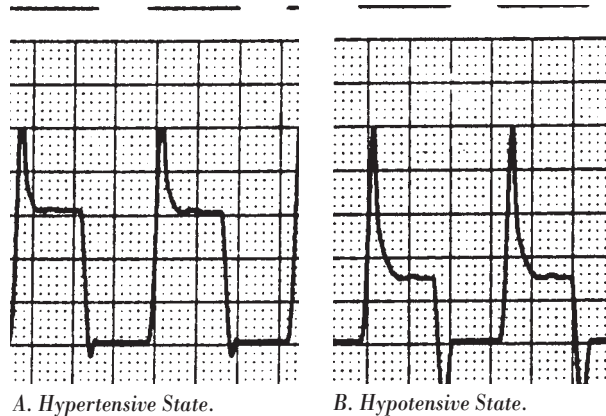


Figure 25. Changing Balloon Pressure Waveform width due to Irregular Diastolic Phase.

12. IABP Operation (continued)



A. Hypertensive State.

B. Hypotensive State.

Figure 26. The Effect of Aortic Pressure on the Balloon Pressure Waveform.

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 not as great, and therefore the pressure in the balloon is also relatively low. Figure 26 shows the effects of aortic pressure on the BPW.

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.

Purge Failure

Figure 27 shows no balloon pressure waveform when an attempt was made to start pumping. If the pump was in OFF and either STNDBY or ON is pressed the pump should purge the system. If it cannot, an alarm (Purge Failure) will sound.

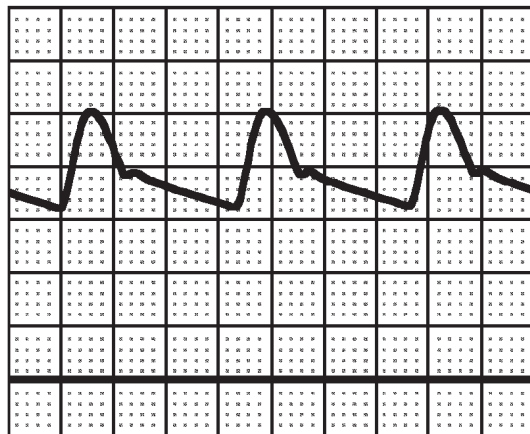


Figure 27. No BPW when pumping attempt is made.

Cause:

The pump can not purge either because there is no valid trigger, there is no helium, or there is a large leak such as the balloon is not connected to the pump.

High Baseline

Figure 28 shows the baseline pressure above +5mmHg. If the baseline is greater than +20mmHg, there will be an alarm associated with this condition. (High baseline) This alarm condition does not occur frequently.

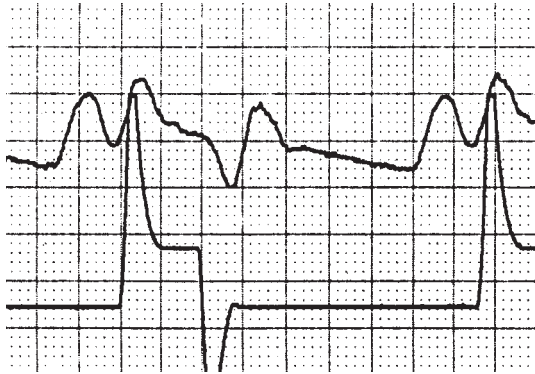


Figure 28. Baseline Pressure above Maximum Limits during Deflation.

Cause:

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 He Loss

Figure 29 shows the opposite condition where the BPW baseline has fallen below -10 mmHg. An alarm will sound (Possible Helium Leak) and the console will suspend pumping until the condition is corrected, and the “pump on” key is pressed.

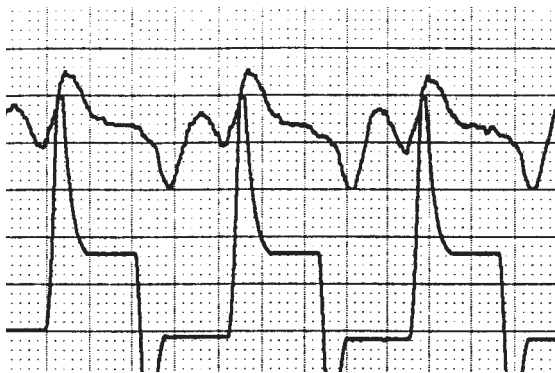


Figure 29. Baseline Pressure below -10mm Hg indicating a small leak.

Cause:

There is a leak somewhere within the gas circuit allowing helium to escape. This may indicate a balloon rupture.

12. IABP Operation (continued)

High Pressure

The next discussion of abnormal balloon pressure waveform morphology will involve a change in the actual shape of the waveform. Figure 30 shows a squared off waveform that can occur with several conditions:

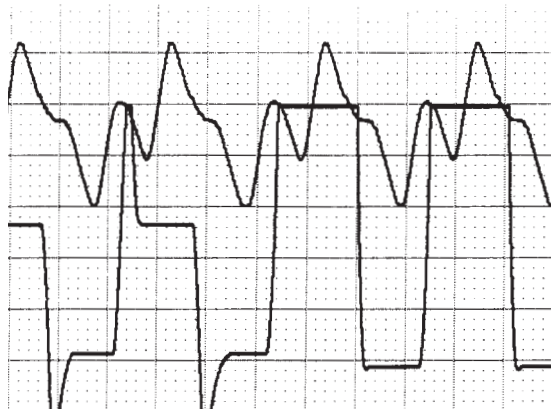


Figure 30. High Pressure during IAB Inflation indicated by Loss of Peak Overshoots and Squared/Rounded Plateau.

Cause:

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 placed or the tail of the balloon may not have exited the sheath. A “High Balloon Pressure” or “He Loss” alarm may be generated.

If at any time balloon behavior should lead the operator to think there exists a potential danger, then the physician should be notified IMMEDIATELY. Situations that need immediate attention of a physician include a suspected balloon leak, suspected insertion within the aortic wall, signs of aortic perforation, and any condition that reduces the effectiveness of balloon pumping in a dependent patient such as incompletely unwrapped balloon or an internally kinked balloon catheter.

WARNING:

Do not pump the balloon at a decreased volume that is less than $\frac{2}{3}$ of the balloon’s capacity. If the balloon volume must be reduced to less than $\frac{2}{3}$ of its capacity to achieve a normal waveform, a smaller balloon should be considered.

CLASS 1 ALARMS:

SYSTEM ERROR
 LARGE HELIUM LEAK DETECTED
 PURGE FAILURE
 HIGH PRESSURE
 HIGH BASELINE
 POSSIBLE HELIUM LEAK

THE PUMP WILL:

- go to PUMP OFF
- deflate the IAB
- initiate an audio alarm
- display an alarm message on the screen
- freeze the waveform display
- activate the recorder to print the last 5 seconds of both the AP and balloon pressure waveforms (7 sec. for ACAT®1)

CLASS 2 ALARMS*:

ECG TRIGGER LOSS
 PRESSURE TRIGGER LOSS
 ECG LEAD FAULT DETECTED
 STANDBY longer than 3 minutes
 STANDBY alarm off

THE PUMP WILL:

- go to pump STDBY (system not vented to atmosphere)
- deflate the IAB
- initiate an audio alarm
- display an alarm message

The following Class 3 and 4 alarms are for information only and alert the operator to less serious conditions that may not require immediate action:

CLASS 3 ALARMS:

DEFLATION > 100%
 DRAIN FAILURE
 BATTERY LIFE LESS THAN 20 MINUTES
 BATTERY LIFE LESS THAN 10 MINUTES
 BATTERY LIFE LESS THAN 5 MINUTES
 SYSTEM RUNNING ON BATTERY
 TIMING ERROR (INSUFFICIENT TIME TO DEFLATE)
 BATTERY INOPERATIVE
 ECG WAVEFORM DETECTED IN INTERNAL TRIGGER**

THE PUMP WILL:

- display an advisory message
- audible alarm (Class 3 Alarm)

CLASS 4 ALARMS:

LOW HELIUM SUPPLY
 DEAD CLOCK BATTERY
 LOW BATTERY FOR STATIC RAM

THE PUMP WILL:

- display message only without an audible alarm (Class 4 alarm)

NOTE: These are considered Class 3 Alarms on the ACAT® Series.

* Pumping will resume automatically with ACAT® Series Class 2 Alarms once problem has been corrected.

** ACAT® Series only

12. IABP Operation (continued)

Arrow International IABP Skills Checklist

Skill	Demo Date/Initials
1. Initial Set Up	
A. Power Up	-----
B. Connect Patient ECG	-----
1. Skin	-----
2. Phono-Nicolay (KAAT II PLUS®)	-----
3. Phono-Phono (ACAT®1 PLUS)	-----
C. Adjust ECG Gain	-----
D. Connect Arterial Pressure	-----
1. Phono-Phono	-----
2. Transducer	-----
E. Initiate 4 beat purge	-----
F. Initiate Pumping	-----
2. Timing, Identify and Correct	
A. Early inflation	-----
B. Late inflation	-----
C. Early deflation	-----
D. Late deflation	-----
3. Change Assist Interval	-----
4. Set Up for Pacemaker Detection/Rejection	-----
(I.D. appropriate ECG cable)	
5. Recorder	
A. Program:	
AP, BPW	-----
AP	-----
Date/Time	-----
B. Change Paper	-----
6. Zero Arterial Pressure Transducer	-----

12. IABP Operation (continued)

Arrow International IABP Skills Checklist (continued)

Skill	Demo Date/Initials
7. Change Arterial Pressure Scale	-----
8. Activate Appropriate Trigger For:	
A. Clear ECG, QRS Normal, Rate 90	-----
B. Clear ECG, QRS Wide, Rate 110	-----
C. Noisy ECG with Excessive Interference	-----
D. A.V. Sequential Pacemaker-Fixed Rate	-----
E. Atrial Pacemaker-Fixed Rate	-----
F. Rapid, Irregular Rhythm	-----
G. Cardiopulmonary Bypass	-----
9. Alarms	
A. Assure Alarms On. If not, turn On.	-----
B. Reset Alarms When Activated and Resume Pumping	-----
10. Change Helium Tank	-----
11. Initiate Battery Operation	-----
12. Empty Water Drain	-----
13. Adjust Balloon Volume	-----
14. Assess IAB Sizing Relative to Patient's PDP	-----



Figure 31

The AutoCAT® IABP offers two distinct modes of operation:

AutoPILOT™ MODE

In AutoPILOT™ mode the console selects the ECG source, AP source, trigger, and timing.

1. Console scans available ECG leads. If the currently selected lead is lost, the console will select the next clear ECG lead.
2. AP source is selected by the console but can be changed by the operator.
3. If trigger is lost, console will select alternate trigger.
4. The console continuously assesses correlation of IAB diameter to patient's aortic diameter. If the IAB is found to be too large for the patient's aorta, the console will decrease the IAB volume to correct this condition.
5. All control keys and knobs, whose functions are adjusted by the console in AutoPILOT™ mode, will not function when this mode is selected.

If, at anytime, the operator prefers to take control of trigger, ECG source, timing, etc. this can be accomplished by selecting OPERATOR mode.

OPERATOR MODE

This is the mode of operating all other models of intra-aortic balloon pumps use. The operator makes all choices regarding ECG source, AP source, trigger, timing, and IAB volume.

1. Once timing is set the console will automatically adjust timing for changes in heart rate and rhythm.

Trigger Modes

The trigger is the event the pump uses to identify the onset of the cardiac cycle (systole). The pump must have a consistent trigger in order to provide patient assist. If the selected trigger signal can no longer be detected, counterpulsation will be interrupted.

Three different trigger selections are available.

ECC

This mode uses the slope of the QR segment to detect the triggering point and reject pacer spikes. This is the recommended trigger mode. ESIS (electrosurgical interference suppression) is active with skin leads. If the patient's rhythm is irregular, the pump will automatically go into ARRHYTHMIA TIMING. If no R-wave is detected, AutoPilot™ will go to AP trigger. If no AP waveform detected, the pump will automatically look for the ventricular pacer spike of a V pacer or AV pacer.

When the pump is in OPERATOR mode, the ECC trigger key can be used to toggle between triggering on the R-wave of the ECG and the V spike of a V or AV paced rhythm.

AP

The systolic upstroke of the arterial pressure waveform is the trigger event. A 14mmHg minimum pulse pressure is required initially then 7mmHg thereafter. Every 64th beat is unassisted when in 1:1 assist and assessed by the console to ensure proper trigger. AP trigger may be used when ECG triggering is not possible. To avoid late deflation, set the deflation point to occur prior to the systolic upstroke. AP triggering is not recommended for use with irregular rhythms.

INT

An internally generated signal provides asynchronous assist. It may be set at 40, 60 or 80 assists per minute. Should the system detect an R-wave while in internal trigger mode, an audible alarm is sounded and the message ECG DETECTED will appear on the monitor screen.

WARNING: DO NOT USE THE INTERNAL TRIGGER MODE IN THE PRESENCE OF ANY INTRINSIC CARDIAC ACTIVITY; SERIOUS COMPETITIVE HEMODYNAMICS WILL RESULT. Available in Operator Mode only.

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 wave will result in a loss of the trigger signal to the IABP. This will generally cause a TRIGGER LOSS alarm and stop counterpulsation. It is strongly recommended that one of the following options be instituted to minimize patient risk of thrombus formation.

1. If counterpulsation is to be continued and synchronized to the CPR effort, then ARTERIAL TRIGGER should be selected*. If the 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 the following options may be considered.
2. A trigger signal generated by the IABP is available through the use of the INTERNAL TRIGGER mode. In most cases, clinicians may decrease the assist interval or decrease the volume of the IAB. This trigger will maintain movement of the IAB, reducing the risk of thrombus formation. Select Operator Mode to access INT trigger.

WARNING: The use of INTERNAL TRIGGER will produce asynchronous counterpulsation and 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 and the IABP is turned OFF, the IAB should be manually inflated. Aspirate with a large Luer-slip syringe to check for blood. Inject volume of air of the total balloon volume capacity (i.e. 40cc for a 40cc IAB) into balloon at quick connector and aspirate it immediately. Manual inflation should be done 4 to 5 times every 5 to 10 minutes that counterpulsation is discontinued.

NOTE: Some clinicians have reported the successful use of the ECG TRIGGER by placing an ECG electrode close to the CPR site. The mechanical motion of the ECG Electrode may produce enough voltage on the ECG waveform to be used.

***Reference:**

Osborn CS, Quaal SJ. Maximizing cardiopulmonary resuscitation in patients with intra-aortic balloon pumps. *Critical Care Nurse*. 18(2):25-27, April 1998.
Quaal SJ. *Comprehensive Intra-Aortic Balloon Counterpulsation*. 2nd Edition. Mosby Publishing, p.131. 1993.

Initiation of Balloon Pumping

1. Power

- Plug in power cord
- Turn on power switch located in recessed area just below direct patient connections

2. Helium

- Verify helium supply

3. Connect ECG Source

- Connect ECG signal using either Skin Lead cable or Phono-to-phono cable
- For maximum flexibility connect both cables
- Verify trigger recognition, indicated by the following:
 - Presence of assist markers under the ECG
 - Flashing heart next to HR on the display

4. Connect AP Source

- Connect AP signal using either the Transducer cable or the Phono-to-phono cable
- If using Transducer cable, zero arterial line

5. Connect IAB Catheter

- Verify correct volumes

6. Select/Verify Operation Mode

7. Initiate Pumping

- Press ASSIST key

8. Assess Timing

**Arrow International 24 Hour Intra-Aortic Balloon Product Hotline:
1-800-447-IABP (4227)**

International/Worldwide: 617-389-8628

What Is It?

During a cycle of inflation/deflation, helium is rapidly moved in and out of the balloon. The environment within the balloon and the surrounding forces that affect balloon behavior all contribute to a predictable pattern of gas flow and pressure. The Arrow International IABP console has an in-line transducer that relays the pattern of gas pressure during the inflate/deflate cycle. The gas pressure characteristics are converted into a waveform that is reflective of the behavior of the gas. This transduced waveform can tell us much about the interaction of the balloon within the patient's aorta. A thorough understanding of the balloon pressure waveform is also important for efficient troubleshooting of the console as most of the alarm states are based on this gas surveillance system.

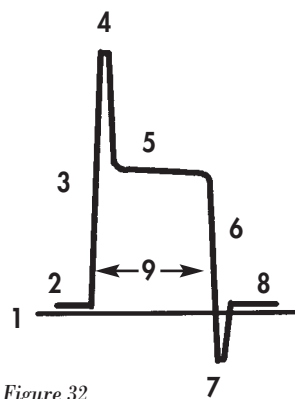


Figure 32

Figure 32. 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 (return to baseline)
8. Return to Baseline
9. Duration of Balloon Cycle

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 a 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.

Figure 32 shows the normal shape of the balloon pressure waveform (BPW). The BPW is shown below the arterial pressure tracing on the balloon pump console. Two very important points to be made about the shape of the BPW that are valuable considerations are:

1. The width of the BPW corresponds to the duration of balloon inflation during the cardiac cycle.
2. 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.

Variations of Normal

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

Variations Due to Heart Rate

Since the balloon remains inflated only during the diastolic phase, it would be expected that heart rates and rhythms with longer diastolic phases would have a wider balloon pressure waveform. (Please see Fig. 33)

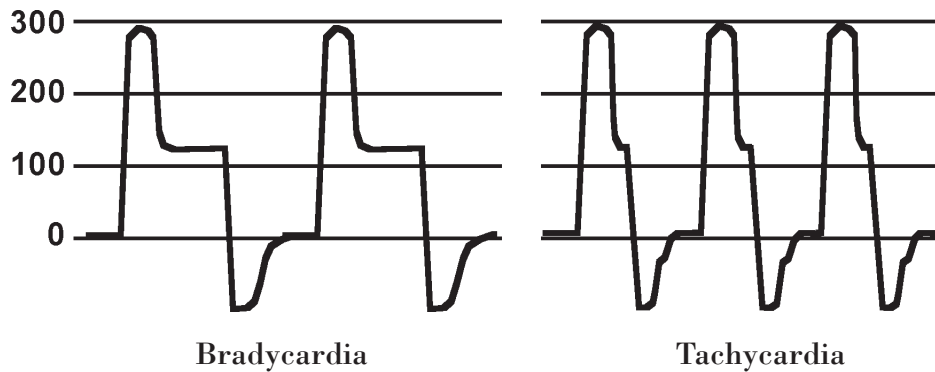


Figure 33. Effects of heart rate on Balloon Pressure Waveform

Changing Balloon Pressure Waveform Width due to an Irregular Diastolic Phase

If the heart rate is erratic, such as in atrial fibrillation or there are frequent premature complexes, the balloon pressure will have varying widths.

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 not great, and therefore the pressure in the balloon is also relatively low. (Please see Fig. 34)

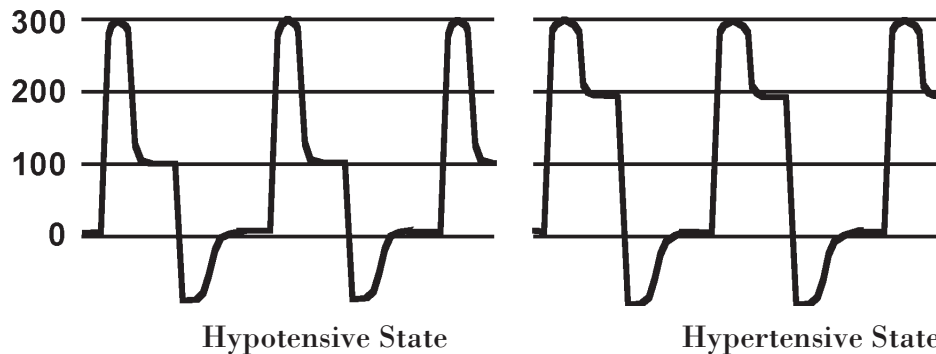


Figure 34. Effects of Aortic Pressure on the Balloon Pressure Waveform

13. AutoCAT® Operation (continued)

Abnormal Variations

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.

High Balloon Pressure Baseline

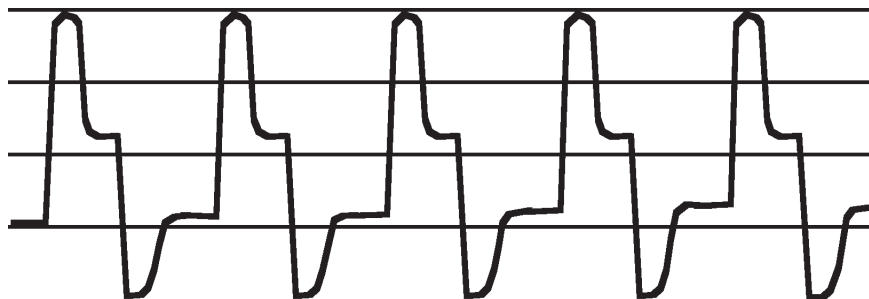


Figure 35. Balloon pressure waveform representing high baseline

DESCRIPTION	The shape of the curve remains normal, with the upward shift of all curve segments. The control system will Auto-vent if the baseline is 18-24mmHg. If the baseline is >24mmHg, the control; system will alarm and turn the pump to STANDBY.
POSSIBLE CAUSES	<ul style="list-style-type: none"> • Auto-vent failure • Possible vacuum malfunction
POSSIBLE ALARMS	<ul style="list-style-type: none"> • FILL PRESSURE • KINKED LINE
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Press ASSIST to see if the problem is corrected • Notify service if there is a vacuum or vent valve malfunction

Low or Falling Baseline

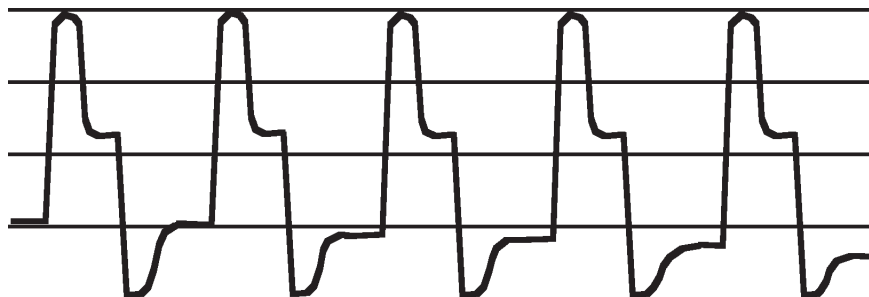


Figure 36. Balloon pressure waveform representing low or falling baseline.

DESCRIPTION	The zero baseline and the balloon plateau begin to drop while the peak inflation artifact remains relatively constant.
POSSIBLE CAUSES	<ul style="list-style-type: none"> • Initial under fill of the intra-aortic balloon • Leak • Gas diffusion when operating in the GAS ALARMS OFF mode for prolonged periods • Auto-fill failure • Balloon disconnected
POSSIBLE ALARMS	<ul style="list-style-type: none"> • GAS LOSS
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Assess for blood in the tubing • Check all connections • If leak repaired press ASSIST

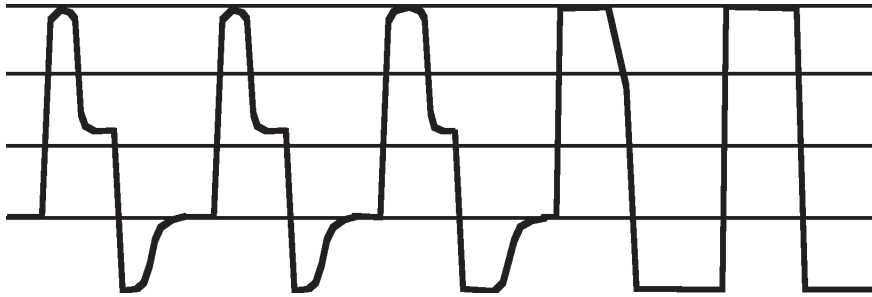
Plateau Distorted or Lost

Figure 37. Distorted balloon pressure waveform

DESCRIPTION	The waveform becomes squared off.
POSSIBLE CAUSES	<ul style="list-style-type: none"> • Kinked catheter. The degree of curve distortion for a kinked catheter will depend on the degree of occlusion.
POSSIBLE ALARMS	<ul style="list-style-type: none"> • KINKED LINE • GAS LOSS
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Remove obstruction to gas flow (e.g. remove kink) • Check balloon placement • Notify service if there is a vacuum or vent valve failure

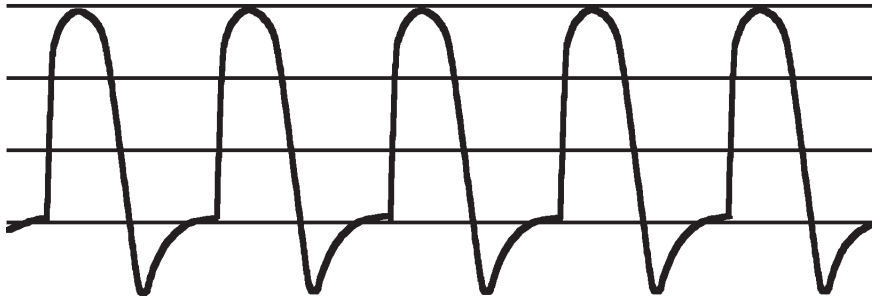
Rounding of Curve and Loss of Plateau

Figure 38. Example of "Balloon Too Large" syndrome

WARNING:

Do not pump the balloon at a decreased volume that is less than 2/3 of the balloon's capacity. If the balloon volume must be reduced to less than 2/3 of its capacity to achieve a normal waveform, a smaller balloon should be considered.

13. AutoCAT® Operation (continued)

Alarm System

The Arrow AutoCAT® system is equipped with a comprehensive surveillance system to alert the operator to alarm and alert conditions. Alarm conditions suspend counterpulsation assist, a message is displayed on the monitor screen and an audible alarm tone is sounded. Alert conditions do not suspend counterpulsation assist, a message is displayed on the monitor screen and in certain conditions an audible alarm tone is sounded.

MESSAGE	PUMP RESPONSE	POSSIBLE CAUSE	OPERATOR ACTION
AP TRIGGER ACTIVE	Message only	System has switched to AP trigger automatically in AutoPilot™ Mode when no ECG trigger can be obtained.	Check ECG source.
ARRHYTHMIA TIMING	Message only	Irregular cardiac rhythm or irregular triggering.	If the rhythm is irregular, treat patient accordingly. Ensure the trigger signal is clear; pump not triggering on artifact. If desired, the automatic afib timing can be overridden by pressing AFIB TIMING OFF .
AVL FAILURE	Audible tone, message, deflate balloon; stop pumping	AVL not functioning properly	Call for service. Try to re-initiate pumping by powering down and back up.
BALLOON DISCONNECT	Audible tone, message, deflate balloon; stop pumping GAS ALARMS OFF Mode: Message only	No pressure in balloon line or balloon line not connected.	Check gas tubing connections at console or at balloon connection. Call for service if all connections are tight and alarm condition persists.
CALL SERVICE	Unable to start pumping, display message.	Computer failure	Call for service. Try to re-initiate pumping by powering down and back up.
CHECK TIMING	Active in OPERATOR Mode only. Message.	Pumping switched from AUTOPILOT mode to OPERATOR mode. Assist interval set to short to fully inflate balloon.	Reminder to assess timing. Adjust as needed. Press ASSIST FREQ to 1:2 to evaluate timing. Readjust timing.
ECG DETECTED	Message and beep tone every 5 seconds.	Cardiac activity (ECG) detected while pumping in INTERNAL trigger.	Switch trigger mode according to patient's rhythm. Readjust timing.
FILL FAILURE	Audible tone, message, deflate balloon; stop pumping GAS ALARMS OFF Mode: None	Failure to fill to 6-10mmHg during fill state.	Press ASSIST key again. Check for adequate supply of helium. If alarm persists, operate in GAS ALARMS OFF override mode until another console available.

13. AutoCAT® Operation (continued)

MESSAGE	PUMP RESPONSE	POSSIBLE CAUSE	OPERATOR ACTION
FILL PRESSURE	Audible tone, message, deflate balloon; stop pumping	Changing balloon volume while pumping. ASSIST again. High helium pressure in balloon line. Condensate removal bottle full	If IAB volume was changed while pumping, depress and begin pumping Notify service if alarm condition continues. Empty bottle
GAS ALARMS OFF	Message only	Pump is set to GAS ALARMS OFF Mode.	Press and hold GAS ALARMS OFF key for 3 seconds to turn this mode off (LED off) and to activate the automatic surveillance systems.
GAS LOSS	Audible tone, message, deflate balloon; stop pumping GAS ALARMS OFF Mode: None	Leak in IAB catheter. Leak in balloon line connections. Insufficient helium pressure.	Inspect balloon gas tubing for blood; if observed, discontinue pumping and notify physician. Secure tubing connections. Check to see if sufficient helium is available. Replace tank if necessary.
HELIUM LOW	Message only. 1 hour autopurge is disabled.	Less than 100psi remaining in helium tank. Helium pressure transducer malfunction.	Replace helium tank. Check that helium tank is properly seated. Ensure that external supply valve is open. Call for service.
KINKED LINE	Audible tone, message, deflate balloon; stop pumping GAS ALARMS OFF Mode: Message only	Kink in balloon catheter or gas tubing.	Find kink or twist in the catheter or tubing and straighten.
LOW AIR DRIVE	Audible tone, message, deflate balloon; stop pumping GAS ALARMS OFF Mode: Message only	Insufficient air drive pressure to inflate the balloon.	Change console. Operate in GAS ALARMS OFF override mode until another console available. Call for service.
LOW VACUUM	Audible tone, message, deflate balloon; stop pumping GAS ALARMS OFF Mode: Message only	Insufficient vacuum.	Change console. Operate in GAS ALARMS OFF override mode until another console available. Call for service.

AutoCAT® Triggering and Troubleshooting

13. AutoCAT® Operation (continued)

MESSAGE	PUMP RESPONSE	POSSIBLE CAUSE	OPERATOR ACTION
LOW (BATTERY)	Message "LOW" inside battery symbol flash and beep tone every 5 seconds	Battery voltage low; less than 20 minutes of battery operation remain.	Attach power cord to AC supply as soon as possible to recharge battery and maintain pumping.
MAP BELOW LIMIT	Message and beep tone every 5 seconds	Mean Arterial Pressure (AP) below operator set limit	Decrease the AP threshold limit. Attend to the patient.
NO TRIGGER	Audible tone, message, deflate balloon; stop pumping Pumping resumes if trigger re-established within 5 minutes	In AUTOPILOT mode: all trigger signals lost to the pump. In OPERATOR mode: the currently selected trigger has been lost. Loose or disconnected ECG leads. ECG signal too small. Monitor input disconnected. If using AP, arterial line dampened, disconnected, or turned OFF. Patient's cardiac activity ceased.	CHECK PATIENT FOR CARDIAC ACTIVITY. Check connections. Check leads and connections. Change lead selection; change trigger source. Check electrode placement. Check input from monitor and secure. Check arterial tracing; flush line; change to ECG trigger; check transducer and monitor input. CHECK PATIENT FOR CARDIAC ACTIVITY.
PUMP IN STANDBY	Message and beep tone every 5 seconds	Pump in STANDBY over 5 minutes.	Press ASSIST to resume pumping. Or press ALARMS MUTE if wish to remain in STANDBY .
REPLACE HELIUM NOW	Message and beep tone every 5 seconds	Helium tank is empty.	Replace helium tank immediately.
SYSTEM RESET	System alarms with logo; unable to start pumping	Improper computer operation.	Call for service. Try to re-initiate pumping by powering down and back up.
UNABLE TO ZERO AP	Alarm and message erase when AP ZERO/CAL button is released	Attempts to ZERO with AP signal present.	Check stopcock and line set-up. ZERO/CAL with stopcock turned off to the patient.
CONSTANT ALARM TONE (NO MESSAGE)	No message, deflate balloon; stops pumping	Prolonged balloon inflation	Call for service. Try to re-initiate pumping by powering down and back up.

Performance Checklist For Arrow International AutoCAT® IABP

Name: _____

Instructor: _____ **Date:** _____

Skill	Observed	Completed With Assistance	Completed Without Assistance
-------	----------	---------------------------	------------------------------

AUTOPILOT™ MODE

Initial Set-Up

- 1. Establish Power
 - a. Plug Power Cord to Wall Outlet _____
 - b. Press Power On Switch _____
 - c. Verify/Select Operation Mode _____
- 2. Connect Patient ECG
 - a. Skin Cable _____
 - b. Phono-Phono Cable (Slave) _____
- 3. Verify Trigger Acceptance
 - a. Assist Marker under ECG _____
 - b. Flashing Heart and Heart Rate _____
- 4. Connect Arterial Pressure
 - a. Transducer Cable _____
 - b. Phono-Phono Cable (Slave) _____
- 5. Connect IAB Catheter _____
- 6. Initiate Pumping _____
- 7. Change Assist Interval (Starts in 1:1) _____

Recorder

- 1. Recorder Timing Strip _____
- 2. Change Recorder Paper _____

Arterial Pressure

- Zero Arterial Pressure Transducer _____
- Set MAP Alarm (Optional) _____

13. AutoCAT® Operation (continued)

Skill	Observed	Completed With Assistance	Completed Without Assistance
-------	----------	------------------------------	---------------------------------

**Assess Balloon Pressure
Waveform Characteristics**

Assess Patient Response

1. Assess Diastolic Augmentation	_____	_____	_____
2. Assess Pressures/Timing	_____	_____	_____
a. Unassisted Pressures	_____	_____	_____
b. Assisted Pressures	_____	_____	_____
c. Mean Arterial Pressure	_____	_____	_____

Alarms

Verify Alarms On	_____	_____	_____
------------------	-------	-------	-------

Helium

Assess Volume of Helium in Tank on Screen	_____	_____	_____
--	-------	-------	-------

Change Helium Tank	_____	_____	_____
--------------------	-------	-------	-------

Empty Condensation Bottle

_____	_____	_____	_____
-------	-------	-------	-------

Initiate Battery Operation

_____	_____	_____	_____
-------	-------	-------	-------

OPERATOR MODE

1. Select ECG Source	_____	_____	_____
a. Skin Leads	_____	_____	_____
b. Monitor Lead (Slaved)	_____	_____	_____
2. Select Arterial Pressure Source	_____	_____	_____
a. Direct Transducer	_____	_____	_____
b. Monitor (Slaved)	_____	_____	_____
3. Select Trigger Mode	_____	_____	_____
a. ECG	_____	_____	_____
b. AP	_____	_____	_____
c. Internal	_____	_____	_____
Change Internal Trigger Rate	_____	_____	_____
4. Timing	_____	_____	_____
a. Assess Inflation and Deflation adjust as necessary	_____	_____	_____
5. Adjust Balloon Volume	_____	_____	_____

Trigger Modes

The trigger is the event the pump uses to identify the onset of the cardiac cycle (systole). The pump must have a consistent trigger in order to provide patient assist. If the selected trigger signal can no longer be detected, counterpulsation will be interrupted.

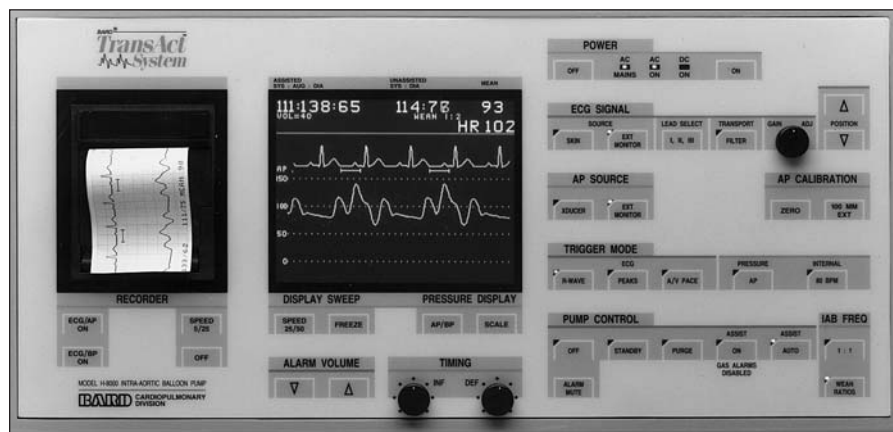
R-WAVE — this mode uses the slope of the QR segment to detect the triggering point and reject pacer spikes. R-wave triggering is the recommended mode, whenever possible.

PEAKS — this mode utilizes either the R-wave or the pacing spike as the trigger. PEAKS is generally used for patients with wide QRS complexes as in fixed-rate ventricular pacing. **WARNING: DO NOT USE PEAKS TO TRIGGER FROM ATRIAL OR AV SEQUENTIAL PACER SPIKES AS PREMATURE INFLATION IN THE CARDIAC CYCLE WILL OCCUR.**

A/V PACE — this mode uses the ventricular spike of the AV pacer to detect the triggering point. AV PACE should only be used in the presence of 100% AV sequential pacing (fixed rate).

AP (PRESSURE) — this mode uses the systolic upstroke to detect the trigger event. A 14mmHg minimum pulse pressure is required. AP trigger may be used when ECG triggering is not possible. To avoid late deflation, set the deflation point to occur prior to the systolic upstroke. AP triggering is not recommended for use with irregular rhythms.

INTERNAL — An internally generated signal provides asynchronous assist. To decrease the internal assist ratio the wean ratio may be utilized. Should the system detect an R-wave while in the internal trigger mode, an audible alarm is sounded and the message ECG DETECTED will appear on the monitor screen. **WARNING: DO NOT USE THE INTERNAL TRIGGERING MODE IN THE PRESENCE OF ANY INTRINSIC CARDIAC ACTIVITY; SERIOUS COMPETITIVE HEMODYNAMICS WILL RESULT.**



14. TransAct® Operation (continued)

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 wave will result in a loss of the trigger signal to the IABP. This will generally cause a TRIGGER LOSS alarm and stop counterpulsation. It is strongly recommended that one of the following options be instituted to minimize patient risk of thrombus formation.

1. If counterpulsation is to be continued and synchronized to the CPR effort, then ARTERIAL TRIGGER should be selected*. If the 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. In most cases, clinicians may decrease the assist interval or decrease the volume of the IAB. This trigger will maintain movement of the IAB and therefore reduce the risk of thrombus formation.

WARNING: The use of INTERNAL TRIGGER will produce asynchronous counterpulsation and 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 reestablished, 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 and the IABP is turned OFF, the IAB should be manually inflated. Aspirate with a large Luer-slip syringe to check for blood. Inject volume of air of the total balloon volume capacity (i.e. 40cc for a 40cc IAB) into balloon at quick connector and aspirate it immediately. Manual inflation should be done 4 to 5 times every 5 to 10 minutes that counterpulsation is discontinued.

NOTE: Some clinicians have reported the successful use of the ECG TRIGGER by placing an ECG electrode close to the CPR site. The mechanical motion of the ECG Electrode may produce enough voltage on the ECG waveform to be used.

***Reference:**

Osborn CS, Quaal SJ. Maximizing cardiopulmonary resuscitation in patients with intra-aortic balloon pumps. *Critical Care Nurse*. 18(2):25-27, April 1998.
Quaal SJ. Comprehensive Intra-Aortic Balloon Counterpulsation. 2nd Edition. Mosby Publishing, p.131. 1993.

Initiation of Intra-Aortic Balloon Pumping**1. Power**

- Plug pump into AC outlet
- Press Power ON key
- Press any other key to silence audible alert

2. Follow HEART acronym

- | | |
|-------------------|---|
| Helium | <ul style="list-style-type: none"> • Verify helium supply • Connect drive line tubing to pump • Ensure IAB VOLUME setting on the display screen is set to the volume of the IAB being inserted |
| ECG | <ul style="list-style-type: none"> • Connect ECG to pump <ul style="list-style-type: none"> - If using the Skin Lead cable select SKIN under ECG SOURCE - If using phono-phono cable select EXT MONITOR under ECG SOURCE • Select good lead for triggering <ul style="list-style-type: none"> - If using Skin Leads, use Lead I, II, III key to toggle through lead choices - If using phono-phono cable select appropriate lead at the monitor • Adjust ECG gain so that there is one assist marker per QRS complex |
| Arterial Pressure | <ul style="list-style-type: none"> • Connect AP to pump <ul style="list-style-type: none"> - If using the Transducer cable select XDUCER under AP SOURCE - If using phono-phono cable select EXT MONITOR under AP SOURCE • Zero and Calibrate AP |
| R-wave Trigger | <ul style="list-style-type: none"> • Verify that R-wave trigger is a valid trigger option at this time by checking to see that there is: <ul style="list-style-type: none"> - One assist marker per QRS complex - Flashing heart by Heart Rate - Accurate Heart Rate • If R-wave is not a valid trigger at this time, select an alternate trigger mode |
| Relative Timing | <ul style="list-style-type: none"> • Pre-set timing to safe setting by either: <ul style="list-style-type: none"> - Setting timing dials in a 12 o'clock position - Use highlight on arterial pressure trace to set inflation to occur just before the Dicrotic Notch and deflation is set to occur just before the next systolic upstroke |

3. Initiate pumping**4. Assess timing**

14. TransAct® Operation (continued)

What Is It?

During a cycle of inflation/deflation, helium is rapidly moved in and out of the balloon. The environment within the balloon and the surrounding forces that affect balloon behavior all contribute to a predictable pattern of gas flow and pressure. The Arrow International IABP console has an in-line transducer that relays the pattern of gas pressure during the inflate/deflate cycle. The gas pressure characteristics are converted into a waveform that is reflective of the behavior of the gas. This transduced waveform can tell us much about the interaction of the balloon within the patient's aorta. A thorough understanding of the balloon pressure waveform is also important for efficient troubleshooting of the console as most of the alarm states are based on this gas surveillance system.

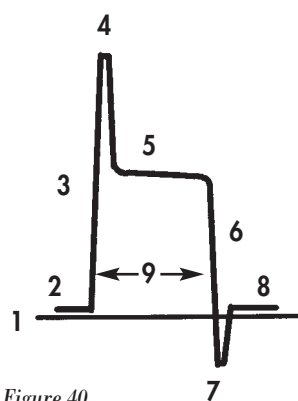


Figure 40

Figure 40. 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 (return to baseline)
8. Return to Baseline
9. Duration of Balloon Cycle

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 a 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.

Figure 40 shows the normal shape of the balloon pressure waveform (BPW). The AP/BP key is used to toggle between displaying the AP and BPW tracing on the display screen. Two very important points to be made about the shape of the BPW are:

1. The width of the BPW corresponds to the duration of balloon inflation during the cardiac cycle.
2. 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.

Variations of Normal

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

Variations Due to Heart Rate

Since the balloon remains inflated only during the diastolic phase, it would be expected that heart rates and rhythms with longer diastolic phases would have a wider balloon pressure waveform. (Please see Fig. 41)

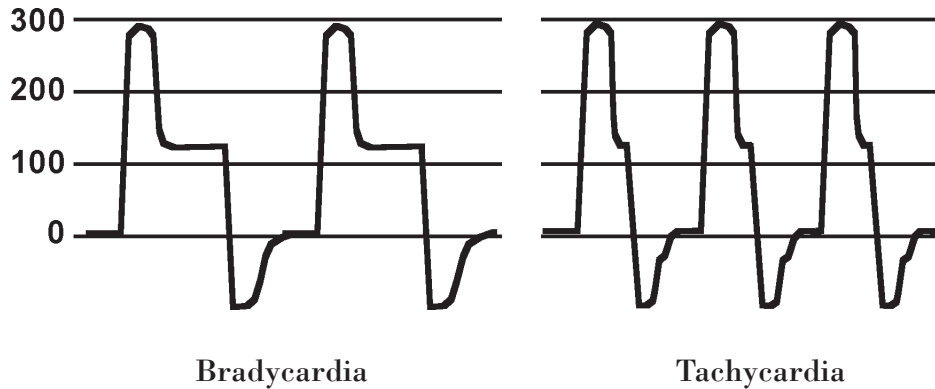


Figure 41. Effects of heart rate on Balloon Pressure Waveform

Changing Balloon Pressure Waveform Width due to an Irregular Diastolic Phase

If the heart rate is erratic, such as in atrial fibrillation or there are frequent premature complexes, the balloon pressure will have varying widths.

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 not great, and therefore the pressure in the balloon is also relatively low. (Please see Fig. 42)

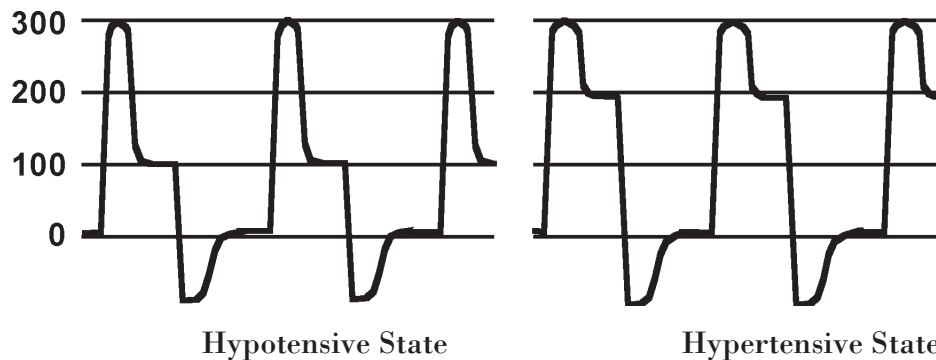


Figure 42. Effects of Aortic Pressure on the Balloon Pressure Waveform

14. TransAct® Operation (continued)

Abnormal Balloon Curve

The most common aberrations in the balloon pressure waveform are:

1. Low or falling baseline
2. High balloon pressure baseline
3. Plateau distorted or lost
4. Rounding of pressure overshoot and loss of plateau

High Balloon Pressure Baseline

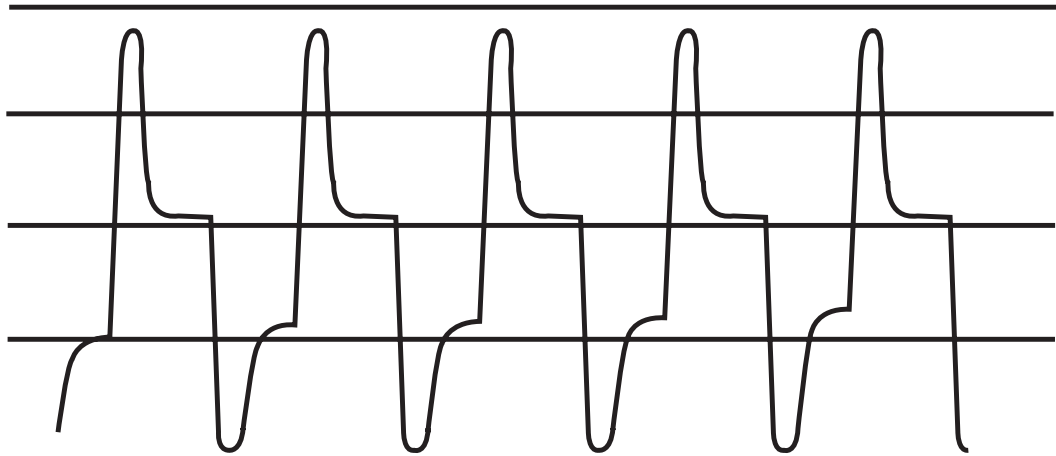


Figure 43. Balloon pressure waveform representing high baseline.

DESCRIPTION	The shape of the curve remains normal, with the upward shift of all curve segments. The control system will Auto-vent, if the baseline pressure is 18-24 mmHg. If baseline is > 24 mmHg, the control system will alarm and shut the pump off.
POSSIBLE CAUSES	<ul style="list-style-type: none"> • Auto-vent failure • Possible vacuum malfunction
POSSIBLE ALARMS	<ul style="list-style-type: none"> • KINKED LINE • POOR DEFLATION • FILL PRESSURE
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Press STANDBY and PURGE to see if the problem is corrected • Notify service if there is a vacuum or vent valve malfunction

Low or Falling Baseline

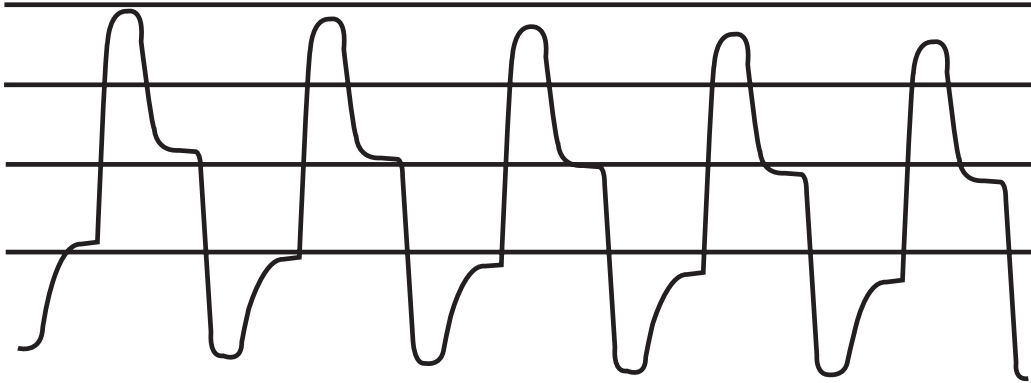


Figure 44. Balloon pressure waveform representing low or falling baseline.

DESCRIPTION	The zero baseline and the balloon plateau begin to drop while the peak pressure overshoot remains relatively constant.
POSSIBLE CAUSES	<ul style="list-style-type: none"> • Initial under fill of the intra-aortic balloon • Leak • Gas diffusion when operating in the ON mode for prolonged periods • Auto-fill failure • Balloon disconnected
POSSIBLE ALARMS	<ul style="list-style-type: none"> • GAS LEAKAGE
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Perform a STANDBY, PURGE, ON, AUTO, sequence • Check all connections • Repair leaks if found • Do not resume pumping until leak has been corrected

14. TransAct® Operation (continued)

Plateau Distorted or Lost

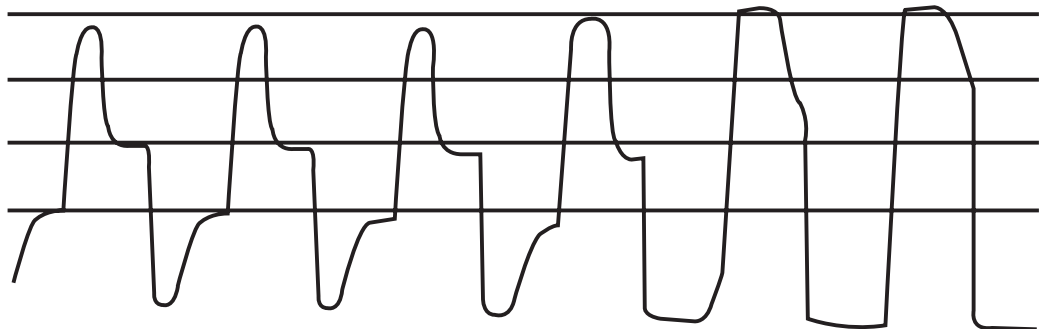


Figure 45. Distorted balloon pressure waveform

DESCRIPTION	The zero baseline is lost, the area within pressure overshoot and zero-undershoot increases. Generally occurs suddenly.
POSSIBLE CAUSES	<ul style="list-style-type: none"> • Kinked catheter. The degree of curve distortion for a kinked catheter will depend on the degree of occlusion. There is less distortion when the catheter is more open (less kinked).
POSSIBLE ALARMS	<ul style="list-style-type: none"> • KINKED LINE
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Notify service if there is a vacuum or vent valve malfunction

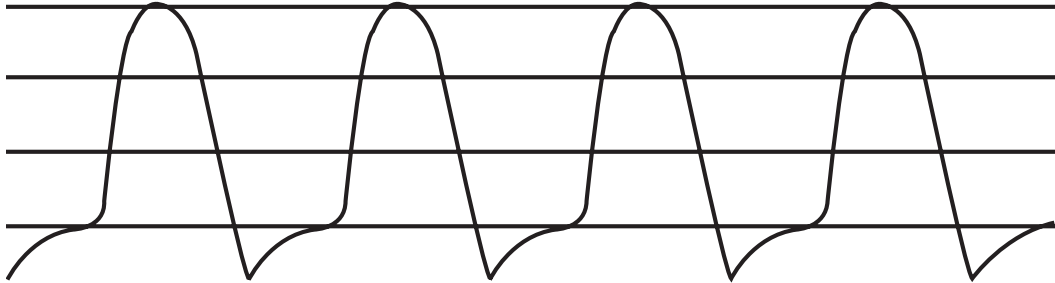
Rounding of Pressure Overshoot and Loss of Plateau

Figure 46. Example of “Balloon Too Large” syndrome

DESCRIPTION	Rounding of pressure overshoot and loss of the plateau. This is called “Balloon Too Large.”
POSSIBLE CAUSES	<ul style="list-style-type: none"> • The inflated balloon has a larger diameter than the aorta. • The balloon is malpositioned in the vessel.
POSSIBLE ALARMS	<ul style="list-style-type: none"> • KINKED LINE • FILL PRESSURE
CORRECTIVE ACTION	<ul style="list-style-type: none"> • Obtain a chest X-ray to check balloon position. • Reduce the helium volume in the balloon catheter by 5-10cc and recheck the pressure waveform. • Check patient hemodynamics frequently. <p>If the “Balloon Too Large” syndrome is due to severe vasoconstriction of the aorta, as the patient’s condition improves the musculature in the aortic wall could relax causing the aorta to dilate (from its constricted state), to a size that will accommodate the balloon.</p>

WARNING:

Do not pump the balloon at a decreased volume that is less than 2/3 of the balloon’s capacity. If the balloon volume must be reduced to less than 2/3 of its capacity to achieve a normal waveform, a smaller balloon should be considered.

14. TransAct® Operation (continued)

Troubleshooting Common Alarm and Alert Conditions

The TransAct® system is equipped with a comprehensive surveillance system to alert the operator to alarm and alert conditions. Alarm conditions suspend counterpulsation assist, a message is displayed on the monitor screen and an audible alarm tone is sounded. Alert conditions do not suspend counterpulsation assist, a message is displayed on the monitor screen and in certain conditions an audible alarm tone is sounded.

MESSAGE	PUMP RESPONSE	POSSIBLE CAUSE	OPERATOR ACTION
No Trigger (ECG)	Audible alarm tone sounds Pump controls go to STANDBY Pumping resumes if trigger is re-established within 5 minutes	Cardiac Arrest ECG leads not connected ECG GAIN set wrong Monitor input disconnected or not selected Low amplitude R-wave	Assess patient for cardiac activity Reconnect ECG leads Increase the gain until one assist marker is present beneath the QRS complex for each identified trigger Check cable from monitor to pump and secure. Select SKIN or EXT MONITOR Adjust GAIN control. Change lead select. Change trigger mode.
No Trigger (AP)	Same as above	Arterial line damped/kinked Monitor input disconnected or not selected Patient pressure inadequate	Check arterial line per hospital policy Check cable from monitor to pump and secure. Select XDUCER or EXT MONITOR Assess patient. Change trigger mode to R-wave.
Gas Leakage	Audible alarm and message activated (AUTO MODE) Pump controls go to OFF (AUTO MODE) No response (ON MODE)	Leak in IAB catheter Loose PVC tubing connection Leak in PVC tubing	Inspect PVC tubing for blood; if observed, discontinue pumping and notify physician Secure PVC tubing connections Change PVC tubing
Kinked Line	Audible alarm and message activated (AUTO MODE) Pump controls go to OFF (AUTO MODE) Message only activated (ON MODE)	Kink in IAB catheter or PVC tubing	Straighten kink or twist Resume assist in the ON mode while observing the BPW

TransAct® Triggering and Troubleshooting

14. TransAct® Operation (continued)

MESSAGE	PUMP RESPONSE	POSSIBLE CAUSE	OPERATOR ACTION
Bal Disconnect (Balloon Disconnect)	Audible alarm and message activated (AUTO MODE) Pump controls go to Off (AUTO MODE) Message only activated (ON MODE)	PVC tubing is not connected to the IAB/pump console	Check PVC tubing connections and reattach Press STANDBY, PURGE, and AUTO
ECG Detected	Audible alarm tone sounds once every five seconds Assist is not suspended	Cardiac activity detected while assisting in INTERNAL TRIGGER MODE	Assess patient for cardiac activity Change trigger mode
Arrhythmia	No audible tone Assist continues	An irregular rhythm has been identified GAIN control set too high/low Inconsistent trigger identification	Assess trigger mode selection. R-wave provides automatic R-wave deflation Assess GAIN control setting. Adjust until one assist marker per trigger appears beneath the QRS Complex Assess ECG connections, lead select, AP line and connection
Set Timing	No audible alarm tone sounds Assist is not suspended	Assist interval set too short to fully inflate balloon	Select 1:2 assist ratio; assess timing and readjust
Gas Alarms OFF	No audible alarm tone Assist is not suspended	Pump Control is in the ON mode	Press AUTO to activate full alarm surveillance
Noisy ECG	Audible alarm tone sounds after 4 seconds of continuous noise Pump controls go to STANDBY	Electrocautery in use Baseline noise in ECG signal Faulty ground in AC outlet	Select Pressure trigger mode Change lead select, electrode patches or lead wires. Select alternate ECG source. Change AC source
BAT LOW(Battery Low)	Audible single beep tone every 5 seconds 20 minutes or less of battery operation remain Assist continues until battery is depleted	AC power cord is not plugged in to console or AC outlet AC main switch is in the off position	Check power cord connection to pump console and AC outlet Check AC main switch on bottom of pump
Helium Low	No audible alarm tone Assist is not suspended	Less than 40 PSI remaining in helium tank External helium tank is not open or connected	Replace helium tank Check external tank connection to bottom of pump. Check gauge and open helium tank if closed

14. TransAct® Operation (continued)

Troubleshooting Common Operational Difficulties

There are times when problems occur that are outside the comprehensive surveillance system. Often, they are due to improper set-up or faulty accessory equipment. This table describes several of these potential problems, the alarm that might be generated (if any), and the corrective actions to take.

PROBLEM	POSSIBLE CAUSE	PROBABLE ALARM OR MESSAGE	CORRECTION
No power or AC MAINS does not illuminate	Power cord not connected to AC Power Fault in the AC power source AC switch in bottom panel is not on Console fuse is blown	BAT LOW (if AC has not been on and battery has run down)	Change AC power source; check connections Check AC power switch Change fuse
No audible alarm	Alarm volume key has been turned to its lowest volume tone		Increase volume tone
No ECG	Improper connections Poor electrode contact Improperly placed electrodes	NO TRIGGER	Check which ECG signal you are using — SKIN or EXT MONITOR and that you have made the proper connections Change the electrodes Ensure that all connections are secure
Wandering ECG baseline	Transport Respiratory variant	ARRHYTHMIA	Engage the transport filter Change the electrodes
No AP waveform	Balloon Pressure has been selected for display Defect in the arterial pressure system	NO TRIGGER (If triggering in AP mode) No hemodynamic values are present on line 1 of the display	Check AP for Display · Check patency of the arterial line · Flush as needed · Check stopcocks · Replace transducer
Transducer cannot be calibrated	Defective transducer		Check calibration procedure Replace transducer

14. TransAct® Operation (continued)

Performance Checklist

Name _____

Date _____

Instructor _____

	INSTRUCTOR INITIALS	CLINICAL SETTING	OBSERVER INITIALS	COMMENTS
Initial Set-Up				
1. Check Helium Tank a. Source <ul style="list-style-type: none"> • disposable • external b. Check minimum PSI				
2. Establish Power a. Plug power cord to wall outlet b. Press power ON c. Press ALARM MUTE d. Verify AC power supply				
3. Connect ECG Source a. Select SKIN or EXT MONITOR b. Adjust ECG GAIN c. Verify trigger acquisition – one assist marker beneath each QRS complex, numerical HR present				
4. Connect AP Source & Zero Transducer a. Select XDUCER or EXT MONITOR b. Press ZERO then 100mm EXT				
5. Select Trigger Note: Console automatically defaults to R-wave a. If necessary select alternative trigger b. Verify trigger acquisition (LED on selected TRIGGER MODE flashes with every detected trigger)				
6. Set Initial Timing a. Select AP from the AP/BP key pad b. While observing the timing markers on the AP waveform adjust the inflation/deflation controls to correspond with the period of diastole				

TransAct® Triggering and Troubleshooting

14. TransAct® Operation (continued)

	INSTRUCTOR INITIALS	CLINICAL SETTING	OBSERVER INITIALS	COMMENTS
Initial Set-Up – (continued)				
7. Connect & Purge IAB Catheter a. Select balloon volume b. Connect IAB catheter and appropriate extender to IAB connection port c. Press STANDBY, PURGE d. Repeat purge sequence				
8. Initiate Pumping a. Press ON to initiate pumping b. Check balloon pressure waveform to ensure the balloon has unfurled c. Press AUTO to activate auto-fill and automatic alarm system				
9. Verify Timing a. Assess inflation then deflation: adjust as necessary to achieve desired hemodynamic effects b. Assess and document timing and patient response to therapy				
10. Assess Balloon Pressure Waveform a. Select balloon pressure waveform from the AP/BP key pad b. Assess and document balloon pressure waveform characteristics				
11. Assess Patient Response a. Assess diastolic augmentation b. Assess afterload reduction c. Assess other hemodynamic parameters				
12. Transport On Cart a. Unplug power cord b. May be removed from bottom panel if desired in transport				
13. Transport Off Cart a. Flip cart pins out b. Tilt pump to its upright position c. Lift pump straight up and out of stand d. May use bedmount if desired				

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.

15. Arrow International IABP Self-Assessment (continued)

6. Contraindications to balloon pumping include:
 - A. Aortic valve insufficiency.
 - B. Mitral valve incompetence.
 - C. Dissecting aortic aneurysm.
 - D. Dissecting thoracic aneurysm.
 - E. Preinfarction 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.
 - 1.
 - 2.
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 _____.

15. Arrow International IABP Self-Assessment (continued)

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:

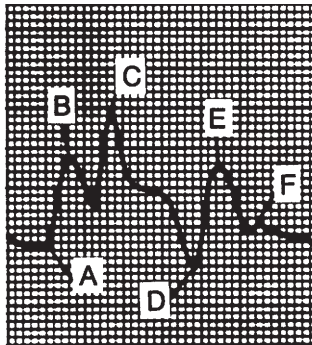
- A. Decrease in afterload.
- B. Decrease in PCWP.
- C. Increase in Preload.
- D. Increase in LV size.
- E. Increase in CO.
- F. Increase in heart rate.
- G. Increase in systemic pulsatile pressure.

Matching Directions

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

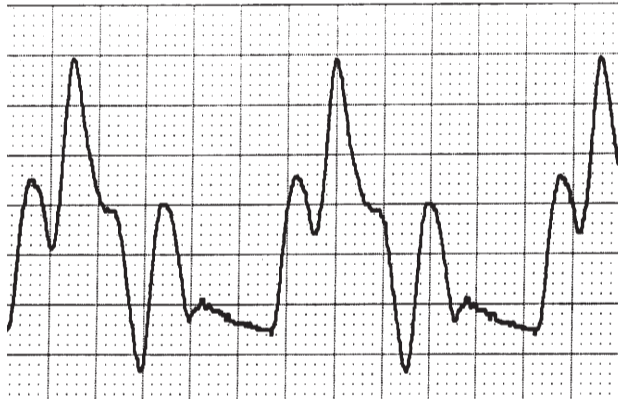
17. Arterial Pressure Tracing

- ___ 1. Peak systole (patient)
- ___ 2. Patient aortic end diastole
- ___ 3. Balloon aortic end diastole
- ___ 4. Dicrotic notch
- ___ 5. Peak diastole
- ___ 6. Assisted systole



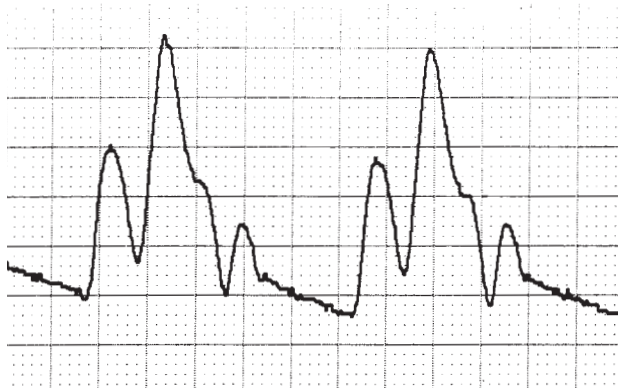
15. Arrow International IABP Self-Assessment (continued)

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



- A. Timing alteration = _____
B. Hemodynamic effect = _____

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



- A. Timing = _____
B. Hemodynamic effect = _____

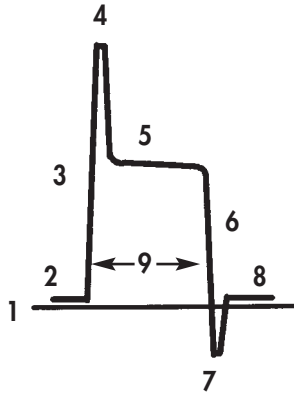
20. Late inflation of the balloon can result in:

- 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.



- ____ peak deflation artifact
- ____ zero baseline on the screen
- ____ peak inflation artifact
- ____ rapid deflation
- ____ rapid inflation
- ____ balloon plateau pressure
- ____ balloon pressure baseline

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

15. Arrow International IABP Self-Assessment (continued)

26. For the ACAT® and KAAT II PLUS® consoles, the major difference between peak and pattern trigger modes is that the pattern mode of recognition:
- A. Measures the width of the QRS complex
 - B. Does not screen muscle artifact as well as peak
 - C. Recognizes only positively deflected QRS complexes
 - D. Is not as discriminating as peak

True or False Directions

Label statements True or False:

27. _____ The dicrotic notch is the landmark used to set balloon deflation.
28. _____ Deflation is timed to occur during the period of isovolumetric contraction.
29. _____ The balloon should be large enough to occlude the aorta, when fully inflated.
30. _____ The most commonly used trigger mode is the arterial pressure mode.
31. _____ The internal trigger mode is acceptable to use for a patient in a normal sinus rhythm.
32. _____ Pacing spikes are automatically rejected in ECG trigger modes.
33. _____ The pacing trigger modes can be used for a patient in a 50% paced rhythm.
34. _____ After percutaneous balloon removal, firm pressure is held at the femoral site for 15 minutes.
35. _____ 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.
36. _____ Blood in the clear plastic tubing of the balloon catheter indicates a hole in the balloon itself.
37. _____ When the console alarms for “high pressure” or “kinked line”, the balloon continues to inflate and deflate.

15. Arrow International IABP Self-Assessment (continued)

<i>Self-Assessment Test Answers</i>	22. 7
1. B	1
	4
2. A	6
	3
3. D	5
	2
4. D	
5. C	23. B or C
6. A, C, D	24. C
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.	25. B or A
	26. A
	27. F
	28. T
8. Complications: Dissection of aorta, emboli, limb ischemia	29. F
9. B	30. F
10. Inflates	31. F
11. Deflates	32. T
12. ECG or R wave	33. F
13. Arterial waveform	34. F
14. B	35. F
15. D	36. T
16. A,B,E,G	37. F
17. 1) B	4) F
2) A	5) C
3) D	6) E
18. A Early inflation	
B Decreased CO, premature closure of aortic valve	
19. A Late Deflation	
B Increased MV02, increased afterload	
20. C	
21. A or D	

15. Arrow International IABP Self-Assessment (continued)

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17. Program Evaluation

**Arrow International –
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Please help us evaluate this program so that we may better meet the needs of future participants. Check the appropriate box.

Instructor: _____

Date: _____

Hospital: _____

4 Hour Program _____ 8 Hour Program _____

	4 Excellent	3 Good	2 Fair	1 Poor	N/A
Program Evaluation					
1. Program met the stated objectives					
2. Content covered topic adequately					
3. Rate overall quality of this program					
4. Rate overall quality of speaker(s)					
5. Rate the program facilities					
6. How well did this program meet your personal objectives?					
7. I can incorporate program content into my practice					
Speaker Evaluation					
1. <i>Objectives</i> – Stated Objectives Met					
2. <i>Audiovisual</i> – Contributed to Presentation					
3. <i>Content</i> – Relevance of Content to Objectives					
4. <i>Presentation</i> – Speaker Qualified and Held Interest					
5. <i>Effectiveness</i> – Speaker was Organized and Effective					
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17. Program Evaluation

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