

**Pre-Inservice  
Self-Study Guide**

**Mechanics of  
Intra-Aortic Balloon  
Counterpulsation**

**Courtesy of Datascope Corp.  
Clinical Services**

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# **PRE-INSERVICE SELF-STUDY**

## **INTRODUCTION**

The intra-aortic balloon was introduced to clinical practice in the late 1960's, primarily for patients in cardiogenic shock. Since then many published reports have documented the efficacy of this mechanical assist device in an expanded number of clinical situations.

The self-study guide is designed to provide the basic principles necessary to understand the theory of counterpulsation and enhance learning in the classroom setting. Included in the guide are a pre- and post test, glossary, and diagrams of assisted and unassisted arterial pressure waveforms.

Datascope is committed to providing quality support to its customers. We hope you find the self-study guide useful.

## **BEHAVIORAL OBJECTIVES**

Upon completion of the self-study the participant will be able to:

1. Identify the five stages of the mechanical cardiac cycle and the resultant arterial waveform.
2. Identify the origin of the coronary arteries.
3. Identify the phase of the cardiac cycle when the majority of coronary artery perfusion occurs.
4. Identify the phase of the cardiac cycle when the majority of myocardial oxygen is consumed.
5. List the major determinants of myocardial oxygen supply and demand.
6. List the two primary and immediate effects of intra-aortic balloon pumping.
7. Identify the following changes in the arterial pressure waveform:  
assisted systole, diastolic augmentation, assisted and unassisted aortic end diastolic pressure.
8. Describe proper timing of the intra-aortic balloon pump.
9. List three indications for intra-aortic balloon counterpulsation.
10. List two contraindications for intra-aortic balloon counterpulsation.

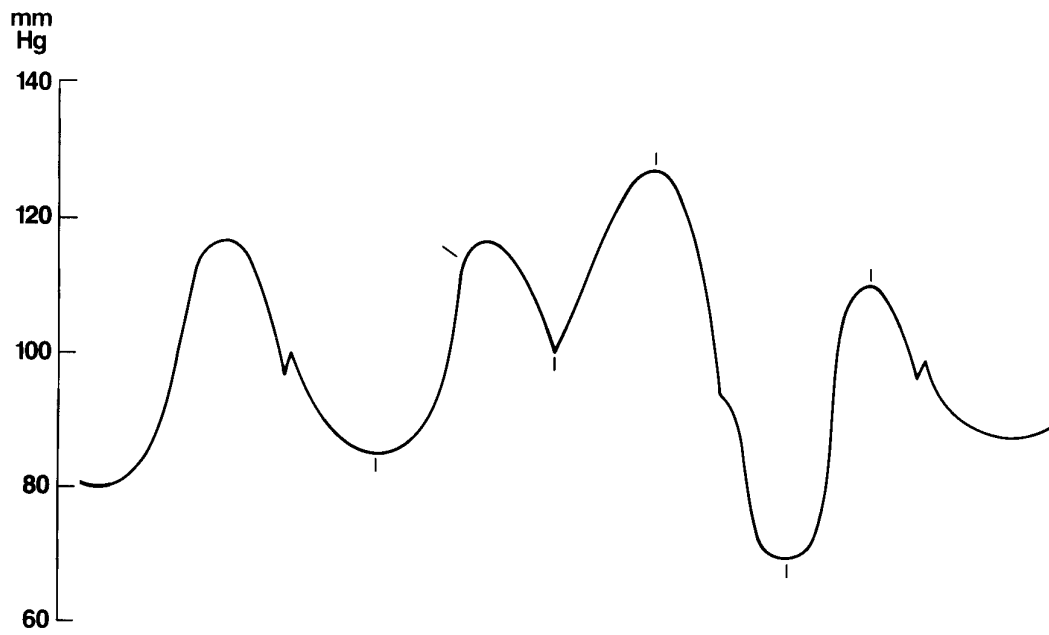
## **PRE-TEST**

1. The primary effects of intra-aortic balloon counterpulsation are:
  - a. increased carotid perfusion and increased renal perfusion
  - b. increased coronary perfusion and afterload reduction
  - c. increased afterload and increased coronary perfusion
2. Proper positioning of the intra-aortic balloon is:
  - a. below the renal arteries and above the right subclavian
  - b. distal to the common carotid and above the diaphragm
  - c. below the left subclavian and above the renal arteries
3. Inflation and deflation occur in concert with the cardiac cycle. Inflation should occur at:
  - a. the aortic notch
  - b. just prior to the opening of the aortic valve
  - c. during peak augmentation
4. The phase of the cardiac cycle where the majority of myocardial oxygen is consumed is:
  - a. the ventricular ejection
  - b. isovolumetric contraction
  - c. atrial systole
5. The phase of the cardiac cycle when the balloon is inflated is:
  - a. systole
  - b. diastole

## **TRUE OR FALSE**

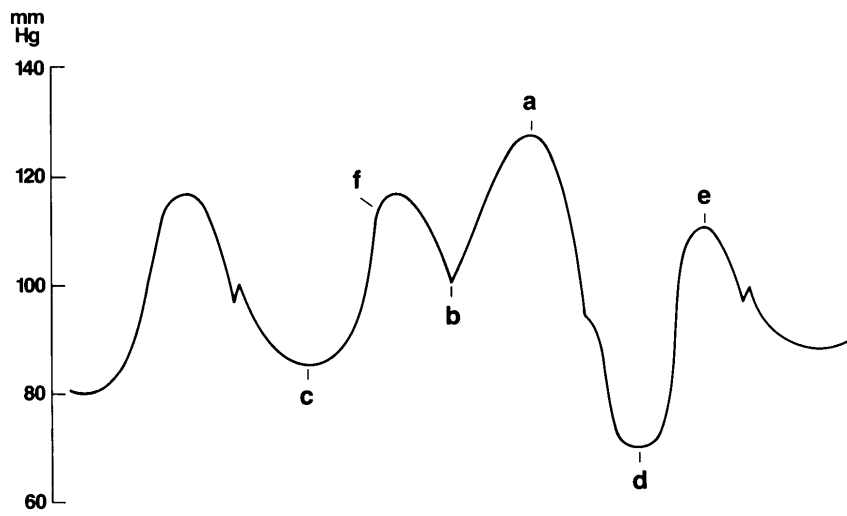
6. Isovolumetric relaxation is the beginning of diastole.
7. Occlusion of the coronary arteries can lead to a medical crisis and be an indication for the intra-aortic balloon pump.
8. Papillary muscle rupture is a contraindication for the balloon pump
9. Coronary arteries receive the majority of their flow during systole.

10. Label the following:
- a. diastolic augmentation
  - b. balloon inflation
  - c. unassisted aortic end diastolic pressure
  - d. assisted end diastolic pressure
  - e. assisted systole
  - f. unassisted systole



## PRE-TEST ANSWERS

1. b
2. c
3. a
4. b
5. b
6. T
7. T
8. F
9. F
- 10.



# MECHANICS OF INTRA-AORTIC BALLOON COUNTERPULSATION

The intra-aortic balloon pump is a cardiac assist device designed to increase coronary perfusion and decrease myocardial oxygen consumption.

To understand the mechanics of intra-aortic balloon counterpulsation, it is first necessary to review the anatomy and physiology of the heart with particular attention to the cardiac cycle, coronary perfusion, myocardial oxygen consumption, and the events of left ventricular failure. We will then show how counterpulsation of the balloon will increase myocardial oxygen supply and decrease myocardial oxygen demands which will assist the failing heart.

The four chambers of the heart are connected by valves. The mitral valve connects the left atrium to the left ventricle, and the tricuspid valve connects the right atrium and the right ventricle. These two valves are known as the atrioventricular valves.

The two atrioventricular valves are the \_\_\_\_\_ valve and the \_\_\_\_\_ valve. mitral  
tricuspid

The \_\_\_\_\_ valve is located between the left atrium and the left ventricle. mitral

The \_\_\_\_\_ valve is located between the right atrium and the right ventricle. tricuspid

The semilunar valves are found between the ventricles and the major arteries. The aortic valve is located between the left ventricle and the aorta, and the pulmonic valve is located between the right ventricle and pulmonary artery.

The two semilunar valves are the \_\_\_\_\_ valve and the \_\_\_\_\_ valve. aortic, pulmonic

The \_\_\_\_\_ valve is located between the left ventricle and the aorta. aortic

The \_\_\_\_\_ valve is located between the right ventricle and the pulmonary artery. pulmonic

All valves open and close in response to changes in pressure within the heart and circulation.

\_\_\_\_\_ cause valves to open and close. Changes in pressure

A review of the events of the cardiac cycle will explain the valvular function.

When the pressure of the atria is higher than the pressure in the ventricles, the AV valves are forced open and the atrial blood volume passively moves across the AV valves into the ventricles. On the left side, the mitral valve opens to allow flow from the left atrium to the left ventricle. On the right side, the tricuspid valve opens to allow flow from the right atrium into the right ventricle. This is the stage of ventricular filling.

Atrial systole then begins. The atria contract in response to an impulse from the sino-atrial node. This inscribes the P wave on the ECG. Atrial contraction accounts for an additional 20%-30% on ventricular filling volume. This additional volume of blood causes ventricular pressure to rise slightly.

During atrial systole, blood volume is forced through the \_\_\_\_\_ and the \_\_\_\_\_ valves from the \_\_\_\_\_ to the \_\_\_\_\_.

mitral, tricuspid  
atria, ventricles

The next stage in the cardiac cycle is ventricular systole and is divided into two phases during which both ventricles contract.

The first phase is isovolumetric contraction. During isovolumetric contraction, the ventricles contract in response to an electrical impulse. The electrical impulse is seen as the QRS complex on the ECG.

Immediately after ventricular contraction begins, the ventricular pressure rises abruptly causing the AV valves to close. The volume of blood within the ventricles just prior to the closure of the AV valves is ventricular preload.

With ventricular contraction, pressure in the ventricles will continue to rise. Because all cardiac valves are closed during isovolumetric contraction, muscular contraction occurs without a change in volume. Wall tension is created as the ventricles work to overcome the pressure or resistance in the arterial circulation. The majority of myocardial oxygen consumption occurs during isovolumetric contraction as the ventricle contracts against arterial resistance. The resistance in the arterial circulation against which the ventricle must pump and the resultant LV wall tension created during systole is afterload.

The first phase in ventricular systole is \_\_\_\_\_.

isovolumetric  
contraction  
increases

During isovolumetric contraction, pressure in the ventricles \_\_\_\_\_ as the ventricles work to overcome the pressure in the arterial circulation.

\_\_\_\_\_ is the resistance or pressure in the arterial circulation against which the ventricle must pump.

afterload

When the pressure in the ventricles exceeds the pressure or resistance in the circulation, the semi-lunar valves open. Hence, on the left side of the heart, when the left ventricular pressure exceeds the systemic pressure in the aorta, the aortic valve opens to allow ejection of left ventricular volume into the aorta. When the right ventricle exceeds the pressure of the pulmonary artery, the pulmonic valve opens to allow flow into the pulmonary circulation.

The ejection phase of the cardiac cycle has three stages: an initial slow ejection stage as the pressure within the ventricle exceeds the pressure in the arterial system; a rapid ejection stage; and a final slow ejection as the volume of blood being ejected from the ventricle decreases.

Ventricular ejection occurs when \_\_\_\_\_ pressure exceeds \_\_\_\_\_ pressure and the \_\_\_\_\_ open.

ventricular, arterial  
semi-lunar valves

At the end of ventricular ejection, the ventricles begin to relax. As the pressure within the ventricles drop below the systemic pressures - the arterial pressure on the left and the pulmonic pressure on the right - the semi-lunar valves close. Isovolumetric relaxation begins with the closure of the semi-lunar valves. This signifies the onset of ventricular diastole.

Ventricular systole ends and ventricular diastole begins when the \_\_\_\_\_

semi-lunar valves close

The semi-lunar valves close when \_\_\_\_\_ drops below systemic pressure.

ventricular pressure

During isovolumetric relaxation, the ventricles continue to relax and the pressure inside the ventricles drop. When ventricular pressure drops below the pressure in the atria, the atrioventricular valves open, ventricular filling occurs and the cycle begins again.

The events of the cardiac cycle can be diagramed on pressure tracings. We will focus our attention on the left side of the heart. See Figure 1. During atrial systole, when the atrium is contracting, the left ventricle is filling with blood volume as the atrium squeezes its contents through the mitral valve. With the increase in ventricular volume, there will be a slight increase in pressure.

The ventricle then receives the electrical impulse to contract. As the ventricle begins to contract, the pressure within the left ventricle rises rapidly. When the ventricular pressure exceeds the atrial pressure the AV valves close.

The mitral valve closes when \_\_\_\_\_ exceeds \_\_\_\_\_.

ventricular pressure  
atrial pressure

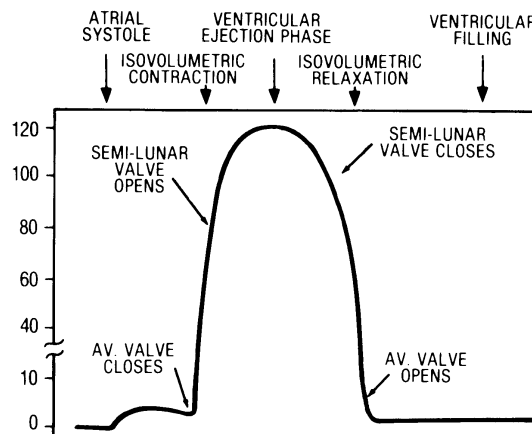
Pressure within the left ventricle builds rapidly until it exceeds the pressure in the aorta. When this happens the aortic valve is forced open and the blood is ejected into the aorta. The pressure falls almost as precipitously as it rose. When it falls below the arterial pressure, the aortic valve closes.

As the left ventricle relaxes, pressure falls further. When it drops below the pressure in the atrium, the mitral valve opens and the cycle starts again.

Ventricular pressure falls as the \_\_\_\_\_ and the \_\_\_\_\_.

ventricle empties  
ventricle relaxes

Figure 1  
Ventricular Pressure  
Waveform



Most of the pressure changes created by the cardiac cycle will also be reflected on the arterial waveform. See Figure 2.

The arterial pressure tracing can be monitored from a central aortic line or from a peripheral arterial line.

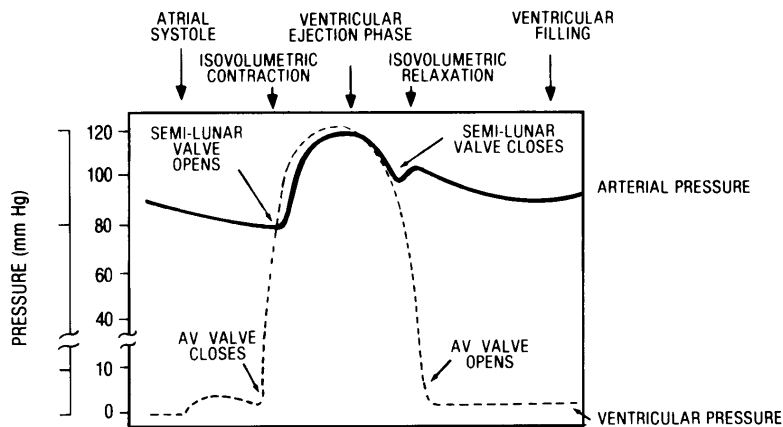
At the beginning of the cardiac cycle before ventricular contraction, the arterial pressure is at the diastolic level. This pressure is determined by the elastic state and vascular resistance of the arterial tree.

As the ventricle contracts, its pressure quickly exceeds the arterial pressure. This pushes the aortic valve open and blood flows into the aorta. Both the velocity and volume of the blood rushing into the aorta raise the pressure of the arterial tree to its systolic level.

Arterial pressure decreases in conjunction with the fall-off in ejection of blood from the left ventricle, however, it will not decrease below its diastolic level which is determined by the arterial walls of the entire circulation. The arterial pressure levels off at the diastolic level while the left ventricular pressure falls toward zero.

As soon as the left ventricular pressure falls below the arterial diastolic pressure, the aortic valve closes. The abrupt closure of the aortic valve causes a brief displacement in the blood column in the aorta which in turn causes a brief drop in pressure within the aorta. This drop is seen on the arterial pressure tracing as the dicrotic notch. The dicrotic notch signifies the beginning of ventricular diastole.

Figure 2  
Arterial Pressure  
Waveform



Arterial blood pressure can be monitored from a \_\_\_\_\_ or a \_\_\_\_\_ arterial line.

central aortic  
peripheral

During ventricular ejection, the \_\_\_\_\_ opens and as blood is ejected pressure in the arterial circulation is \_\_\_\_\_.

aortic valve  
raised to its systolic  
level

When the left ventricular pressure drops below arterial pressure the \_\_\_\_\_ closes.

aortic valve

The \_\_\_\_\_ is created by the abrupt closure of the aortic valve.

dicrotic notch

Two aspects of coronary artery anatomy should be reviewed to understand the theory of balloon pumping. The coronary arteries originate from the aorta immediately above the aortic valve. There are two coronary arteries that originate from the aorta. They are the left main coronary artery that bifurcates into the left anterior descending coronary artery and the circumflex coronary artery, and the right coronary artery.

Most of the blood flow into the coronary circulation takes place during diastole while the ventricular muscle is in a relaxed state. Adequate diastolic pressure must be maintained to ensure perfusion of coronary arteries. This will impact myocardial oxygen supply.

In addition to the coronary arteries and diastolic pressure, heart rate can also have an impact on coronary artery blood flow. An increase in heart rate will shorten diastolic time with each beat and filling time for the coronary arteries will be reduced. This would compromise myocardial oxygen supply.

The majority of coronary artery blood flow occurs during \_\_\_\_\_.

diastole

The coronary arteries originate from the \_\_\_\_\_ immediately above the \_\_\_\_\_.

aorta  
aortic valve

The \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_ can all affect oxygen supply.

coronary arteries  
diastolic pressure  
heart rate

Myocardial oxygen supply must balance myocardial oxygen demands (or myocardial oxygen consumption) to meet the metabolic requirements of the myocardium. Factors that can affect oxygen demands are heart rate, afterload, preload and contractility.

An increase in heart rate will increase myocardial work and oxygen consumption. If afterload or blood pressure is elevated, the workload of the ventricle will increase in order for the ventricle to eject blood against the greater resistance. This increase in workload will increase oxygen demands. An increase in contractility either alone or in response to an increase in preload volume will result in a greater demand for oxygen by the myocardium.

\_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_ can all affect oxygen demands.

preload, afterload  
heart rate  
contractility

If there is injury to the myocardium, a series of physiologic changes occur which will result in an imbalance between myocardial oxygen supply and demand. With cardiac failure, cardiac output falls which will reduce myocardial oxygen supply. In an attempt to compensate, preload, afterload and heart rate increase. This will result in an increase in myocardial oxygen demands. As the failure progresses a cycle develops whereby a greater imbalance between myocardial oxygen supply and demand results in a further failure of the pumping action of the heart. Myocardial oxygen supply will continue to decrease and myocardial oxygen demands will continue to rise. Medical intervention is aimed at correcting the cause of the imbalance between supply and demand. When the cardiac failure is refractory to medical intervention, balloon counterpulsation may be the next step in treatment.

Correcting the cause of the imbalance between \_\_\_\_\_ is the goal in treatment of left ventricular failure.

Myocardial oxygen supply and demand

Let us now describe what the balloon does. The intra-aortic balloon catheter consists of a slender polyurethane balloon mounted on a catheter. The balloon catheter is inserted into the patient's aorta, either surgically or percutaneously by threading the balloon catheter up through the femoral artery into the descending aorta. Percutaneous insertion of the balloon may be a bedside procedure. The ideal position for the balloon is in the descending thoracic aorta, just distal to the left subclavian artery.

The balloon catheter is usually inserted \_\_\_\_\_ through the \_\_\_\_\_.

percutaneously  
femoral artery

The balloon is positioned in the \_\_\_\_\_ distal to the \_\_\_\_\_.

descending thoracic  
aorta  
left subclavian artery

It is connected to a console that shuttles helium in and out of the balloon to inflate and deflate the balloon in concert with the mechanical cardiac cycle. The balloon assists the heart in two ways. It increases aortic pressure during diastole to augment coronary perfusion, and it decreases aortic pressure during systole to lessen the work load on the left ventricle. This is accomplished through inflation and deflation of the balloon. The balloon will be inflated during diastole and deflated during systole.

During diastole, the balloon will be \_\_\_\_\_.

inflated

During systole, the balloon will be \_\_\_\_\_.

deflated

During diastole, when the left ventricle is relaxed and the coronary arteries are filling with oxygenated blood, the balloon is timed to inflate. This increases the pressure pushing blood to the coronary circulation, increasing the oxygen supply to the ischemic myocardium. This is referred to as augmentation of aortic diastolic pressure or diastolic augmentation. Inflation of the balloon augments or increases diastolic pressure.

Inflation of the balloon during \_\_\_\_\_ will \_\_\_\_\_ diastolic pressure. This will increase blood flow to the \_\_\_\_\_ and will increase \_\_\_\_\_.

diastole, augment  
coronary arteries  
myocardial oxygen s  
supply

Just before the left ventricle contracts to pump blood forward, the balloon suddenly deflates. This decreases the pressure against which the heart has to work, and subsequently, the systolic wall tension of the ventricle, or the afterload. This reduction in pressure makes it easier for the heart to empty and allows cardiac output to increase. This is reflected by a reduction in aortic end-diastolic pressure and systolic pressure.

Deflation of the balloon just prior to \_\_\_\_\_ will decrease \_\_\_\_\_.

systole  
aortic end diastolic  
pressure  
myocardial oxygen  
demands

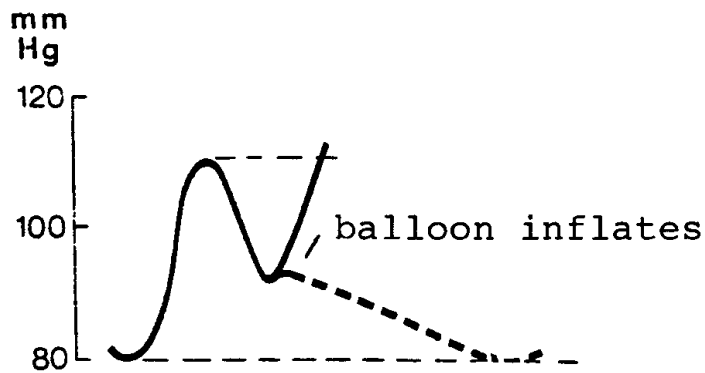
Decreasing the pressure against which the heart has to work will decrease \_\_\_\_\_.

Through a combination of augmentation of aortic diastolic pressure and a decrease in aortic end-diastolic pressure, afterload decreases, cardiac output increases, and blood circulation through the coronary vessels increases.

The balloon pump must be timed accurately to allow full benefit to the patient. The balloon is inflated throughout diastole. Diastole begins when the aortic valve closes and the left ventricle relaxes. This is the period during the cardiac cycle when blood is not being pumped forward by the heart. Having the balloon inflated at this time will not impede forward flow of blood. Closure of the aortic valve is identified on the arterial pressure tracing by the dicrotic notch, the impact on arterial pressure created by the closure of the aortic valve.

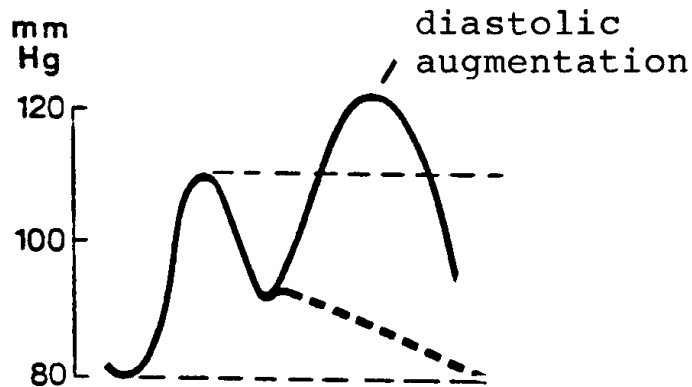
Inflation of the balloon is timed to occur at the dicrotic notch on the aortic pressure tracing. See Figure 3.

Figure 3  
Balloon Inflation



As the balloon inflates, diastolic pressure is augmented, increasing coronary artery blood flow and increasing myocardial oxygen supply. See Figure 4.

Figure 4  
Diastolic Augmentation

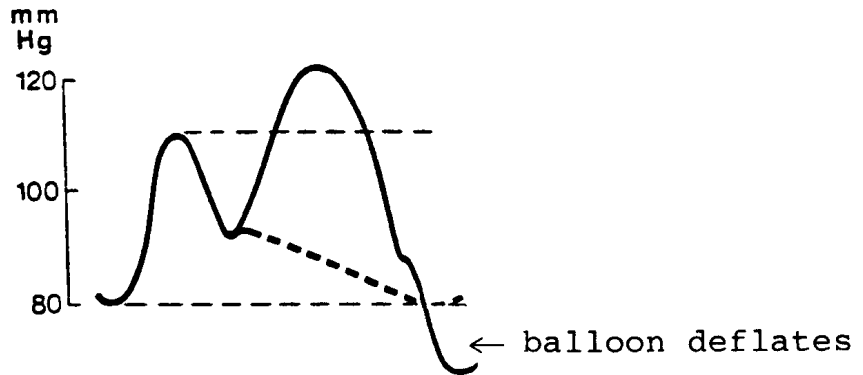


The intra-aortic balloon will be timed to inflate at the \_\_\_\_\_ which signifies the onset of diastole and will remain inflated during \_\_\_\_\_.

dicrotic notch  
diastole

The balloon must be deflated before the aortic valve opens to allow forward flow of blood. The most effective time for the balloon to deflate is immediately before the aortic valve opens. Deflation decreases the aortic end-diastolic pressure. See Figure 5.

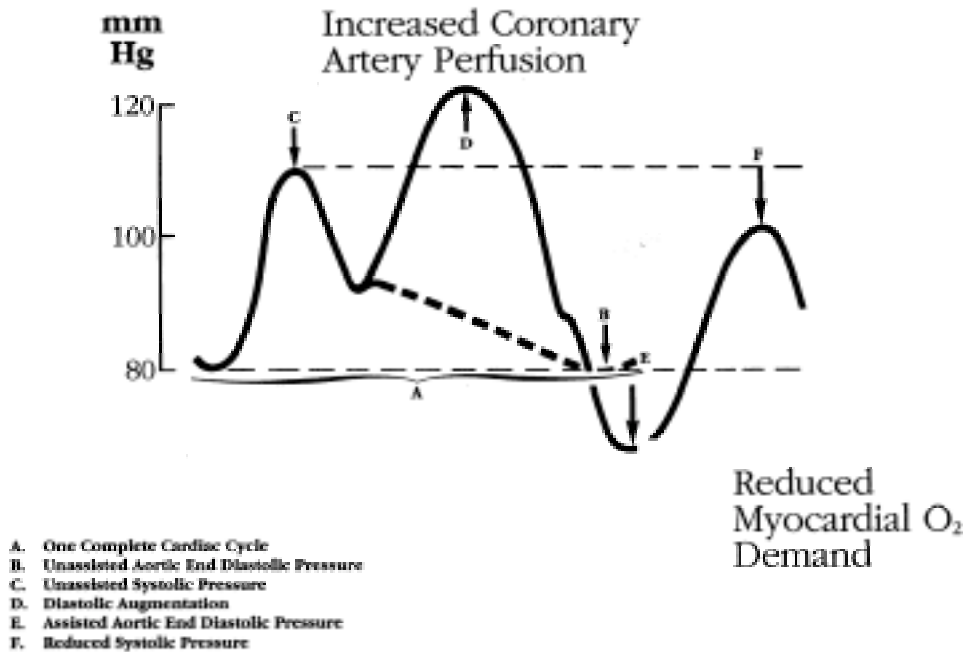
Figure 5  
Balloon Deflation



Deflation is timed, then, to occur just prior to the next systole. The precise timing of deflation is found by observing the pressure tracings with the balloon in place. Proper timing of deflation will result in a lower peak systolic pressure.

See Figure 6 for complete waveform alterations associated with inflation and deflation of the balloon.

Figure 6  
Alterations in Arterial  
Waveform



The balloon is timed to deflate \_\_\_\_\_.

before the aortic  
valve opens  
afterload

Rapid deflation of the balloon will decrease \_\_\_\_\_.

Optimal timing of deflation will result in a \_\_\_\_\_ pressure.

lower assisted  
systolic pressure

In addition to the decrease in myocardial oxygen consumption associated with the decrease in workload and the increase in myocardial oxygen supply due to the increase in coronary perfusion, secondary effects associated with counterpulsation are: a decrease in heart rate, and increase in cardiac output, a decrease in systemic valvular resistance (SVR), a decrease in left ventricular end-diastolic pressure or PACWP and in increase in mean arterial pressure. With an increase in mean arterial pressure, perfusion to all organ systems will be improved. For example, as renal perfusion improves an increase in urine output may be noted. As cerebral perfusion improves an improvement in the level of consciousness is usually seen.

Additional parameters to monitor to assess the effectiveness of balloon counterpulsation are: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

heart rate  
cardiac output  
wedge pressure  
SVR  
mean arterial  
pressure  
urine output  
level of  
consciousness

The balloon has been in clinical use since 1968 in hospitals throughout the world. It has had significant impact on patient survival in the acute setting. Indications for balloon counterpulsation include: cardiogenic shock, weaning from cardiopulmonary bypass, mechanical complications of acute myocardial infarction such as papillary muscle rupture and ventricular septal defect, pre-infarction or post infarction unstable angina resistant to medical therapy and prophylactic support for severely ischemic myocardium during coronary arteriography or anesthesia induction. The balloon has been instrumental as a bridge to cardiac transplantation. Viable myocardium can be supported until a donor organ has been obtained.

Contraindications to the balloon's use are aortic insufficiency, dissecting aortic aneurysm, chronic end-stage heart disease, and severe peripheral vascular disease.

The availability of this mechanical assist device has greatly increased the contribution that nurses and doctors can offer to patients with heart disease. The balloon allows patients to survive acute insults until definitive treatment is able to be performed.

## POST TEST

1. The intra-aortic balloon is usually inserted through the \_\_\_\_\_.
2. \_\_\_\_\_ is defined as the volume and pressure inside the ventricle at the end of diastole.
3. \_\_\_\_\_ is defined as resistance to flow or impedance to ejection.
4. Proper timing of the intra-aortic balloon consists of balloon inflation at the \_\_\_\_\_ and deflation occurring prior to the next \_\_\_\_\_.
5. The coronary arteries originate above the \_\_\_\_\_ and receive the majority of their flow during \_\_\_\_\_.
6. \_\_\_\_\_ supply and \_\_\_\_\_ demand are the primary effects of intra-aortic balloon counterpulsation.
7. Which of the following are indications for the intra-aortic balloon?
  - a. Cardiac support for high risk general surgery and coronary angiography/angioplasty patients.
  - b. End stage cardiac disease
  - c. Incompetent aortic valve
  - d. Peripheral vascular disease
  - e. Brain death
  - f. Mechanical complications of acute MI
  - g. Cardiogenic shock
  - h. Ischemia related intractable ventricular arrhythmias
  - I. Weaning from cardiopulmonary bypass

## POST TEST ANSWERS

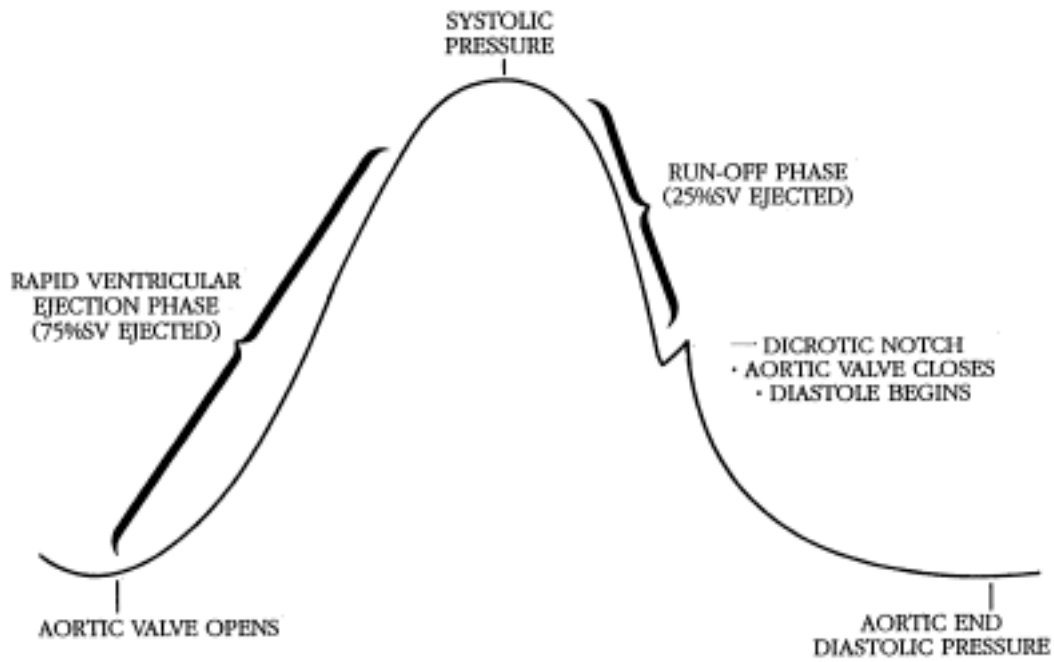
1. femoral artery
2. preload
3. afterload
4. aortic valve  
systole
5. aortic valve  
diastole
6. Increase  
Decrease
7. a.  
f.  
g.  
h.  
I.

## GLOSSARY of IABP TERMINOLOGY

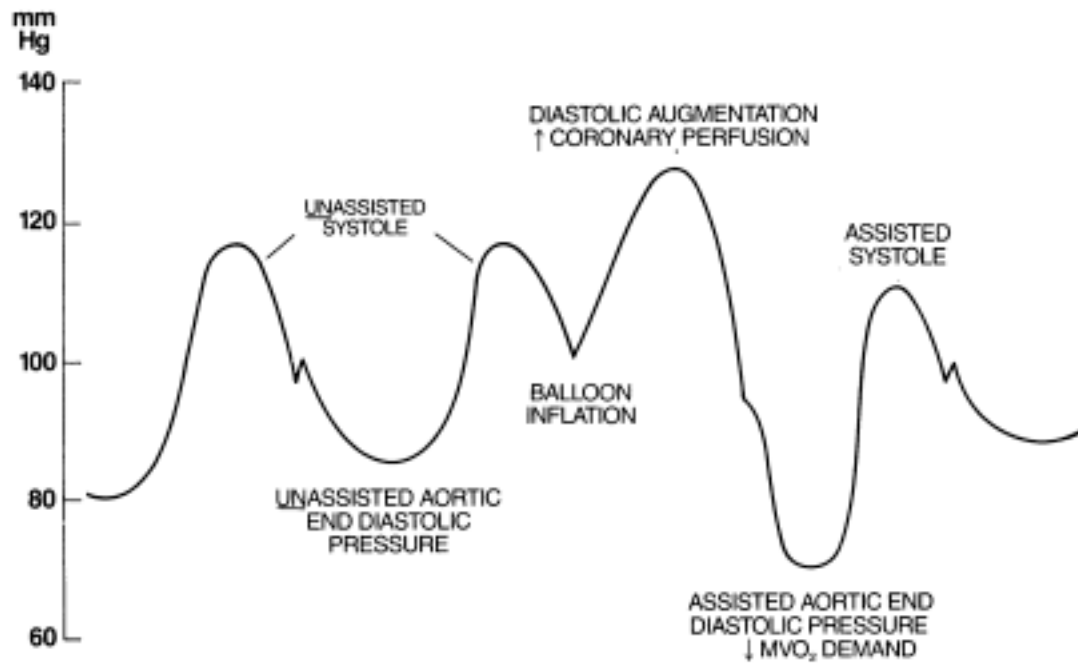
Afterload	Amount of pressure against which the left ventricle must work during systole to open the aortic valve or the amount of wall tension created within the ventricle during the systolic phase of cardiac cycle. Clinically measured by systemic vascular resistance or systolic blood pressure
Assisted Aortic End-diastolic Pressure (AOEDP)	The diastolic pressure in the aorta just prior to the onset of systole which is affected by deflation of the intra-aortic balloon
Assisted Systole (AS)	Systolic pressure which follows an assisted aortic end diastolic pressure. Characteristically it is lower than the unassisted systolic pressure
Atrial Systole	Contraction of the atria which causes an increase in volume to the ventricles, often referred to as "atrial kick"
Autofill	Ability of System 90 Series IABP to automatically refill the closed gas system with a preset volume of helium q2h or whenever the IAB fill button is depressed
Autotiming	Based on a unique timing algorithm, the System 90 Series IABP automatically and instantly adjusts IABP timing for changes in heart rate and rhythm
Blood Pressure	The measurement of peak and trough pressures in the arterial system. It is the force exerted by the blood against a vessel wall
Cardiac Index	Cardiac output divided by the patient's body surface area (BSA) expressed in liters/minute/meter <sup>2</sup>
Cardiac Output	Amount of blood ejected by left ventricle per minute. Determined by multiplying heart rate x stroke volume. Expressed as liters/minute (normal values are 4-6L/min.)
Counterpulsation	Alternating inflation and deflation of the intra-aortic balloon during diastole and systole respectively
Diastole	Relaxation of the heart muscle, begins when the aortic valve closes
Diastolic Augmentation	Resultant elevation of peak diastolic blood pressure due to inflation of the intra-aortic balloon and subsequent displacement of stroke volume
Dicrotic Notch	Signifies aortic valves closure on an arterial pressure waveform
Ejection Fraction	Percent of left ventricular end diastolic volume which is ejected during systole (normal values 60-70%)
Electrocautery	Device consisting of a needle heated by electric current which decreases tissue bleeding by cauterization
ESIS (Electrical Surgical Interference Suppression)	Built in circuitry that suppresses electrosurgical interference (60 cycle) caused by electrocautery equipment used in the operating room
Intra-aortic Balloon	Polyurethane balloon attached to a vascular catheter which is placed in the aorta for the purpose of counterpulsation
Intra-aortic Balloon Pump	The console to which the intra-aortic balloon is attached in order to achieve safe, effective counterpulsation
Isovolumetric Contraction	Phase in mechanical cardiac cycle when all four valves are closed. There is no change in volume but a rapid increase in ventricular pressure due to the ventricle attempting to overcome the unassisted end diastolic pressure. The majority of

	myocardial oxygen is consumed during this phase. This is the onset of systole
Isovolumetric Relaxation	Phase in mechanical cardiac cycle when all four valves are closed. There is no change in ventricular volume but a rapid decrease in pressure. This is the beginning of diastole
Manual Timing	Timing logic which requires readjustment by the operator of inflation and deflation slide controls for change in heart rate of 10-12 beats per minute
MAP-Mean Arterial Pressure	The time-averaged pressure throughout each cycle of the heartbeat
Pacer Reject	The ability of the System 90 Series IABP to distinguish between an R wave and a pacer spike. The pacer spike is rejected and the R wave is used as the trigger event
Preload	The left ventricular end diastolic volume and the amount of pressure it exerts on the walls of the left ventricle. Clinically, it is assessed by the PCWP (pulmonary capillary wedge pressure)
Rapid Ventricular Ejection Phase	Period following opening of aortic valve where approximately 75% of stroke volume is ejected from left ventricle
Refractory Period	A 300 msec window after the R wave in which the IABP will not accept another trigger event
Safety Chamber (90/90T) Safety Disk (95/97/97e/98)	Closed gas, volume limiting chamber. It is filled with helium during the autofill cycle
"Slaving"	The ability to bring a signal (ECG/pressure) from an external source into the IABP console
Stroke Volume	Amount of blood ejected by the left ventricle with each beat
Suprasystolic Augmentation	Diastolic augmentation greater than systolic pressure
Systemic Vascular Resistance	Resistance to ventricular ejection. Clinical measure of afterload. (normal value 900-1200 dynes/sec/cm <sup>-5</sup> )
Systole	Phase of the cardiac cycle in which the heart is contracting
Threshold	Minimum voltage required by IABP to sense ECG trigger
Timing	Inflation and deflation of the IABP in concert with the mechanical cardiac cycle
Trend	Function of the System 97/97e/98 to store heart rate, systolic, diastolic, mean and diastolic augmentation pressures for up to eight hours
Trigger	Signal used by the IABP to identify the beginning of the next cardiac cycle and deflate the IAB (if not already deflated)
Unassisted Aortic End Diastolic Pressure	Aortic end diastolic pressure without IABP intervention
Unassisted Systole (UAS)	Systolic pressure which does not follow deflation of the IAB
Ventricular Filling	Passive flow of blood from atria into ventricles

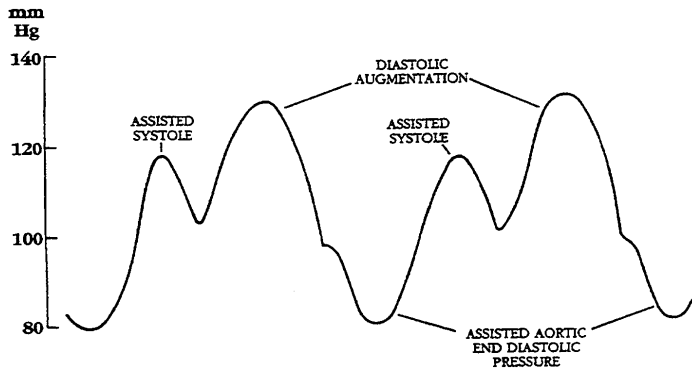
## Normal Arterial Waveform



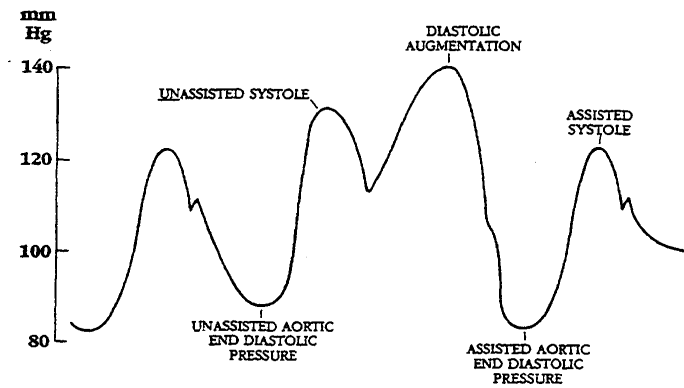
## Arterial Waveform Variations During IABP Therapy



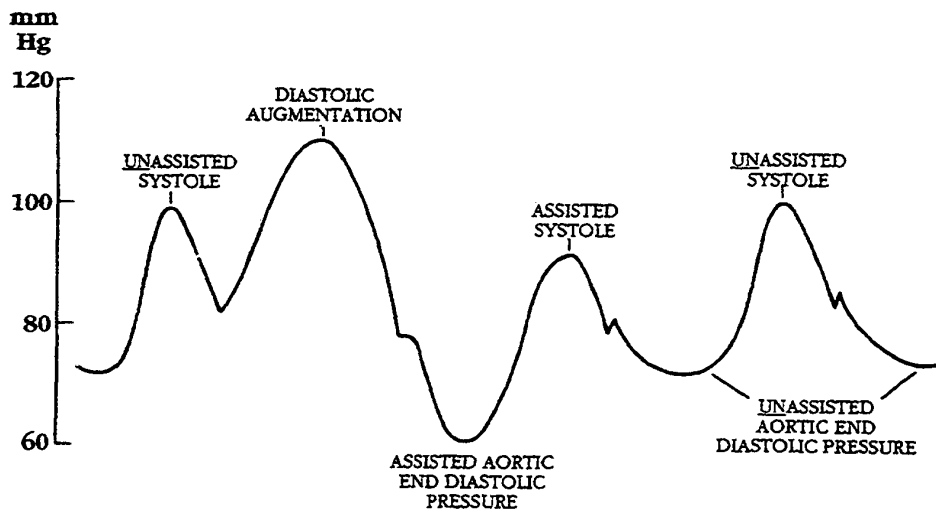
### 1:1 IABP Frequency



### 1:2 IABP Frequency



### 1:3 IABP Frequency



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