MedStar Washington Hospital Center

Knowledge and Compassion
Focused on You

Intra-aortic Counterpulsation

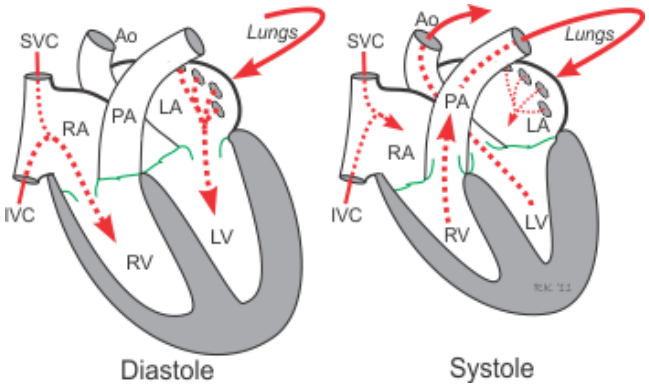
March 2016

Behavioral Objectives

At the conclusion of this program, the participants will be able to:

- ❑ Describe the two physiological effects achieved by the mechanics of inflation and deflation of the IABP as it relates to the cardiac cycle illustrated by an augmented arterial pressure waveform
- ❑ Identify four indications and three contraindications for IABP therapy
- ❑ Delineate the major clinical complications associated with IABP therapy
- ❑ Discuss operation and troubleshooting of the CARDIOSAVE IABP

Cardiac cycle

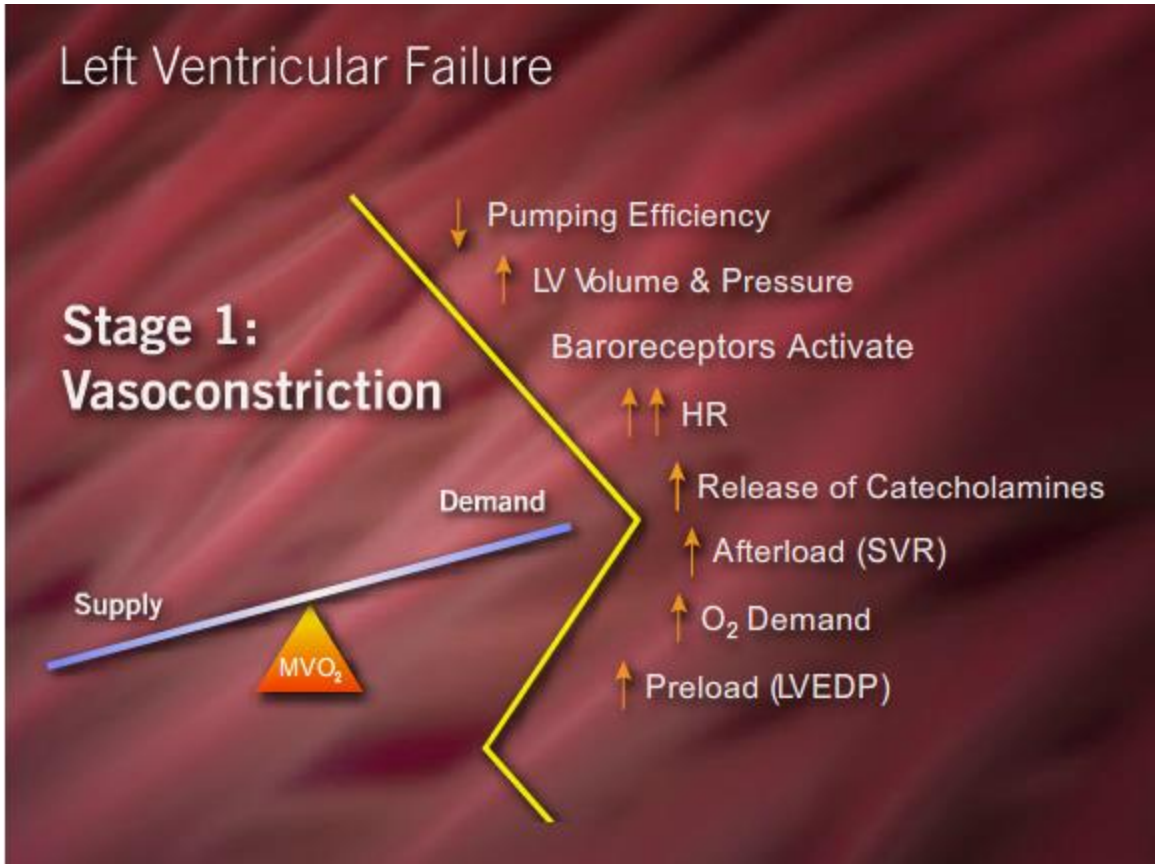


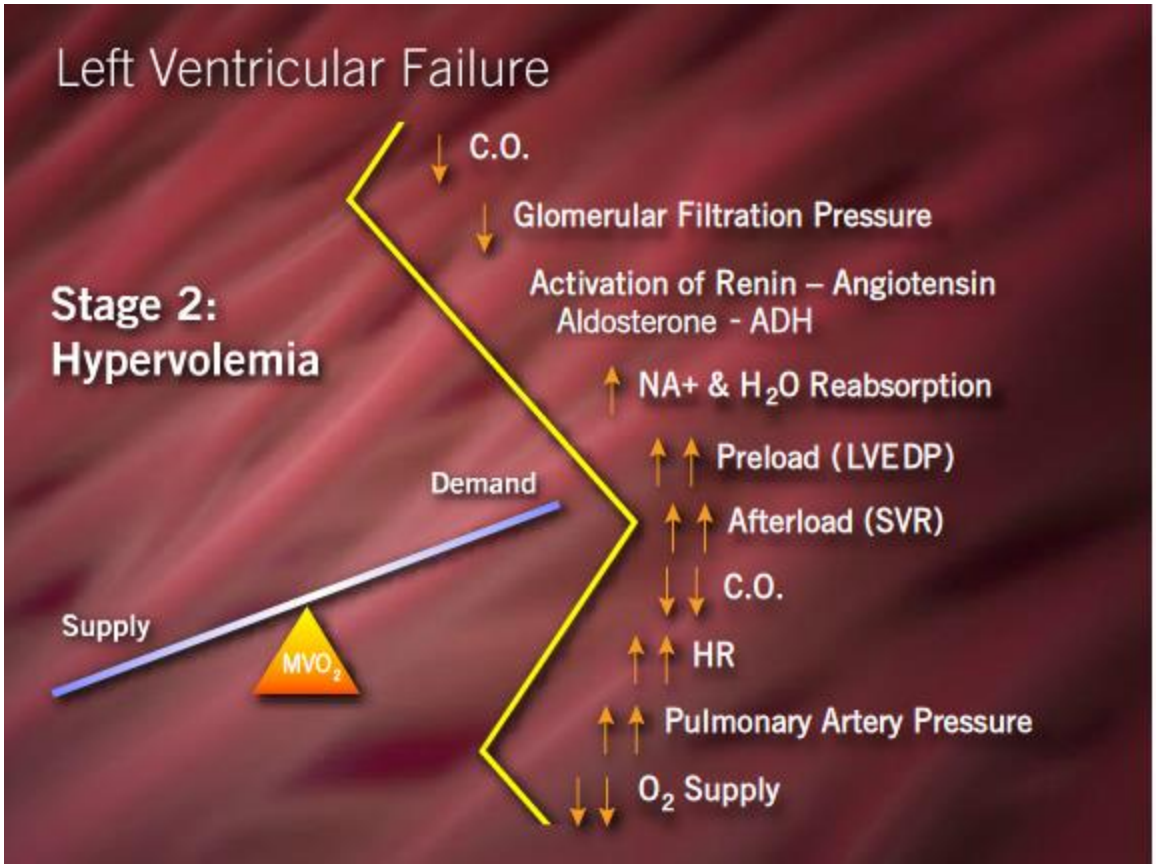
- Relaxation→ diastole filling
  - Atrial kick
- Contraction → systole filling
  - Isovolumetric contraction: all valves closed→ ventricular ejection (AV/PV open)

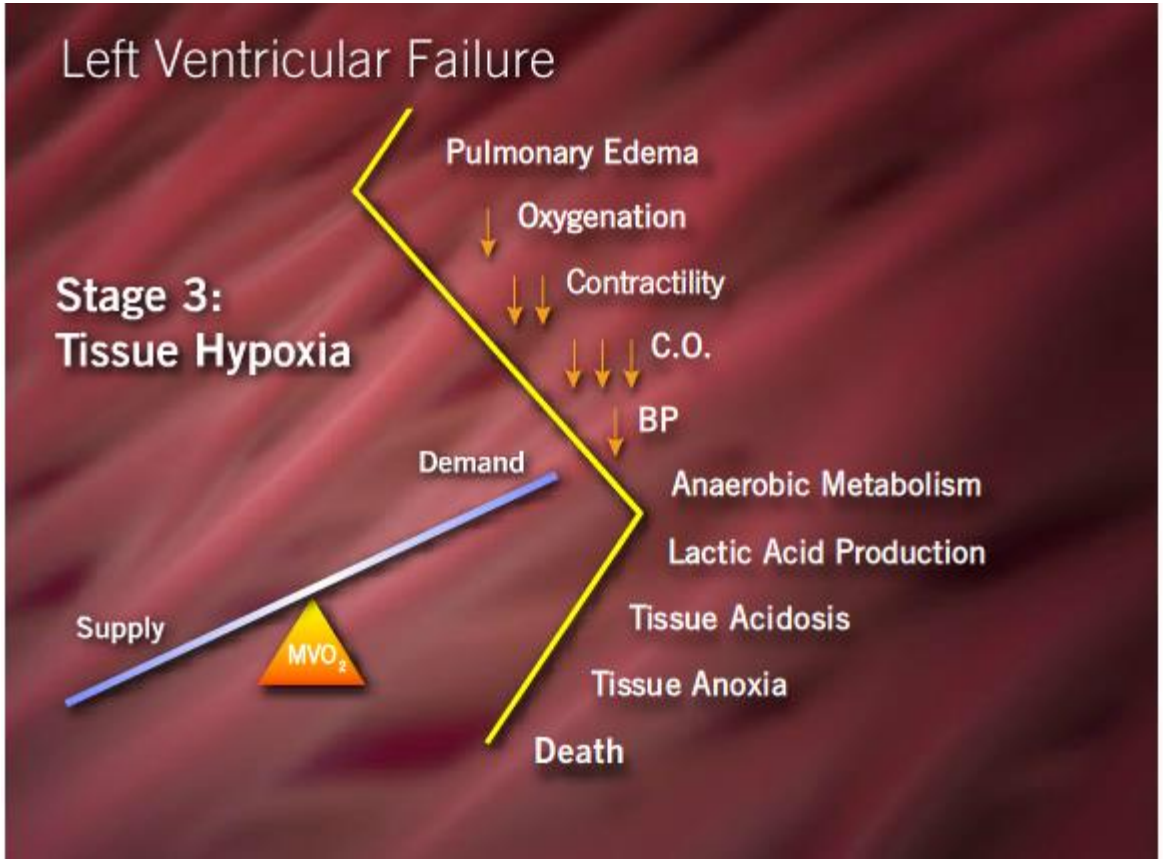
OVERVIEW OF CARDIAC PERFORMANCE

MAQUET
GETINGE GROUP

- Coronary perfusion
  - Coronary artery anatomy
  - Diastolic time/pressure
- Oxygen extraction
  - Hemoglobin & PaO_2
- Heart rate
- Afterload
- Preload
- Contractility


Left Ventricular Failure
Stage 1:
Vasoconstriction
Pumping Efficiency
LV Volume & Pressure
Baroreceptors Activate
HR
Release of Catecholamines
Afterload (SVR)
O_2 Demand
Preload (LVEDP)
Demand
Supply
MVO_2


Left Ventricular Failure
C.O.
Glomerular Filtration Pressure
Activation of Renin – Angiotensin
Aldosterone - ADH
NA+ & H_2O Reabsorption
Preload (LVEDP)
Afterload (SVR)
C.O.
HR
Pulmonary Artery Pressure
O_2 Supply
Stage 2:
Hypervolemia
Demand
Supply
MVO_2


Left Ventricular Failure
Stage 3:
Tissue Hypoxia
Pulmonary Edema
Oxygenation
Contractility
C.O.
BP
Demand
Anaerobic Metabolism
Lactic Acid Production
Supply
MVO2
Tissue Acidosis
Tissue Anoxia
Death

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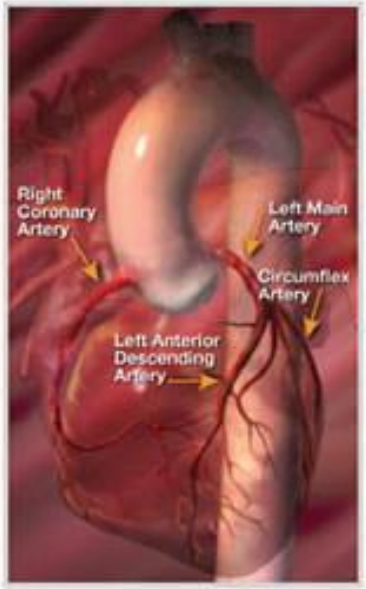
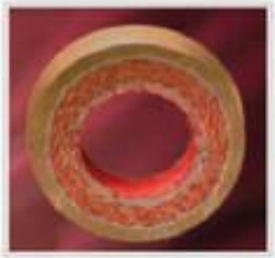
Oxygen Supply - Coronary Anatomy

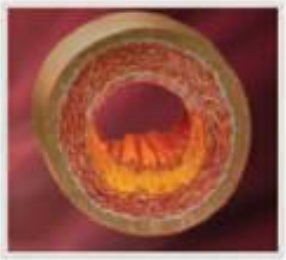


Coronary Arteries



Normal

Autoregulation



70% or < occlusion

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Oxygen Supply - Diastolic Time/Pressure

Diastolic Phase
60 BPM

Diastolic Phase
130 BPM

- Decreased diastolic filling time = decreased stroke volume
- Decreased diastolic pressure = decreased myocardial oxygen supply

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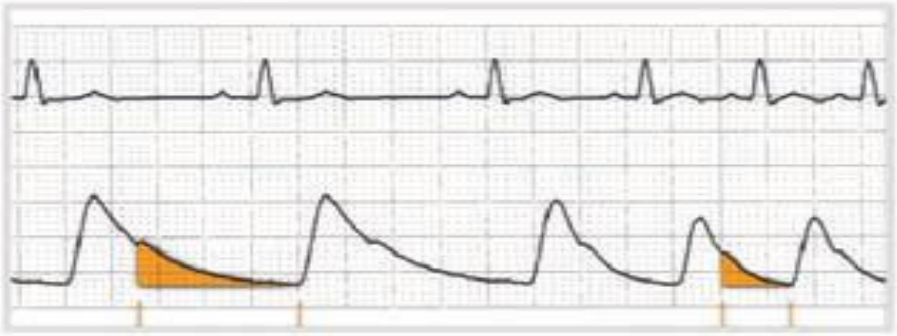
Oxygen Demand - Heart Rate



- Increased heart rate = increased demand for myocardial oxygen

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Oxygen Demand - Preload (Left Side)

Volume of blood in left ventricle at end of diastole, creating a "stretch" in muscle fibers

- Measured by Pulmonary Artery Wedge Pressure (PAWP)
  – Normal values: 4-12mmHg

Klein DG. AACN Procedure Manual for Critical Care. 6th Edition 2011; 578-579

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Oxygen Demand - Contractility

Ability of muscle fibers to contract in order to eject blood into the circulation

- Measured by Ejection Fraction (EF)
  - Normal values: 60% - 75%

Klein DG. AACN Procedure Manual for Critical Care. 6th Edition 2011; 578-579

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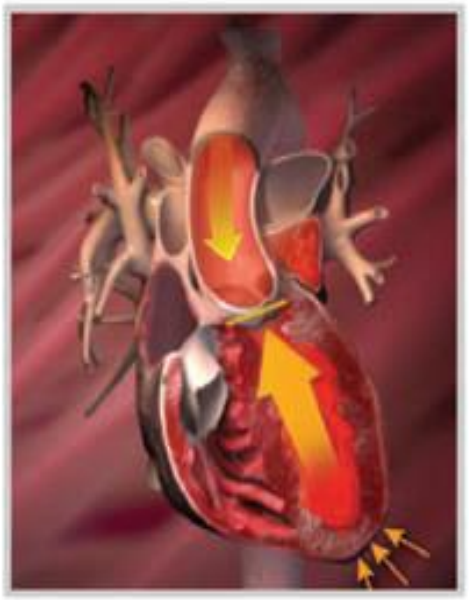
Oxygen Demand - Afterload (Left Side)

Resistance left ventricle has to overcome to eject blood from heart

- Measured by Systemic Vascular Resistance (SVR)
  - Normal values: 900 - 1400 dynes/s/cm^{-5}



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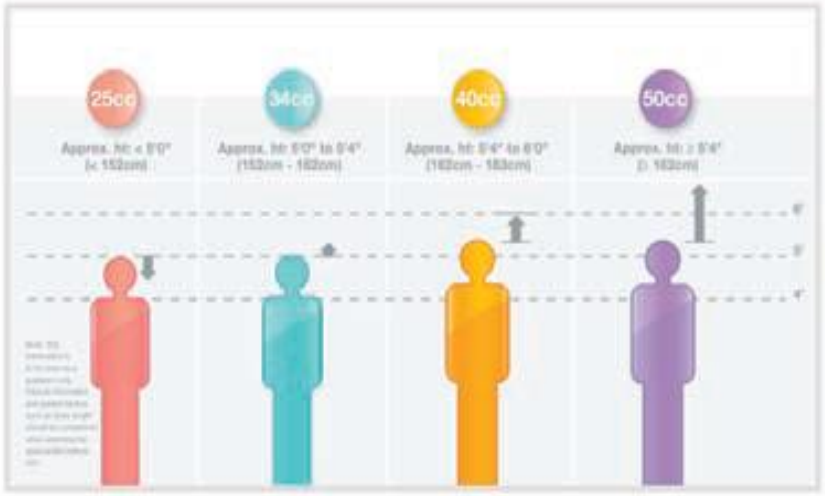
Intra-Aortic Balloon
New Clinical Reference Sizing Guide



IAB CATHETER SIZING & PLACEMENT

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Verification of proper placement

IAB CATHETER SIZING & PLACEMENT

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Important tips to remember

- Whenever possible, use fluoroscopy
- If fluoroscopy is not used, a CXR should be taken as soon as possible after insertion to identify placement
- Place IABP in Standby when obtaining CXR to enhance visualization of IAB tip

IAB CATHETER SIZING & PLACEMENT

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Proper placement of IAB catheter

- Tip of IAB catheter
  - Positioned approximately 1 to 2cm distal to the left subclavian artery
- Base of balloon
  - Positioned above renal arteries

THEORY OF COUNTERPULSATION

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IAB Inflation:
Increases supply of oxygen to myocardium

How it works

- Balloon inflates at onset of diastole (when aortic valve closes)
- Displaces blood, causing an increase in aortic pressure

Benefits

- Increases coronary artery perfusion
- Increases mean arterial pressure

THEORY OF COUNTERPULSATION

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IAB Deflation:
Decreases demand for oxygen by left ventricle

How it works

- Balloon deflates just prior to systolic ejection (before aortic valve opens)
- Results in a rapid decrease in aortic pressure

Benefits

- Decreases afterload
- Decreases cardiac workload
- Increases cardiac output

THEORY OF COUNTERPULSATION

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What are the effects of IABC therapy on the following?

- Coronary perfusion
- Cardiac output
- Heart rate
- PAWP
- SVR
- Systolic BP
- Diastolic pressure with balloon inflation
- End diastolic BP
- MAP
- Systemic perfusion (neurologic, respiratory, renal, vascular)

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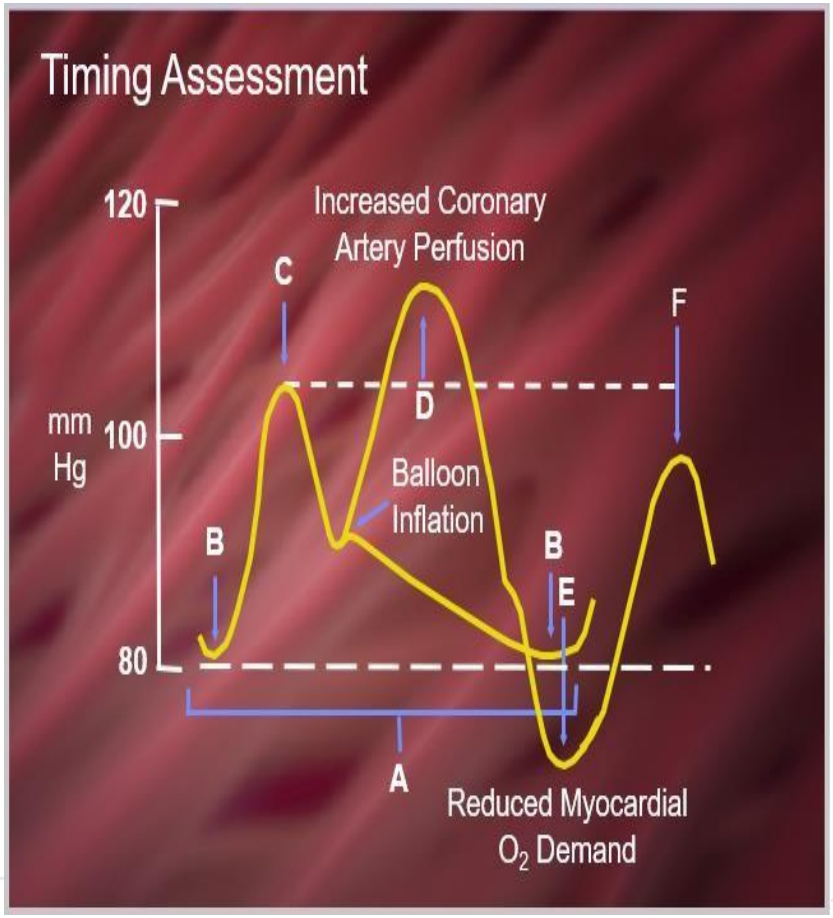
Review Questions

1. The IAB inflates when the aortic valve _____
2. The IAB deflates just before the aortic valve _____
3. The IAB is inflated during which phase of the cardiac cycle? _____
4. The IAB is deflated during which phase of the cardiac cycle? _____
5. The main benefit of inflation is _____
6. The main benefit of deflation is _____



A = One cardiac cycle
B = Unassisted End Diastole
C = Unassisted Systole
D = Augmented Diastole
E = Assisted End Diastole
F = Assisted Systole

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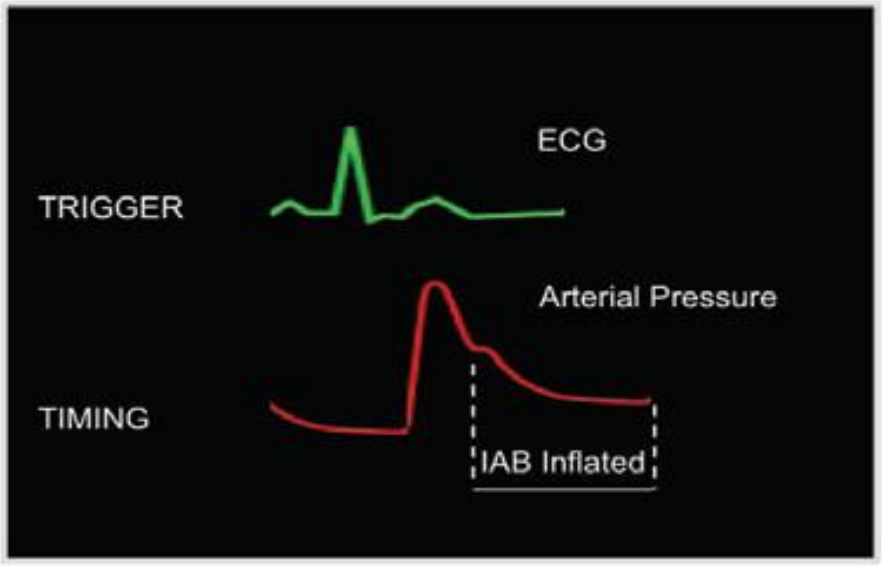
Synchronization with the cardiac cycle



TIMING & TIMING ERRORS

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Timing

Refers to the positioning of inflate and deflate points on the arterial pressure waveform

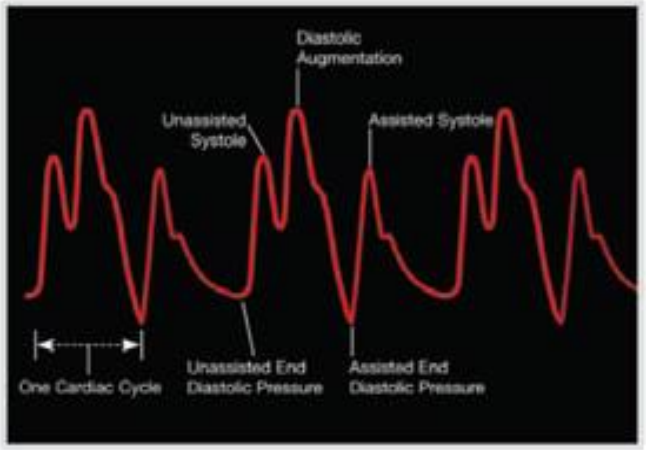
Proper IABP Timing

Inflation

- Occurs at the dicrotic notch
- Appears as a sharp "V"
- Ideally diastolic augmentation rises above systole

Deflation

- Occurs just prior to systolic ejection
- Results in a reduction in assisted end diastolic pressure
- Results in a reduction in assisted systolic pressure



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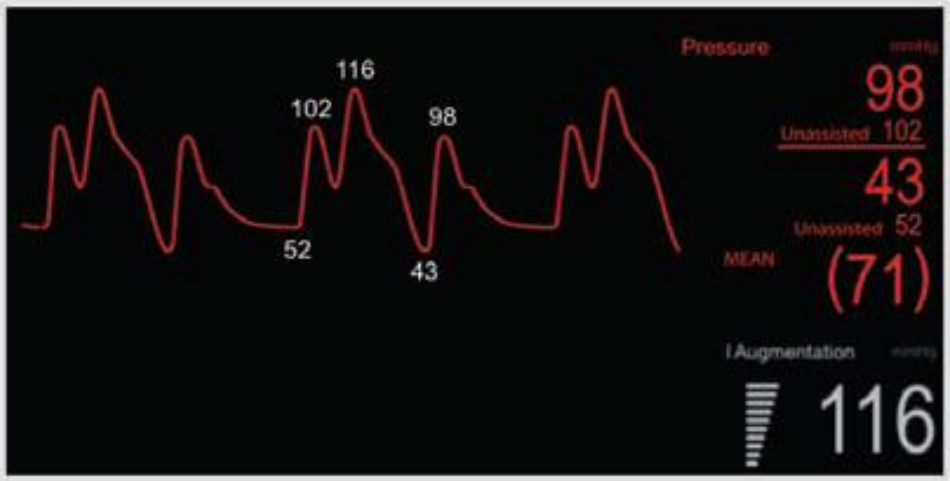
Timing Assessment



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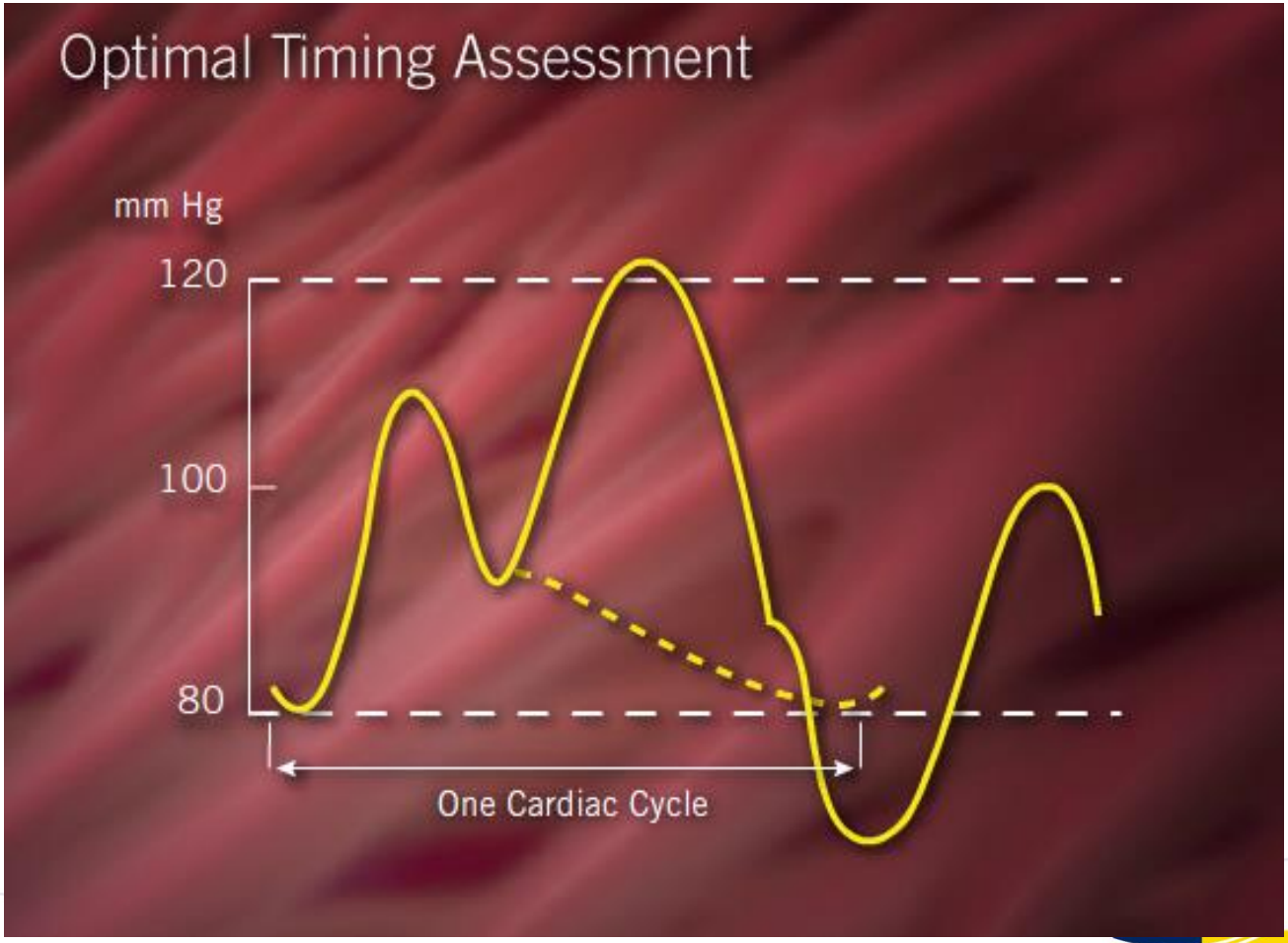
Mean Arterial Pressure Calculation

- IABP samples BP every 4msec on pressure waveform, then averages measurements
- IAB increases MAP due to augmentation of blood pressure during diastole


Optimal Timing Assessment
mm Hg
120
100
80
One Cardiac Cycle

TIMING & TIMING ERRORS

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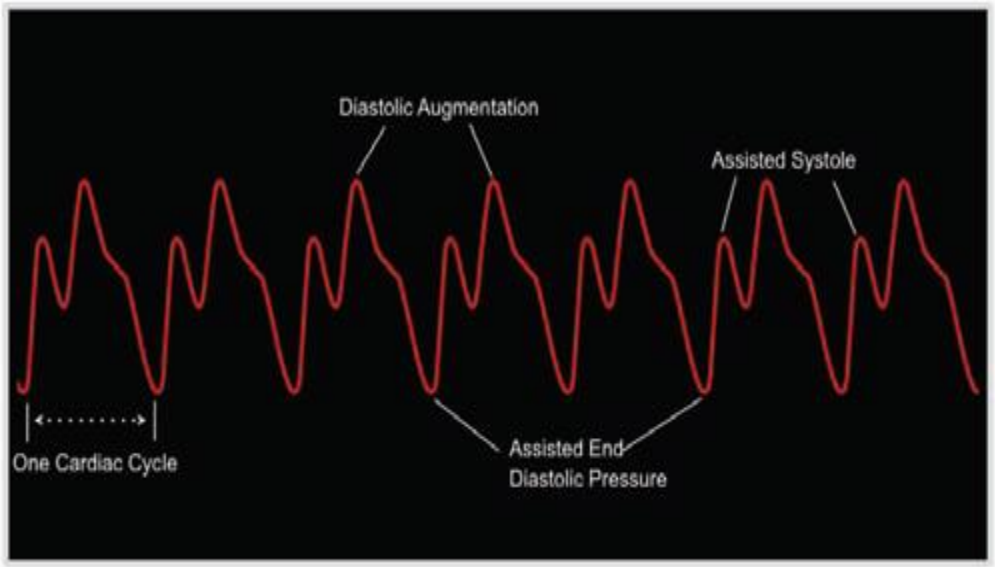
1:1 Frequency



TIMING & TIMING ERRORS

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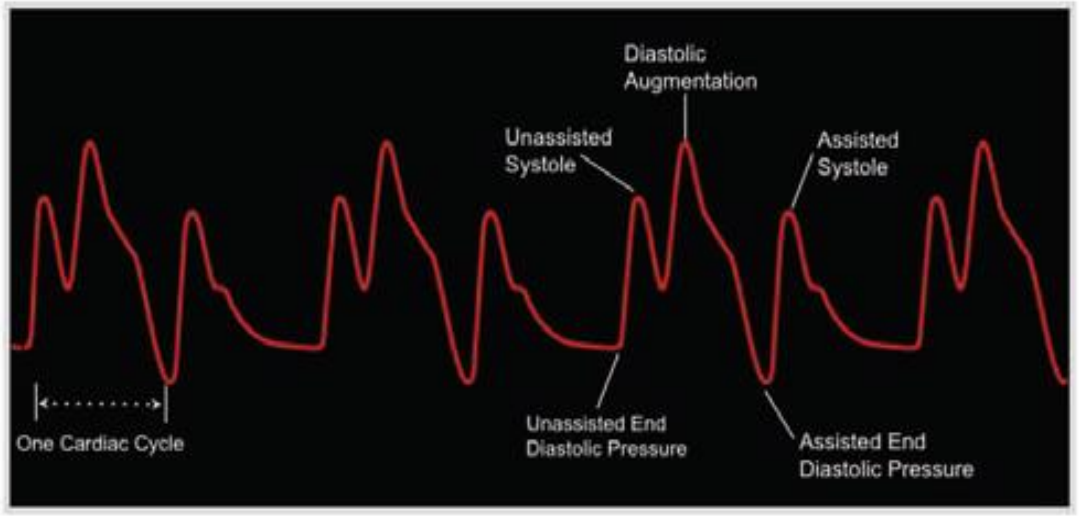
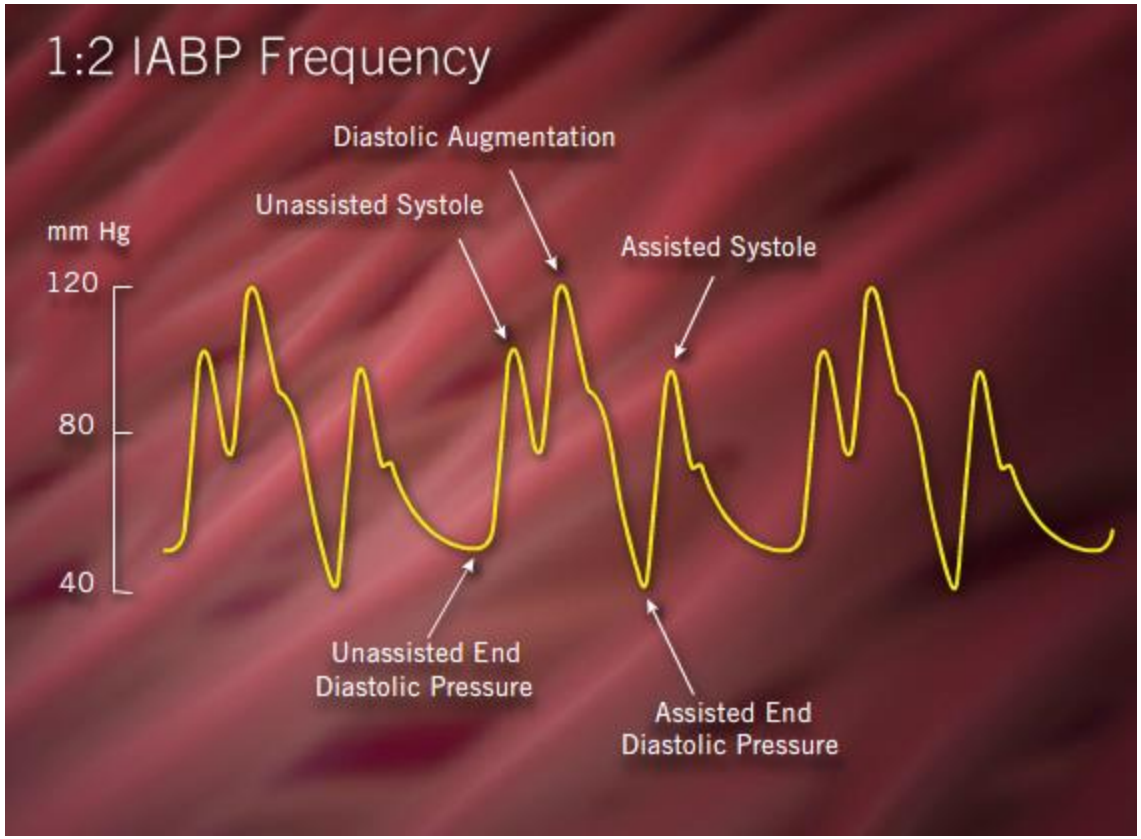
1:2 Frequency




1:2 IABP Frequency
Diastolic Augmentation
Unassisted Systole
Assisted Systole
mm Hg
120
80
40
Unassisted End
Diastolic Pressure
Assisted End
Diastolic Pressure

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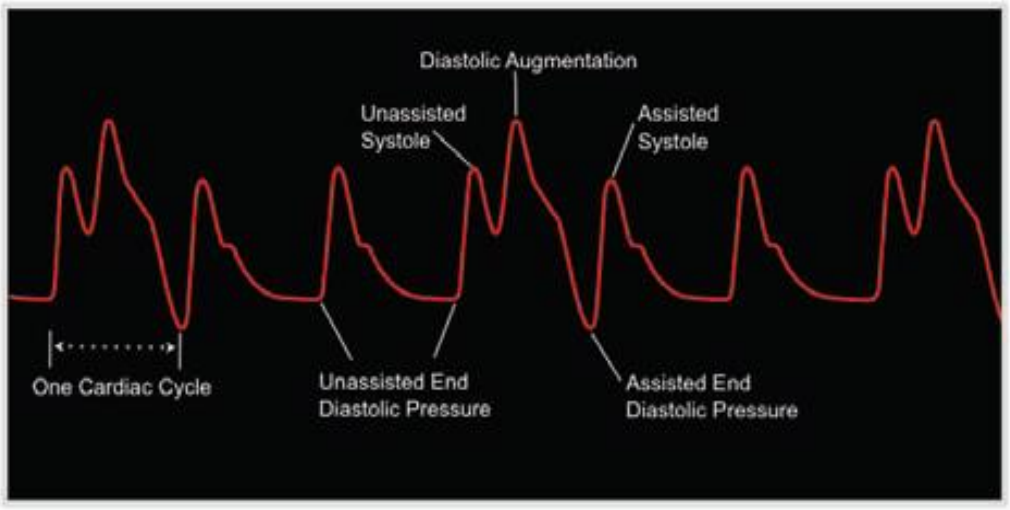
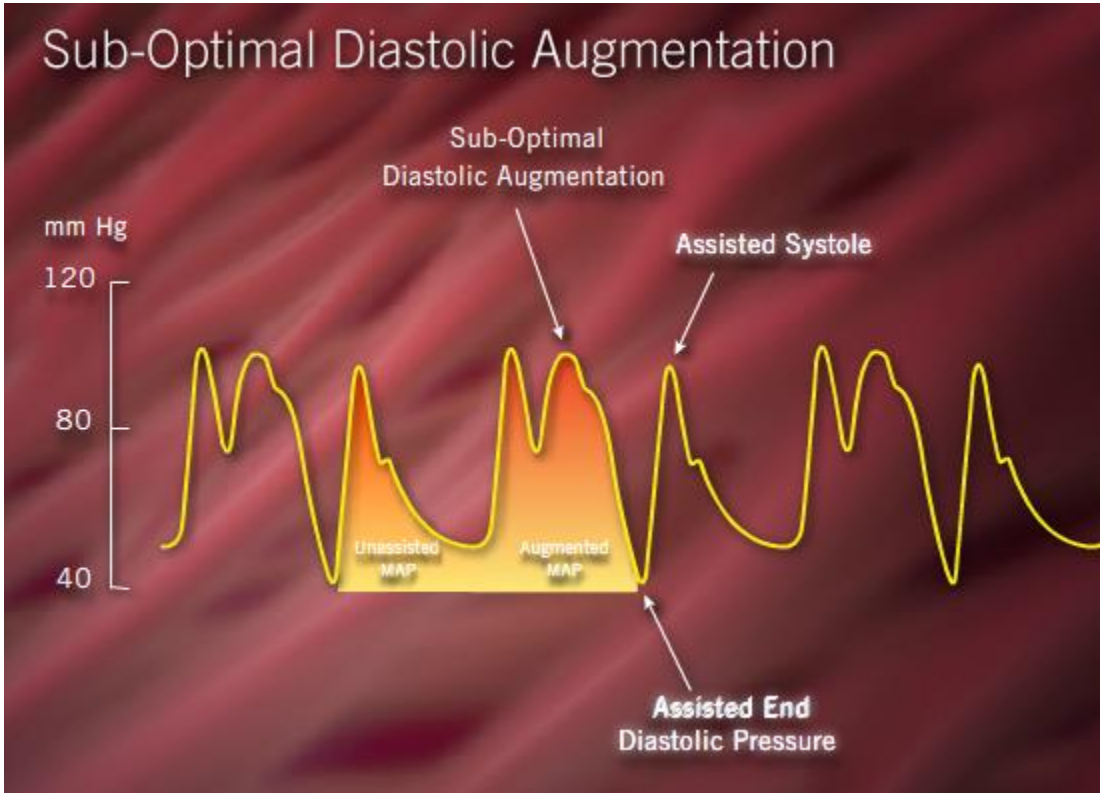
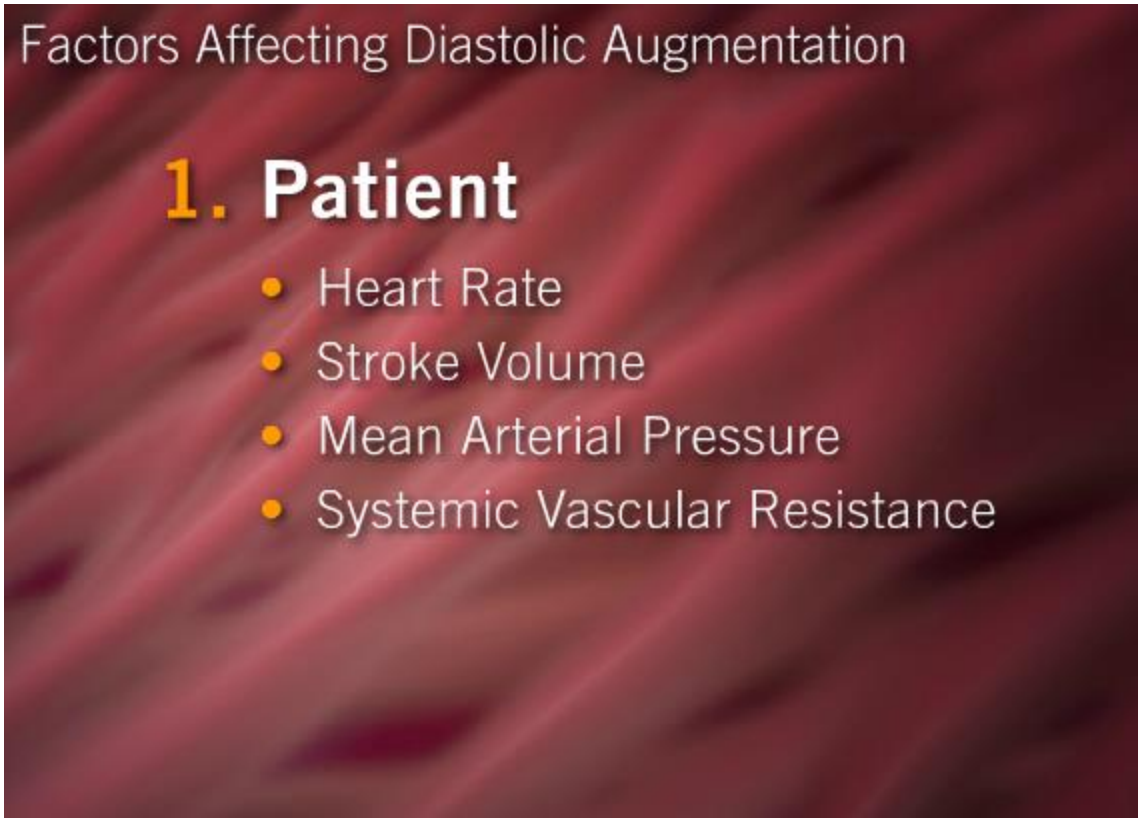
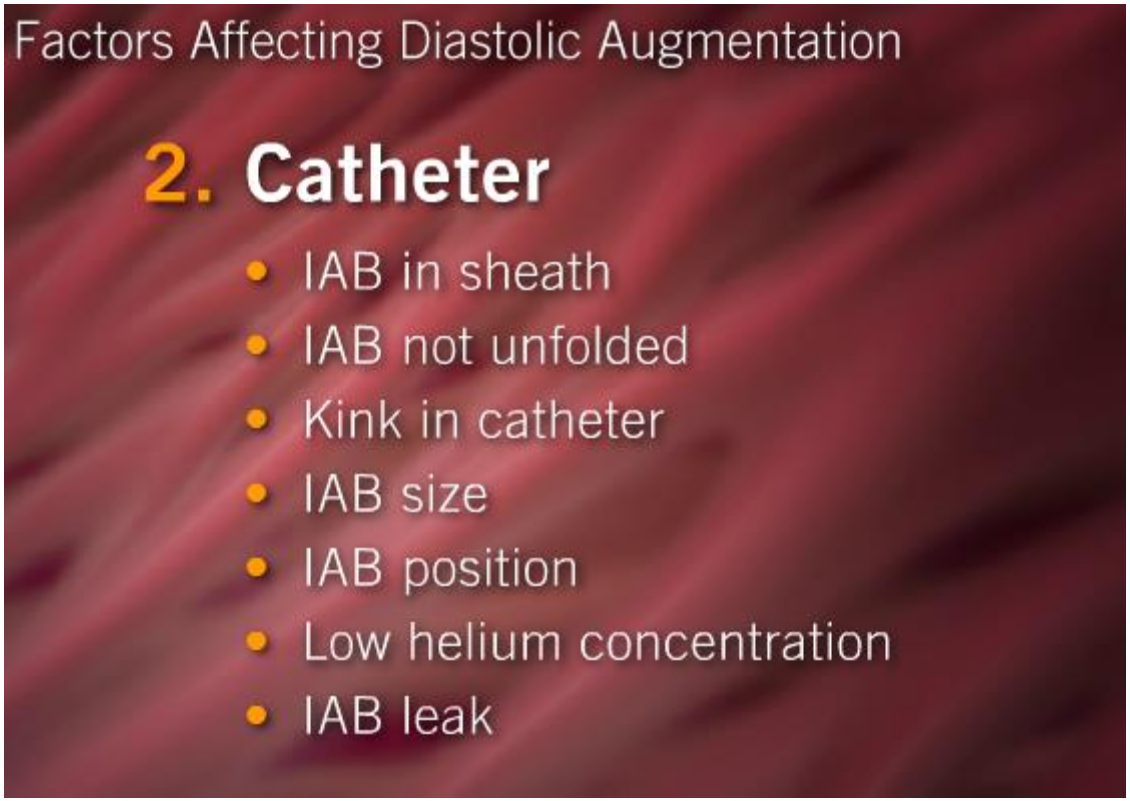
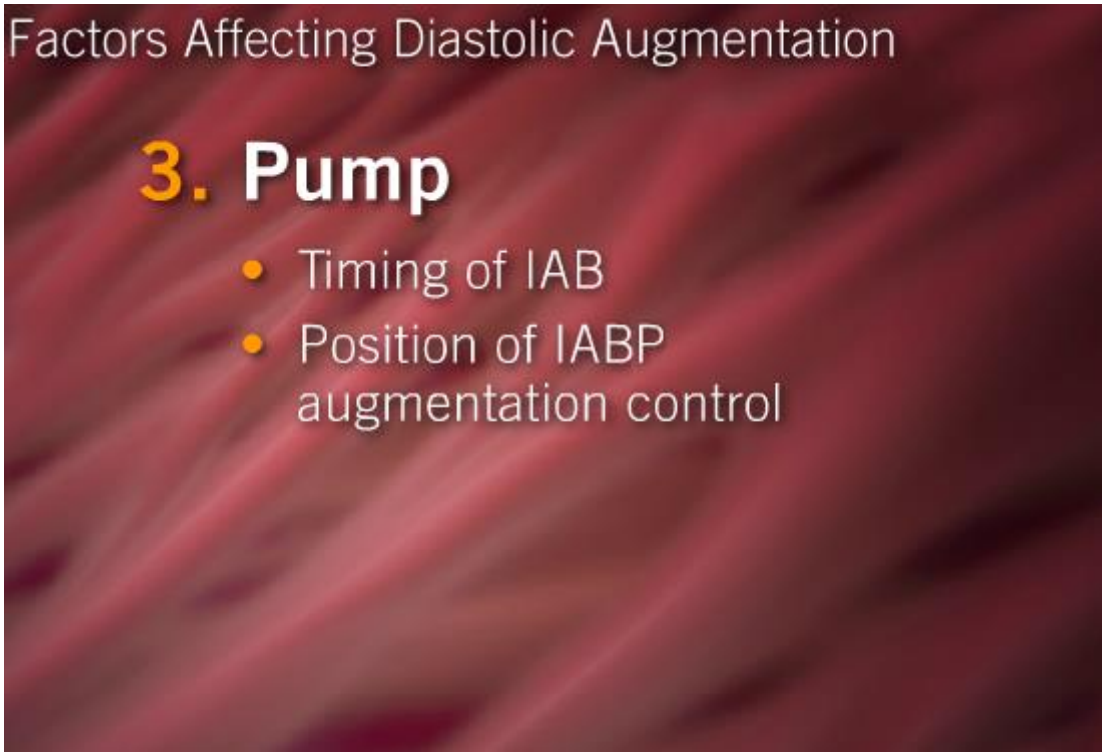
1:3 Frequency




Sub-Optimal Diastolic Augmentation
Sub-Optimal
Diastolic Augmentation
mm Hg
120
80
40
Assisted Systole
Unassisted
MAP
Augmented
MAP
Assisted End
Diastolic Pressure


Factors Affecting Diastolic Augmentation
1. Patient
Heart Rate
Stroke Volume
Mean Arterial Pressure
Systemic Vascular Resistance


Factors Affecting Diastolic Augmentation
2. Catheter
IAB in sheath
IAB not unfolded
Kink in catheter
IAB size
IAB position
Low helium concentration
IAB leak


Factors Affecting Diastolic Augmentation
3. Pump
• Timing of IAB
• Position of IABP augmentation control

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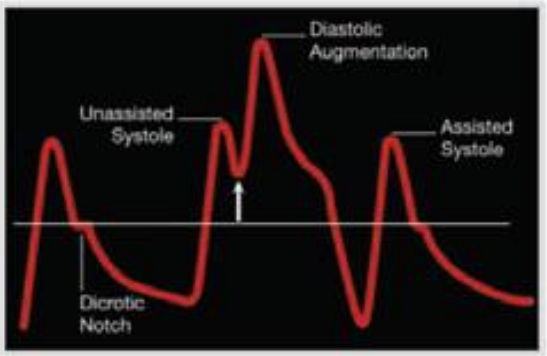
Timing Error – Early Inflation

Inflation of IAB prior to aortic valve closure

Waveform Characteristics

- Inflation of IAB prior to dicrotic notch
- Diastolic augmentation encroaches onto systole (may be unable to distinguish)



Physiologic Effects

- Potential premature closure of aortic valve
- Potential increase in LVEDV/LVEDP/PCWP
- Increased left ventricular wall stress or afterload
- Aortic regurgitation
- Increased MVO_2 demand

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Timing Error – Late Inflation

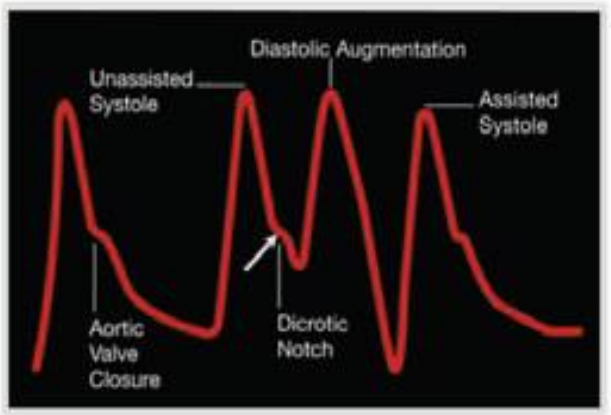
Inflation of IAB markedly after closure of aortic valve

Waveform Characteristics

- Inflation of IAB after dicrotic notch
- Absence of sharp "V"
- Sub-optimal diastolic augmentation

Physiologic Effects

- Sub-optimal coronary artery perfusion



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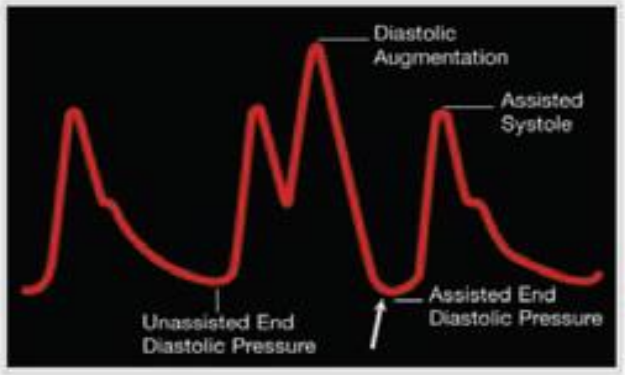
Timing Error – Early Deflation

Premature deflation of IAB during diastolic phase

Waveform Characteristics

- Deflation of IAB is seen as a sharp drop following diastolic augmentation
- Sub-optimal diastolic augmentation
- Assisted end diastolic pressure may be equal to or less than unassisted end diastolic pressure
- Assisted systolic pressure may rise



Physiologic Effects

- Sub-optimal coronary perfusion
- Potential for retrograde coronary and carotid blood flow, which may result in angina
- Sub-optimal afterload reduction
- Increased MVO_2 demand

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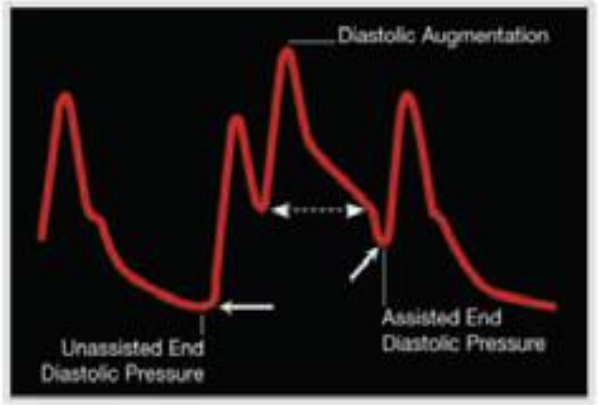
Timing Error – Late Deflation

Deflation of IAB after aortic valve has opened

Waveform Characteristics

- Assisted end diastolic pressure may be equal to or higher than unassisted end diastolic pressure
- Rate of rise of assisted systole is prolonged
- Diastolic augmentation may appear widened



Physiologic Effects

- Afterload reduction is essentially absent
- Increased MVO_2 consumption due to left ventricle ejecting against a greater resistance and a prolonged isovolumetric contraction phase
- IAB may impede left ventricular ejection and increase afterload

TRIGGERS

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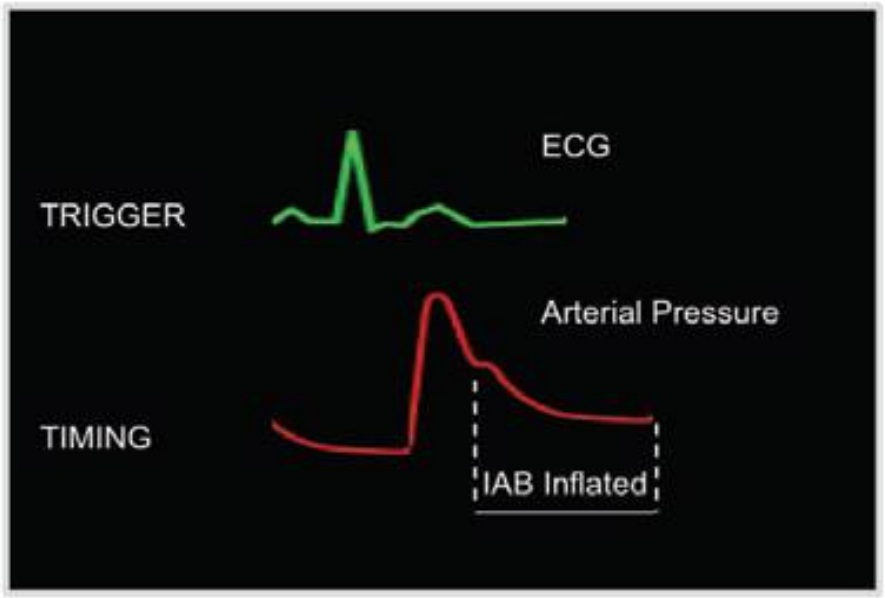
Synchronization with the cardiac cycle



TRIGGERS

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Triggering

- A Trigger is the signal that CARDIOSAVE uses to identify the beginning of the next cardiac cycle
- When CARDIOSAVE recognizes the trigger event, it will deflate the balloon if not already deflated

TRIGGERS

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ECG Trigger

Trigger Event

- **R-Wave**

Applications

- Preferred trigger (must have reliable R-Wave)
- Recommended for patients with arrhythmias
- Recommended for paced rhythms (demand or asynchronous pacing)

TRIGGERS

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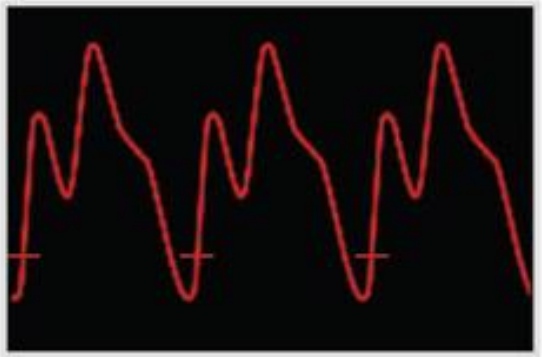
Pressure Trigger

Trigger Event

- **Systolic upstroke of arterial waveform**

Applications

- Backup trigger when ECG trigger is not appropriate
- Reoccurring ECG artifact
- Electrocautery interference in OR
- Low voltage R-Wave
- Cardiac arrest/CPR



TRIGGERS

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Internal Trigger

Trigger Event

- **Asynchronous**
- Balloon inflates/deflates at a set rate of 80 BPM
- Internal rate is adjustable

Applications

- Only use when patient is not generating a cardiac output on their own
- Cardiac arrest
- Cardiopulmonary bypass
- Only available in Semi-Auto operation mode

FACTORS AFFECTING DIASTOLIC AUGMENTATION

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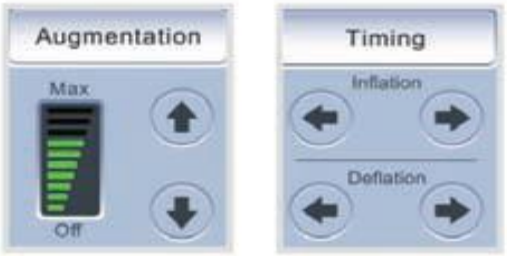
Intra-aortic Balloon Pump

- Timing
  - Late inflation
  - Early deflation
- Position of the IAB augmentation control



INDICATIONS/CONTRAINDICATIONS

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Indications

1. Refractory unstable angina
2. Impending infarction
3. Acute MI
4. Refractory ventricular failure
5. Complications of acute MI
6. **Cardiogenic shock**
7. **Support for diagnostic, percutaneous revascularization, and interventional procedures**
8. Ischemia related intractable ventricular arrhythmias
9. Septic shock
10. Intra-operative pulsatile flow generation
11. Weaning from bypass
12. Cardiac support for non-cardiac surgery
13. **Prophylactic support in preparation for cardiac surgery**
14. Post surgical myocardial dysfunction/ low cardiac output syndrome
15. Myocardial contusion
16. Mechanical bridge to other assist devices
17. Cardiac support following correction of anatomical defects

INDICATIONS/CONTRAINDICATIONS

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Contraindications

- Severe aortic insufficiency
- Abdominal or thoracic aortic aneurysm
- Severe calcific aorta-iliac disease or peripheral vascular disease
- Sheathless insertion with severe obesity, scarring of the groin

SIDE EFFECTS & COMPLICATIONS/PATIENT ASSESSMENT

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Side Effects & Complications

- Limb Ischemia
- Bleeding at the insertion site
- Thrombocytopenia
- Immobility of the balloon catheter
- Infection
- Aortic dissection
- Compartment syndrome
- Balloon leak

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Balloon Leak

What causes a balloon leak?

- Majority are caused by plaque abrasion

How are balloon leaks diagnosed?

- Blood appears in extracorporeal tubing or helium extender tubing
- Be suspicious with any "Gas Loss in IAB Circuit" alarm

What is the treatment?

- Stop pumping and notify physician
- Remove IAB catheter

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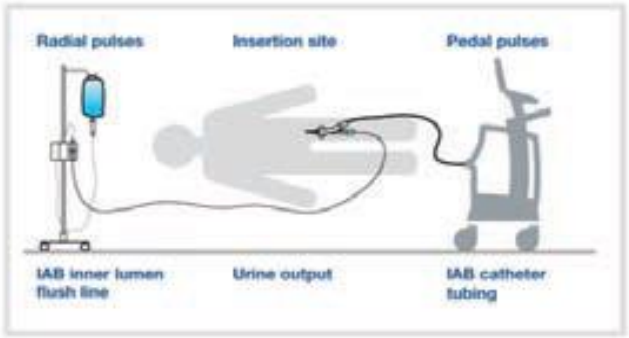
Patient Assessment

Assessment	Corrective Action
Radial pulses Left radial pulse weak or left arm ischemia	Check position of IAB
Insertion site Excessive bleeding from insertion site	Apply pressure, ensure distal flow
Pedal pulses Limb ischemia detected	Consider removing IAB, consider insertion via opposite limb
IAB inner lumen flush line Pressure waveform damped (if using a conventional IAB)	Aspirate inner lumen. If line patent, flush for 15 seconds (with IABP on Standby)
Urine output Urine output low	Check position of IAB
IAB catheter tubing Blood observed in catheter tubing	STOP pumping and prepare for IAB removal



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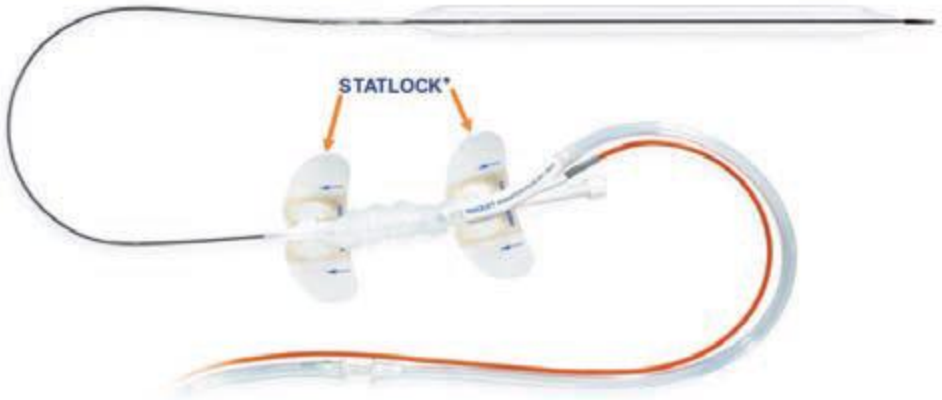
STATLOCK® Stabilization Device



TECHNICAL ASPECTS – CARDIOSAVE IABP

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Helium Tank

Back Panel

Back Panel – Hot Swappable Lithium Ion Batteries

Back Panel – Retractable Power Cord

Transport Configuration

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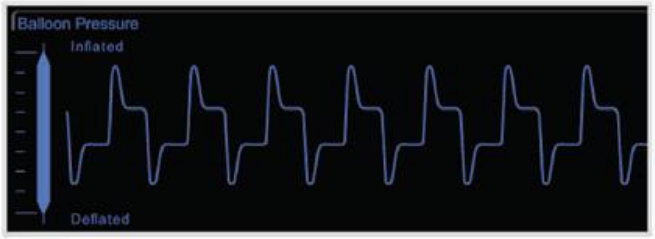
Monitor Display

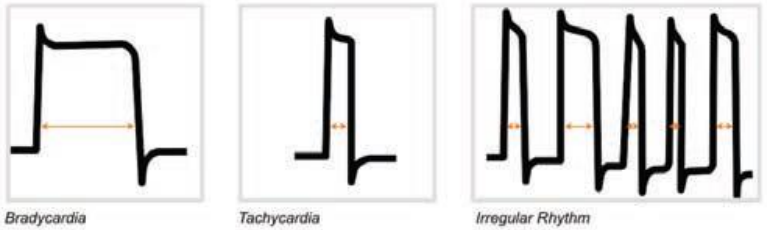
IABP Pressure Waveforms

Normal Balloon Pressure Waveform



TECHNICAL ASPECTS – CARDIOSAVE IABP
MAQUET GETINGE GROUP

Variations in Balloon Pressure Waveform



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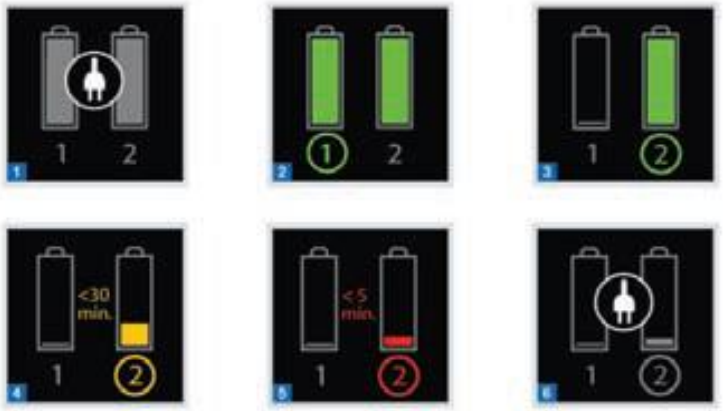
Battery Status (Examples)



TECHNICAL ASPECTS – CARDIOSAVE IABP

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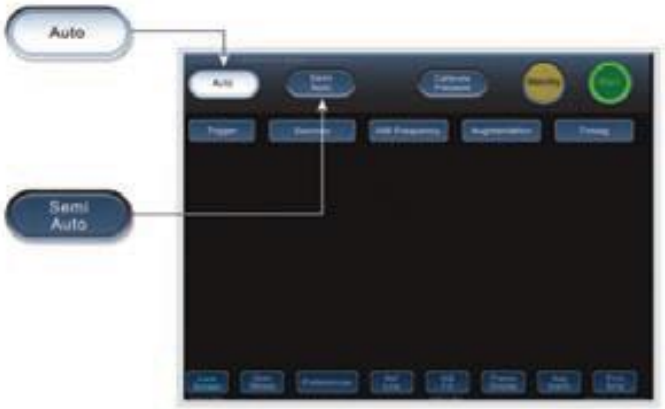
Auto Operation Mode

- Automatic lead and trigger selection
- Automatic and continuous inflation and deflation timing management
  - User has ability to fine-tune deflation timing
- Automatic management of irregular rhythms
- Automatic *in vivo* calibration (when using a MAQUET/Datascope fiber-optic IAB)

Semi-Auto Operation Mode

- Operator selects most appropriate lead and trigger source
- Operator establishes timing, then CARDIOSAVE automatically adjusts timing with heart rate and rhythm changes
- Automatic management of irregular rhythms
- Automatic *in vivo* calibration (when using a MAQUET/Datascope fiber-optic IAB)



Touchscreen

Touchscreen

TECHNICAL ASPECTS – CARDIOSAVE IABP

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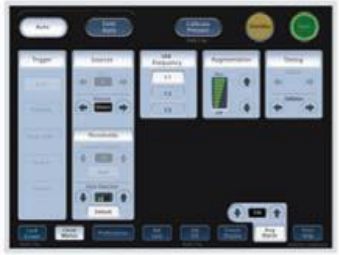
Lock Screen Feature



Touchscreen Unlocked

Touchscreen Locked

Touchscreen will Lock:

- Automatically after 2 min. of inactivity
- When operator presses **LOCK SCREEN** key for 2 sec.

Touchscreen will Unlock:

- Automatically with any Technical, High, Medium, or Low Priority Alarm
- When operator presses **UNLOCK SCREEN** key

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Touchscreen with Help Screen displayed

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Alarms

Augmentation Below Limit Set

Probable Cause	Corrective Action
Hemodynamic status has changed	Attempt to optimize patient's hemody-namic status
Alarm limit set too high	Press AUG. ALARM key, decrease limit

Autofill Failure

Probable Cause	Corrective Action
IAB disconnected	Attach IAB catheter
Helium tank is closed	Open helium tank
Helium tank is empty	Change helium tank
Incorrect IAB catheter extender tubing length	Ensure only one IAB catheter extender tubing is connected

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Alarms

IAB Catheter Restriction

Probable Cause	Corrective Action
Restriction in IAB catheter or tubing	Relieve restriction if possible, press START
Membrane has not completely unfolded	Manually inflate and deflate IAB
IAB remains in sheath	Check markings on IAB and if IAB has not exited sheath, refer to IFU to reposition sheath

IAB Disconnected

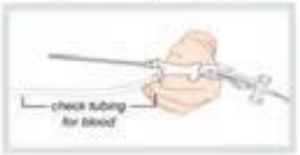
Probable Cause	Corrective Action
IAB catheter or extender tubing is disconnected	Reattach IAB, press START

Alarms

Prolonged Time in Standby

Probable Cause	Corrective Action
IABP has been in Standby for at least 10 minutes	Verify whether it is appropriate to resume pumping

Gas Loss in IAB Circuit



Probable Cause	Corrective Action
A helium loss has been detected in IAB circuit	If blood observed - STOP pumping and prepare for removal If blood not observed - verify connections are tight If appropriate, perform an Autofill, then press START

references

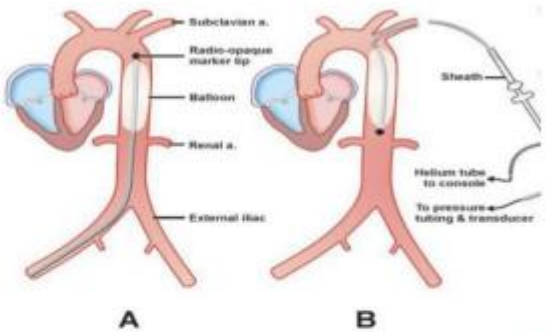
Maquet mLearning:
https://getinge.training/d/course/1010001718/

http://www.cvphysiology.com/Heart%20Disease/HD002

Axillary

Why?

- Allows patients on IABP support to ambulate and engage in physical rehabilitation, conditioning for further interventions.
- Reduces complications of bedrest and infection



A=Femoral IABP B=Axillary-> SC IABP

Nursing Considerations

Insertion:

- **Left Axillary Artery insertion is more common than right.**
- **Right Axillary if pt has PP/AICD on left may be considered**
- **Small, infraclavicular incision**

Monitoring:

- Axillary site assessment for bleeding/hematoma (axillary compartment can hide a significant hematoma)
- Neurovascular checks hourly; brachial/radial pulses to affected arm Q1hr (due to nerve manipulation during insertion, numbness and tingling expected for first 24 hrs.-NOTIFY PROVIDER)
- Utilize as conventional IABP: Level/Zero to phlebostatic axis Q4hr
- Due to placement, (upside down), the arterial waveform on the console and via sheath are likely to be dampened. Preference is a radial arterial line for accurate MAP trending.
- Titrate vasoactives using MAP from radial arterial line
- Continue to transduce all arterial access ports!

Dressing:

- NO Biopatch (risk of sheath displacement
- Use large, CHG impregnated dressing
- Securement- Sutures at site and distally; 3 separate anchors along catheter. (*see photo*)
- Surgical incision: remove/change dressing at 24 hours; open to air if not draining.

Activity:

- Do not raise affected arm higher than shoulder height and/or 90 degrees
- OOB post op day 1. *Risk of malposition/kinking higher with activity!*

Anticoagulation: CHECK YOUR ORDERS

- BIVALIRUDIN RN PROTOCOL
- If Argatroban: remember PTT Q4/6hr, never QD
- If Heparin: Know Anti Xa goal; Q4/6hr, (QD with Attending Order only)
- Begin Anticoagulation infusion 6 hours post op

Assess for Migration (*higher risk*)

- Daily CXR
- Change in UOP, Abdominal distention or discomfort, neuro changes, change in neurovascular assessment are clues!

EMERGENCIES

Balloon rupture/ vessel dissection:

- Clamp gas line
- Call for help
- Prepare for catheter removal

Console Failure:

- *NO MANUAL INFLATION* for axillary IABP (ensure order is present)
- Prepare for possible switch to femoral IABP

Urgent Repositioning:

- Repositioning Kit at bedside/with pt at all times
- Includes: Sterile gloves, Sterile drape, 2 Masks,2 Hats, Dressing supplies