Intra-aortic balloon counterpulsation

Intra-aortic balloon pump (IABP) is the most common device used for mechanical circulatory support in the peri-operative period for cardiac surgical patients. The IABP is a long balloon (25-50ml), which is inserted via Seldinger technique. It has an 8 to 9 French catheter attached to an arterial pressure transducer and a console for operation. Charts are available for correct sizing of the balloon according to the patient's height –there is some variability between manufacturers so referring to user manual is recommended. When inflated, the balloon should not fully occupy the diameter of the aorta. Helium is used for inflation due to its favourable flow characteristics (low density) and because it is relatively easily absorbed into the bloodstream in case of balloon rupture. It is usually inserted in a retrograde fashion via the femoral artery, though rarely may be inserted in an antegrade fashion directly into the aorta during sternotomy. When conventionally placed via the femoral approach, the tip of the catheter should lie 1-2cm distal to the left subclavian artery take off (can be visualized with TOE) or between the 2nd and 3rd intercostal space as seen on chest radiograph or with fluoroscopy. Once correctly placed the balloon should lie between the left subclavian and renal arteries without occluding either. The benefit of anticoagulation with IABP is unproven (unless it is turned off but remains in situ) though often heparin is administered to reduce the risk of thromboembolism and limb ischaemia. Case series of patients treated by IABP without anticoagulation suggest a low thrombotic risk. As such, the role of anticoagulation should be assessed on a case-by-case basis.

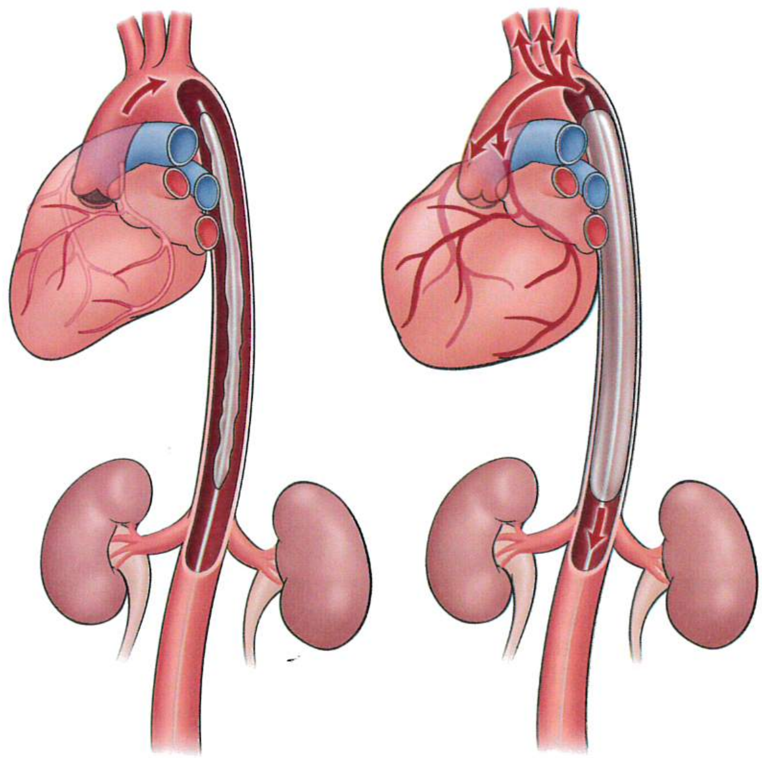

Figure 38. Intra-aortic balloon counterpulsation

In diastole, the balloon inflates and displaces a volume of blood. This serves to augment the diastolic pressure, increase coronary perfusion and therefore myocardial oxygen supply. Prior to the onset of ventricular systole the balloon then deflates and the diastolic

pressure falls.
Ventricular contraction then occurs at a low systemic pressure, which effectively decreases LV afterload and LV work (i.e. the energy consumed in contracting by the LV), decreases LVEDP, LVEDV and LV wall tension. This decreases myocardial oxygen consumption and increases the cardiac output. Unlike inotropes, myocardial oxygen consumption is decreased and myocardial supply is increased whilst the cardiac output is increased. Use of the IABP may also improve RV function by increasing RV oxygen supply and unloading of the left ventricle, hence reducing the pulmonary pressures and left atrial pressure.

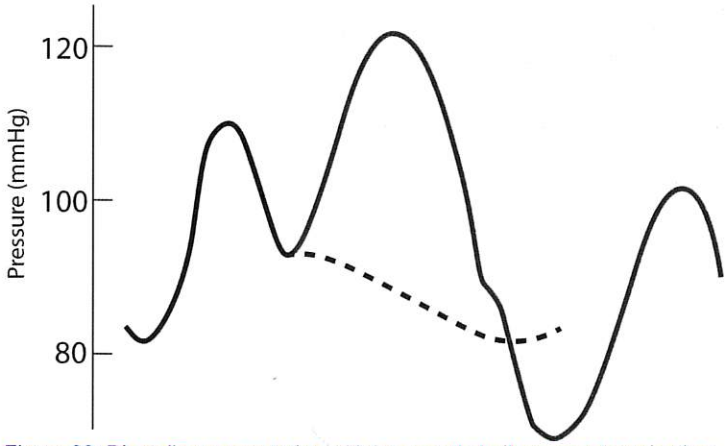

Figure 39: Diastolic augmentation with intra-aortic balloon counterpulsation

Indications for use:

- acute myocardial infarction
- cardiogenic shock
- acute mitral regurgitation
- ventricular septal defect before and after repair
- refractory unstable angina prior to revascularization
- to aid weaning from CPB

Contra-indications:

- severe peripheral vascular disease / mobile aortic atheroma
- significant aortic regurgitation
- aortic dissection
- abdominal aortic aneurysm
- aortic stents or grafts

Triggering

To synchronise with the cardiac cycle, the IABP may be set to ECG or pressure trigger. ECG trigger is preferred, though the patient must have a reliably distinguished T and R wave. Auto mode will preferentially use an ECG trigger but switch to pressure trigger in the event of a poor ECG trace. It is recommended for patients with arrhythmias and for paced rhythms. The pressure trigger uses the upstroke of the arterial waveform to time inflation. Pressure triggering is used as a back-up in auto mode, with ECG artefact e.g. intra-operatively or during cardiac arrest. Internal mode will set the balloon to inflate without a trigger in an asynchronous fashion at 80bpm. This mode is rarely indicated and should never be used if the patient has a native cardiac output. It is occasionally used with extra-corporeal support.

Frequency

The IABP may be set to augment at a ratio of 1:1 (inflates every beat), 1:2 (inflates every other beat) or 1:3. The frequency may be reduced as a method of weaning from the IABP or to assess the heart's function without augmentation. It is also useful to see unassisted waveforms to diagnose timing errors with the IABP.

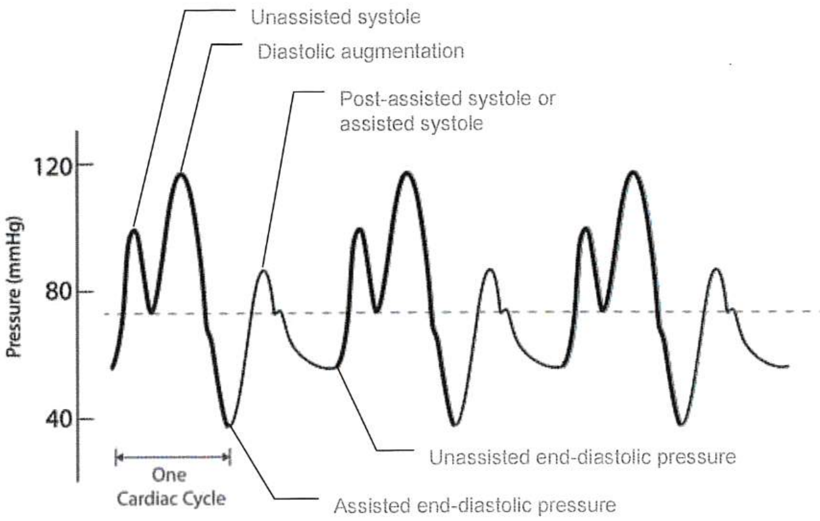

Figure 40: 1:2 augmentation with IABP

Augmentation

Refers to the volume of blood displaced by the balloon and can be set to a maximum and minimum level. Reductions in augmentation can be used as another method of weaning from IABP.

Timing Errors

Early inflation

Inflation prior to the dicrotic notch and aortic valve closure. This can cause premature closure of the aortic valve, reduced cardiac output and increases LV afterload. Diastolic augmentation appears very close to the systolic peak.

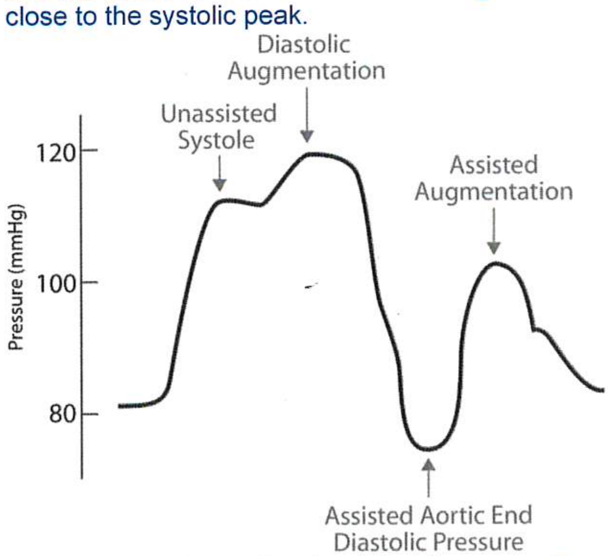

Figure 41: Early inflation with reduced diastolic augmentation and encroachment onto unassisted systole

Late inflation

Inflation delayed after the dicrotic notch and closure of the aortic valve (the dicrotic notch is therefore visible on the arterial waveform before the diastolic augmentation wave is seen) reduces the diastolic augmentation so the diastolic augmentation waveform may not be greater than unassisted systole. Late inflation causes reduced coronary perfusion.

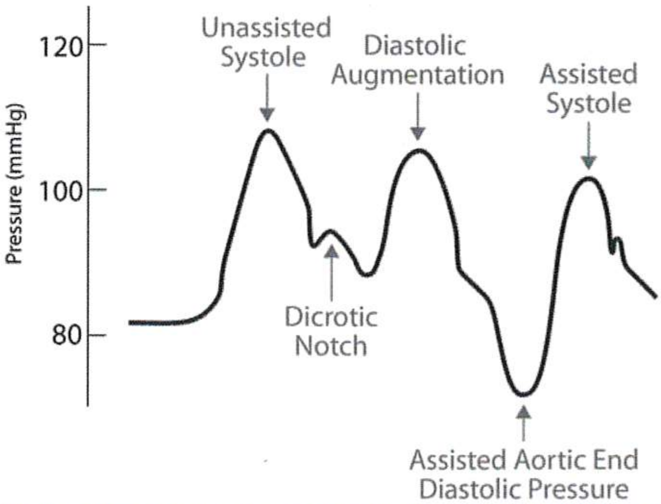

Figure 42: Late inflation showing inflation after the dicrotic notch and reduced diastolic augmentation

Early deflation

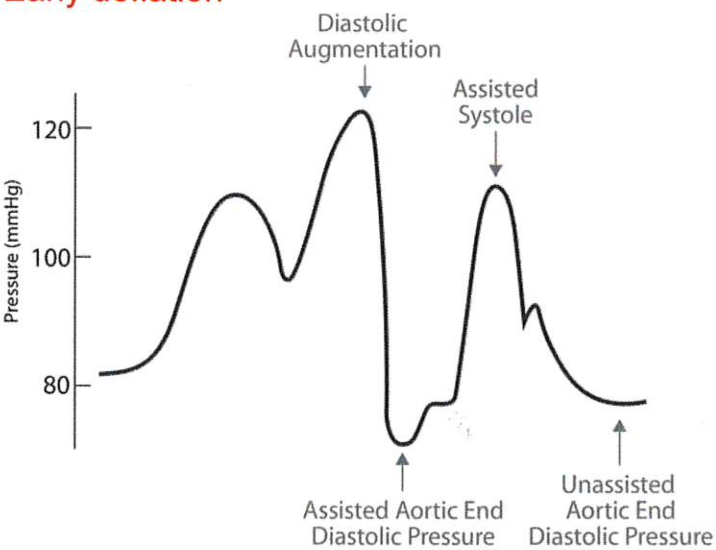

Figure 43: Early deflation causes less of a reduction in assisted end diastolic pressure and assisted systole. In this example, assisted and unassisted diastole occur at almost the same pressure.

Usually identified when the assisted end diastolic pressure is greater than the unassisted end diastolic pressure. This may reduce coronary perfusion and cause less of a reduction in LV afterload.

Late deflation

Seen as a widened diastolic augmentation waveform and a high assisted end diastolic pressure. Late deflation means the LV ejects with the balloon still inflated which increase LV afterload, increases LV myocardial work and reduces cardiac output.

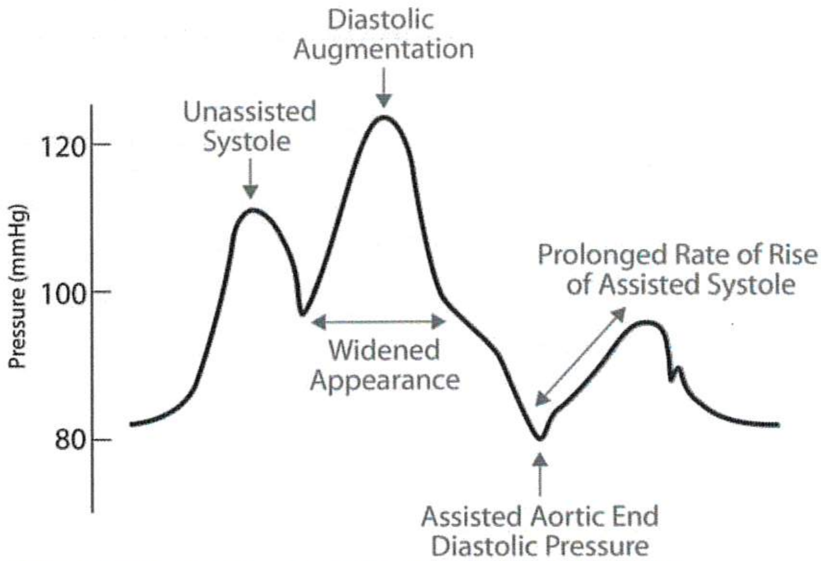

Figure 44: Late deflation causes a widened appearance of the diastolic augmentation waveform and a slow upstroke of the assisted systole due to increased afterload

Most modern IABP machines may be used in in manual, automatic mode or a semi-automatic mode. In automatic mode, the most appropriate trigger source is selected by the machine, and the timing of inflation and deflation controlled. In the event of an unreliable trigger source, the next best trigger source will be switched to automatically. Conversely, in manual mode both the trigger source and the timing of inflation and deflation require the operator to appropriately set the variables. Semi-automatic modes are between the previous two modes. Typically, the operator will select the most appropriate trigger source and also the initial timing of inflation and deflation, after which, changes in heart rate and rhythm are adjusted for by software algorithms.

In situations where the operator requires the pressure trigger to be set (e.g. cardiac arrest or transfer), it may be pertinent to switch to a semi-automatic mode to ensure this setting is delivered to the patient.

Complications

The IABP should never be left *in situ* switched off due to the risk of clot formation and systemic embolization.

Complications of IABP include:

- insertion complications (pseudo aneurysm formation, bleeding, vascular injury)
- aortic damage
- systemic embolization
- limb ischaemia
- compartment syndrome
- haematological effects (haemolysis and thrombocytopenia)
- malpositioning causing arterial occlusion:
  - too high -> myocardial ischaemia in patients with left internal mammary artery (LIMA) to left anterior descending (LAD) coronary artery if the left subclavian artery is occluded
  - too low –> renal and mesenteric ischaemia
- timing errors worsening myocardial oxygen supply- demand ratio
- balloon rupture (if blood enters balloon lumen may clot and cause difficulty in removing – if suspected remove immediately)

- infection

Weaning

Prior to weaning, consider the overall stability of the patient in terms of:

- Ventilation – respiratory function should be stable (IABP and respiratory weaning should not be undertaken concurrently as it may mask the cause of subsequent deterioration).
- Cardiovascular system – inotropes and vasopressors should be at low levels in case of instability during the IABP weaning process.
- Electrolytes and haemoglobin optimised.

Augmentation Weaning

Currently the preferred method as it is more physiological. The IABP augmentation may be weaned in 10% increments, if tolerated, every 30 minutes. The augmentation should not be reduced below 50% as this increases the risk of thromboembolic complications.

Frequency weaning

Reducing the frequency from 1:1 to 1:2 and then potentially 1:3. This is not recommended as with the change of 1:1 to 1:2 frequency diastolic coronary blood flow is reduced by more than 50% and so is considered much less controlled than augmentation weaning.

During the weaning process, assess for:

- chest pain or ischaemic ECG changes
- pulmonary oedema
- confusion, tachycardia or hypotension
- reduced cardiac output and elevated filling pressures

Before IABP removal the patients clotting should be normalised.