

## Supplemental Material – Mechanical Circulatory Support

### *Intra-aortic balloon pump*

Intra-aortic balloon pumps (IABP) are placed in the descending aorta, usually via the femoral artery, and sited distal to the origin of the left subclavian artery. The balloon is inflated immediately following aortic valve closure in early ventricular diastole, thereby reducing blood flow run off from the proximal aorta and maintaining aortic root pressure without aortic occlusion. It is hypothesised that coronary perfusion is enhanced. The balloon is deflated just before the aortic valve opens thereby acutely dropping the afterload presented to the ejecting ventricle. Accurate timing of inflation and deflation is vital.

IABPs have not been shown to improve patient survival from cardiogenic shock (CS) in clinical trials, despite their haemodynamic effects [1]. However, IABPs continue to be deployed in CS as well as mechanical complications of myocardial infarction including severe mitral regurgitation and ventricular septal rupture, often as a bridge to surgical or percutaneous intervention. IABPs are contraindicated in patients with severe aortic regurgitation, severe aorto-vascular disease and aortic dissection. Patients are generally anticoagulated with unfractionated heparin to reduce the risk of thromboembolism and limb ischaemia.

### *Extracorporeal membrane oxygenation (ECMO)*

Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) can provide total cardiopulmonary support by pumping a patient's blood from the venous system through an artificial lung (membrane oxygenator) retrogradely into the femoral artery or directly into the ascending aorta. Typically, a centrifugal continuous flow pump is used to return blood and pressurise the arterial system and vital organs. The membrane oxygenator fulfils the gas exchange requirements. Patients receive unfractionated heparin during ECMO to reduce the risk of thrombosis in the extracorporeal circuit. It is possible to commence VA-ECMO emergently in patients with circulatory collapse or in cardiac arrest to minimise ischaemic organ injury.

VA-ECMO may reduce cardiac work (the product of stroke volume, aortic pressure and heart rate) by diversion of venous return. Whilst this may restore the oxygen balance in a myocardium with limited supply, this benefit may be offset by increased aortic pressure and resultant increased cardiac work. Myocardial oxygen supply can be further compromised if the ventricular wall tension rises if LV volume and pressure increases. Thus, VA-ECMO is excellent for organ perfusion in cardiogenic shock but may be sub-optimal for cardiac recovery. It is therefore important that the goals of support are established and exit strategies such as ventricular assist device, cardiac transplantation or end of life care are discussed early.

Outcome benefit from VA-ECMO support has not yet been proven in a randomised trial although at least 2 multicentre trials are currently recruiting (ClinicalTrials.gov Identifiers: NCT03813134 and NCT03637205).

#### *Univentricular support devices*

Ventricular assist devices provide cardiac support to one side of the heart, although some can be combined to provide biventricular support. The Impella™, Tandem Heart™ and Heartmate PHP™ are short-term (days to weeks) devices, inserted percutaneously and can be rapidly deployed in CS or electively to support high risk percutaneous coronary or catheter ablation procedures in parallel to VA ECMO. Compelling randomised trial data supporting the use of these short-term devices is currently lacking.

Ventricular assist devices are orientated such that blood is drained directly usually from the ventricle or associated atrium. The pumps are either axial (Impella™, Heartmate PHP)™ or centrifugal (Tandem Heart™). The speed of the rotating impellor is set and blood flow calculated through a proprietary algorithm. Flow is dependent on the pressure gradient across the pump and thus all devices require adequate preload and the avoidance of high afterload for efficient operation.

Complications are common and relate to the anticoagulation necessary to prevent pump thrombosis, haemolysis and iatrogenic vascular damage or associated limb ischaemia on or following device implantation.

#### References

1. Thiele H, Zeymer U, Neumann FJ, et al. Intraaortic balloon support for myocardial infarction with cardiogenic shock. *The New England journal of medicine* 2012;367(14):1287-96. doi: 10.1056/NEJMoa1208410