Number of Contact Hours – 5.0

Audience RN

Pharmacology Hr : 0

CERP :A

Goals and Objectives

Goals

The goal of this article is to review the evidence of revascularization strategies for CAD in patients undergoing percutaneous coronary intervention

Objectives

Discuss the effectiveness of IABP for Myocardial Infraction patients

Describe the clinical utility of IABP in patients with cardiogenic shock

Identify three cardiovascular consequences of IABP

Describe the balloon pump device

Discuss the effect of IABP on mortality in CABG patients

Introduction

Treatment with the intraaortic balloon pump (IABP) is the most common form of mechanical support for the failing heart. Augmentation of diastolic pressure during balloon inflation contributes to the coronary circulation and the presystolic deflation of the balloon reduces the resistance to systolic output. Consequently, the myocardial work is reduced. The overall effect of the IABP therapy is an increase in the myocardial oxygen supply/demand ratio and thus in endocardial viability.

Acute myocardial infarction (AMI) complicated by cardiogenic shock (CS) is one of the leading causes of death in patients hospitalized with AMI. IABP support effectively reduces the left ventricular wall stress and myocardial demand, increases the coronary perfusion pressure, stroke volume, cardiac output, and ameliorates ischemia, making it a potentially valuable therapy in CS. Reports elsewhere suggest that IABP offers a substantial advantage when used in combination with thrombolytic therapy. In a study, the use of IABP in conjunction with thrombolytic therapy decreased the odds of death by 18 %. In addition, IABP has been widely used in the prevention of adverse catheter laboratory events during elective high-risk PCI. [1, Rank 3]

The Effectiveness of IABP for Myocardial Infarction Patients

Despite its frequent use in the clinical practice for the treatment of AMI, recent reports dispute whether intra-aortic balloon counterpulsation provides any incremental benefit to reperfusion therapy. In patients with AMI and CS, the evidence in favor of IABP is currently limited to registry data and retrospective analyses, and small, prospective studies without any reliable mortality data. A recent systematic review and meta-analysis comparing IABP versus no IABP in patients with AMI and CS concluded that the available data did not provide a convincing evidence for either benefit or harm to support the use of IABP counterpulsation. According to the 2011 guidelines released by the American College of Cardiology Foundation (ACCF) and American Heart Association (AHA), IABP counterpulsation is reasonable in non-ST-elevation myocardial infarction (NSTEMI) patients for severe ischemia that is continuing or recurs frequently despite medical therapy, for hemodynamic instability in patients before or after coronary angiography, and for mechanical complications of MI.

In 2013, ACCF/AHA has released an updated guideline for patients with STEMI, where the recommendation for the placement of IABP in CS was downgraded from Class I to Class IIa, because of the lack of clear superiority in clinical benefit and reduction of mortality. Similarly, IABP was recommended in ST-elevation myocardial infarction (STEMI) patients with CS by the European Society of Cardiology in 2008 but an updated guideline released by European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) in 2014 did not recommend routinely using IABP in patients with CS.

Use of elective IABP support in patients undergoing high-risk PCI is still debatable. The evidence suggests that routine IABP use does not provide clinical benefit in patients undergoing high-risk procedures or those with AMI in the absence of CS, but it causes a relative reduction in the long-term all-cause mortality. Researchers also indicated that while IABP is not beneficial in high-risk AMI patients without cardiogenic shock, there was significant reduction in mortality with IABP in patients having AMI with cardiogenic shock.

Considering the contrasting reports in the field and the necessity for unified guidelines for the use of IABP, it is of utmost importance to evaluate the clinical relevance of IABP as an adjunct therapy to PCI in patients with acute myocardial infarction with or without CS. [7, Rank 4]

The Clinical Utility of IABP in Patients with Cardiogenic Shock

IABP increase diastolic aortic pressure, which improves the diastolic coronary flow. IABP simultaneously reduces systolic aortic pressure, which in turn decrease the afterload and oxygen consumption of the myocardium. In addition to AMI, IABP has been widely used in indications including, CS, high risk percutaneous coronary intervention and cardiac surgery for hemodynamic support. Besides its long-standing clinical use as the main form of mechanical circulatory support, the long-term benefits of IABP are still controversial due to the paucity of prospective, randomized clinical trials. The current study was undertaken to broaden the understanding through a systematic review and meta-analysis of the existing literature in the clinical practice of IABP in terms of AMI with/without CS as well as in patients with high risk PCI. The pooled results of the current meta-analysis do not favor the overall survival and hence, the clinical utility of IABP, in patients suffering high-risk PCI without CS and AMI complicated with CS. However, for patients with MI but without CS, IABP may reduce 30-day and 6-month mortality rate.

CS is a clinical state of hypoperfusion characterized by a systolic pressure, 90 mmHg and a central filling pressure (wedge pressure), .20 mmHg, or a cardiac index,1.8 L/min/m2, and caused by the extensive loss of viable myocardial tissue. IABP is recommended by ACCF/AHA guideline (2013), which stated that "The use of IABP counterpulsation can be useful for patients with cardiogenic shock after STEMI who do not quickly stabilize with pharmacological therapy. However, researchers have challenged the existing general recommendations for the use of IABP in patients with ST-segment elevation myocardial infarction (STEMI) complicated by CS and have confirmed that IABP do not offer any advantage during PCI. These findings were further supported by a well-powered, prospective, randomized clinical trial, where they demonstrated that IABP did not reduce 30-day mortality or 12 month all-cause mortality in patients undergoing early revascularization for myocardial infarction complicated by cardiogenic shock.

In addition, in patients with acute anterior STEMI without shock, no reduction in the infarct size was noted for IABP along with PCI as compared to PCI alone. The current results are in agreement with the previous meta-analyses, where the benefit of adjunctive IABP therapy was not statistically significant in STEMI patients complicated by CS, and IABP did not show a significant reduction of mortality in patients with AMI and cardiogenic shock. In an updated ESC/EACTS Guidelines in 2014, routine use of IABP in patients with cardiogenic shock was not recommended. IABP insertion should only be considered in patients with haemodynamic instability/cardiogenic shock due to mechanical complications.

The role of IABP support in the management of high-risk patients with AMI remains unclear. In a registry of unselected patients with STEMI complicated by CS, the long term outcomes were similar between the high risk population with IABP and the low risk non-IABP patients, indicating that IABP may be effective in high risk patients. The results are consistent with the previous systematic review and meta-analysis that, in high-risk STEMI patients without CS, the majority of the studies could not demonstrate an efficacy benefit for IABP as compared to the control group in terms of in-hospital mortality, left ventricular ejection fraction, and rate of recurrent ischemia.

However, in patients with MI without CS, a meta-analysis showed a different result from the previous reports. A recent meta-analysis found that IABP treatment had no statistically significant effect on mortality. This outcome was consistent when the articles were stratified by the presence or absence of CS. A meta-analysis of six randomized trials concluded that IABP did not reduce all-cause death. In a systematic review including randomized controlled trials published between 1981 and 2011, the majority of the studies could not demonstrate a beneficial effect of IABP therapy in patients with STEMI without CS.

Moreover, a retrospective analysis on the role of IABP in patients with acute MI without CS also found no difference in the in-hospital rate of cardiac death among patients who received IABP at the time of their coronary revascularization and the control group. However, we found that IABP may reduce 30-day and 6-month mortality rate in patients with MI, but without CS. This is in agreement with a systematic review reported by Ye et al. where they reported that while IABP did not reduce mortality within 2 months and 6–12 months of intervention in AMI patients with CS, but it can reduce 6–12 month mortality in patients with AMI without CS. Since we only included two RCTs in this subgroup, the clinical benefit of IABP in patients with acute MI without CS remains to be explored further in future studies.

Though IABP did not offer any major advantage during primary PCI, it was effective as an adjunctive therapy to thrombolysis in patients with MI. Subgroup analysis even showed that, in patients with high-risk PCI without CS, IABP had higher odds of 30-day bleeding than those without IABP.

Correspondingly, researchers did not observe any difference in the secondary outcomes like, 30-day mortality rate, 6-month mortality, 30-day reinfarction rate, 30-day revascularization rate, or 30-day stroke rate between the IABP and the control groups. The meta-analysis reported had similar conclusion that IABP significantly reduced recurrent myocardial ischemia and increased the risk of bleeding. Another meta-analysis reported also found that IABP significantly increased the risk of moderate to major bleeding. Major bleeding associated with IABP, thus requiring increased transfusion, was also demonstrated in retrospective studies. For revascularization rate after treatment, the meta-analysis found that IABP showed a significantly higher revascularization rate compared to patients without support.

Though the majority of the recent reviews had failed to demonstrate a survival benefit for IABP, it was shown to have some beneficial effect on hemodynamic parameters, like cardiac index, mean arterial pressure, and pulmonary capillary wedge pressure. It has been suggested that the use of IABP should be reserved for patients with severe hemodynamic compromise. However, it should be noted that the improved hemodynamic status does not always translate into improved survival outcomes. In a recent research, it was suggested that IABP might have a greater effect in patients with reduced coronary perfusion and those with severely reduced left ventricular function, like in patients with AMI who need to be temporized prior to cardiac bypass surgery. Researchers did not analyze the hemodynamic parameters due to the limited number of data available in included studies.

The current meta-analysis is an updated review of the available data on the utility of IABP during PCI. However, there are several limitations to our analysis, including the limited number of included studies in each subgroup and the heterogeneity in patient characteristics among the studies. The publication bias is difficult to interpret due to the limited number of included studies. Furthermore, there is a potential bias resulting from the inadequate blinding of patients and the study personnel. [12, Rank 5]

The Description of Balloon Pump Device

The Console

The IABP console delivers a specific volume of gas through a pneumatic system into a balloon during a predetermined time interval followed by retrieval of the gas. The console contains:

1. A cylinder of gas source (usually helium).
2. A valve unit, which allows delivery of the gas.
3. A monitor system for acquisition of electrocardiogram and arterial blood pressure.
4. Control unit which processes the electrocardiogram and develops a trigger signal; this is used for timing of balloon inflation and deflation by activating the valve unit

and allowing either opening of the valve in order to deliver the gas, or closure of the valve unit in order to stop the gas flow.

The Driving Gas

Both Helium and Carbon dioxide have been used as driving gases, however the use of helium has theoretical advantages: These include the speed of gas entry and retrieval as well as maintenance of a larger volume of gas within the balloon for a longer period of time; due to lower viscosity of helium as compared with CO2.

Balloon catheters /sizing

Appropriate /inappropriate sizing/ balloon volume and aortic occlusivity

The size of the aorta is related to patient size, age and weight.

The ideal balloon for any patient has to have the length from the left Subclavian artery to the coeliac artery take off, the inflated diameter 90 to 95 % of that of the discending aorta and has to be equal in volume to the volume of blood in the aorta at any given time. The latter statement confirmed by Kantrowitz and colleaques who stated that the balloon is limited by the volume of blood contained within the aorta just prior to inflation (ie. The aortic volume doubles between a shock mean of 30 to 40 mm of Hg and a normal mean pressure of 80 to 90 mm of Hg). Further increases in pumping volume result only in distention of the aorta (due to aortic elasticity) and not in the effective pumping of the balloon.

IABP usage for adult patients has mainly been limited (82 % of the cases) to the use of 40 cc balloon, with membrane length (non tapered section plus tapered ends) varying between different manufacturer from 22 to 27.5 cm and inflated diameter between 15 to 18 mm. [10, Rank 2]

While in many clinical situations volume of 40 cc are appropriate, it should be said that too large IAB increases vascular morbidity whereas too small IAB reduces the cardiac benefit. 50 cc Balloon has been used in taller patients.

Position of the balloon within the aorta

The closer the balloon is to the aortic valve, the greater the diastolic pressure elevation. It is obvious that local anatomical factors limit the position of the balloon within the aortic arch therefore the optimal balloon position will be that where the tip is situated distal to the left Subclavian artery take off. The proximal balloon end should be lying above the renal vessels. Incorrect balloon position results in reduced diastolic augmentation or vascular morbidity due to direct intimal injury or plaque distortion and embolization or finally direct occlusion of the arterial lumen.

Hemodynamic criteria for mechanical circulatory support

Despite adequate preload, max pharmacological support and IAB pumping:

- Cardiac Index < 1.8lt/min
- Systolic arterial pressure < 90 mmHg
- LA or RA pressure > 20 mmHg
- UO < 20 ml/h
- SVR > 2100
- Metabolic acidosis

  “Relative” Exclusion criteria
- Severe Peripheral Vascular disease
- Infection
- Hepatic disease
- Cancer with metastasis
- Severe Coagulopathy

The balloon function

Following the principle of counterpulsation, the IAB is deflated during systole which coincides with QRS –T interval (R wave always triggers balloon deflation). In this manner balloon inflation during cardiac systole is prevented. The IAB is inflated during diastole, which coincides with T-P interval [20, Rank 5]

Cardiovascular Consequences of IABP

Cardiovascular consequences are mainly due to the effect on preload and afterload. Balloon inflation causes volume displacement resulting in a change in coronary circulation with redistribution of blood flow and alteration of oxygen consumption.

Intraaortic balloon counterpulsation is instituted by insertion of a catheter mounted with a distensible polyurethane balloon in the patients descending aorta. Helium gas is shuttled from the balloon pump console. Inflation occurs immediately upon onset of diastole. Deflation occurs during isometric contraction. In a mechanical sense balloon inflation causes volume displacement. Total or regional blood flow is potentially improved with counterpulsation. Coronary circulation and perfusion to the aortic arch trifurcated vessels is potentially increased. Balloon inflation augments the intrinsic Windkessel effect, which augments peripheral perfusion. At the time of deflation intraaortic blood volume is decreased with concomitant lowering of pressure. This process occurs at the end of diastole just as isovolumetric contraction is commencing and reduces the impedance against which the left ventricle must eject.

Cardiovascular changes in systolic events

Decrease in systolic blood pressure

With proper timing if one compares the systolic pressures of non-assisted beats with systolic pressures following IABP assist one would conclude that intra-aortic balloon pumping results in a decline in systolic pressure by up to 10 %. A decrease in aortic systolic pressure in the course of balloon pumping indicates proper systolic unloading and afterload reduction. An alteration in baroreceptor response may account for this effect.

Decrease of the isometric phase of left ventricular contraction

The Aortic valve during balloon pumping opens early therefore the isometric phase of LV contraction is decreased. This time interval is proportionally related to myocardial oxygen consumption. The peak rate of LV pressure rise decreases with IABP up to 20 % compared with control values.

Effects in ejection fraction, cardiac output and starling law for the left ventricle

There is an increase in LV Ejection Fraction during IABP. Likewise there is an increase in Cardiac Output between 0.5 and 1.0 Lt/per min or up to 30 %.The Starlings law curve for the left ventricle is affected by IABP. There is a shift of the curve to the left showing improvement of the left ventricular function. This has been used as a prognostic indicator: by enlarged survivors show a sustained effect while non survivors show a shift to the right indicating ventricular deterioration.

Cardiovascular changes in diastolic events

LVEDP and volume (preload)

The left ventricular diastolic volume is decreased due to systolic unloading.

The relation between left ventricular diastolic pressure change and left ventricular diastolic volume change (LV stiffness) exhibits a trend towards reduced values, a fact that translates into an improvement in left ventricular compliance.

Cardiovascular changes in coronary blood flow

IABP and myocardial oxygen supply/demand

The IABP effect on improving myocardial oxygen supply could be better understood by examining the diastolic pressure time index (DPTI) and tension time index. [12, Rank 4]

DPTI reflects diastolic and subendocardial blood flow and depends on aortic diastolic pressure, left ventricular end diastolic pressure and diastolic duration. DPTI increases with IABP due to an increase in diastolic blood pressure and a decrease in end diastolic pressure.

The ratio DPTI/TTI reflects the relation between oxygen supply and consumption of the myocardium representing the Endocardial Viability Ratio (EVR). A value of 1.0 or higher signifies a normal supply/demand balance. An EVR of less than 0.7 indicates severe myocardial ischaemia

Researchers introduced endocardial viability ratio (EVR) in conjunction with intra aortic balloon and stated that an increased EVR will reflect the increased blood flow occurring during augmentation, however only a period of EVR observation without balloon may assist in determining prognosis. With utilization of IABP the DPTI/TTI ratio is increased. The EVR index is useful as a criterion to decide early utilization of IABC in intra-operative failure.

It has to be clarified that TTI as an index of oxygen demand only accounts for pressure; on the other hand myocardial oxygen consumption is a function of force that is proportional to both pressure and volume, therefore although EVR will only reflect the decrease in pressure IABC produces a decrease in volume as well as pressure. As a consequence the decrease in myocardial oxygen consumption will be underestimated.

IABP and coronary artery perfusion

Balloon inflation displaces blood proximally increasing coronary perfusion by also increasing diastolic pressure and the diastolic perfusion gradient.There are various animal studies that assessed the contribution of the intra aortic balloon on myocardial perfusion. Results were variable. Researchers stated that in animals with normal systemic arterial pressure intraaortic balloon pumping reduced myocardial oxygen consumption without significantly changing total coronary flow.

They undertook a study to determine if balloon pumping increased flow distal to a severe coronary stenosis, however found that despite using IABP blood flow distal to the stenosis remained unchanged. It was found that IABC increased prestenotic but not postenotic flow. They observed relieved anginal symptoms in a population with coronary artery disease and concomitant severe aortic disease. They concluded that improvement in coronary flow must occur with pumping.

Some researchers called myoconservation technique the initiation of IABC. They stated that the balloon action stimulated collateral circulation in the area surrounding the core of myocardial damage. Researchers agreed that collateral circulation was encouraged during diastolic augmentation. They assessed intracoronary flow velocity during catheterization in 12 patients treated with IABC. Diastolic flow velocity time integral was recorded; the greatest increase in diastolic flow velocity time integral occurred in patients with a baseline systolic pressure of <90 mmHg. They concluded that IABC augments proximal coronary blood flow velocity by doubling the coronary flow velocity integral. During counterpulsation aortic end diastolic pressure is lowered. Applying Laplaces low, lowering of aortic end diastolic pressure during static work (refers to development and maintenance of ventricular pressure before opening of the aortic valve) will decrease the amount of tension generated at the time the aortic valve opens. Researchers undertook a study to determine the systolic unloading effects of IABC independent of diastolic augmentation. This was carried out by counterpulsating dogs while their coronary arteries were perfused from an extracorporeal source. The perfusion pressure was lowered to produce acute cardiac failure. When IABC was instituted, systolic unloading (a reduction in left ventricular sustolic pressure) was evident in normotensive states, but not in hypotensive states (coronary perfusion pressure < 80 mmHg). During hypotension, aortic compliance increases which causes the aortic wall to expand with inflation of the balloon, therefore blood volume displacement does not occur. **IABC and peripheral blood flow**

Peripheral blood flow is determined by pressure, resistance, length and viscosity. Balloon inflation during diastole increases the arterial pressure, which increases the arterial-venous gradient and thus improves flow. In addition balloon inflation in diastole displaces stroke volume and thus activation of the aortic baroreceptors inhibits the medullary vasoconstrictor reflex. Peripheral resistance decreases, which, as demonstrated by Poiseuilles low improves blood flow.

The impact of IABC on splachnic blood flow has also been studied. Researchers studied the effects of intraaortic balloon pump assist upon splahnic blood flow during sustained hemorrhagic shock and following volume resuscitation. The IABP group was found to have a return to preshocksplachnic visceral perfusion without the hyperemic reperfusion phenomenon seen in control animals. They concluded that IABPC during hemorrhagic shock appears to improve vasomotor control of splachnic blood flow by eliminating the hyperemic reperfusion phenomenon resulting in less reperfusion injury.

It outlines the variables that influence diastolic pressure augmentation during balloon inflation. The variables are:

1. Balloon position: The closer to the Aortic valve the greater the diastolic pressure elevation.
2. Balloon Volume: When the balloon volume is equal to the stroke volume the diastolic augmentation is maximized.
3. Balloon diameter and occlusivity: The greatest augmentation occurs with complete aortic occlusion.
4. Balloon Configuration/Driving gas & Timing.
5. Stroke volume: If stroke volume is less than 25 ml little diastolic augmentation can be expected.
6. Arterial pressure: The significance of aortic elasticity is illustrated by the fact that aortic volume doubles between a mean arterial pressure of 30 mmHg and a normal mean pressure of 90 mmHg. Researchers calculated an algorithm for optimal balloon sizing in order to improve diastolic augmentation and minimise patient-balloon mismatching. [14, Rank 5]

Indications for IABP

Overall incidence of IABP utilization

The incidence of IABP treatment following Cardiac surgery is reported to be around 7 % in various units. This of course is dependent on the case mix and stratifying patients according to the Euroscore, one would obviously suggest that IABP usage correlates with ascending scoring.

According to various reports, Poor LV function, History of Myocardial Infarction, Female sex, Diabetes mellitus, Peripheral Vascular Disease and also Left Main Stem Disease are incremental risk factors for IABP utilization.

The unique physiological balance of benefits of IABP, include support of the coronary circulation, as well as reduction in left ventricular stress and reduction in cardiac work-load.

The indications for use of an IABP involve two areas:

1. Temporary support of the left ventricular function due to cardiac failure, due to myocardial infarction or due to intraoperative injury.
2. Improvement in the oxygen supply/demand balance to decrease the extent of the ischaemic zone and to preserve myocardial viability.

However the efficacy of IABP is dependent upon the phase of myocardial ischaemia or the time elapsed from initiation of myocardial infarction as well as the stage of left ventricular function.

The value of the balloon pump as a circulatory assist device in the treatment of cardiogenic shock is well established. Researchers suggested criteria for which IABC would be most successful:

1. Triple Vessel disease with moderately preserved left ventricular function and good distal targets.
2. Significant mechanical lesions such as mitral insufficiency or ischaemic ventricular septal defect.

IABP following unstable angina refractory to medical measurements

Various clinicians must agree that during ischaemic episodes there is a potential window of opportunity were adequate hemodynamic support would ensure that adequate myocardium would remain viable to allow resumption of function, following coronary artery bypass grafting. This is the concept of myoconservation and where the intraaortic balloon pump exerts major impact.

Researchers showed that the usage of IABP abolishes the pain, ameliorates ST segment elevation and prevents left ventricular tachyarrhytmia. The same group showed that if the balloon treatment was followed with a CABG then outcome was statistically better than if the balloon treatment had not been instituted.

In unstable patients especially in the presence of left ventricular dysfunction, the use of IABP allows safe performance of diagnostic studies followed by surgical intervention. Researchers agree that following those lines of treatment, the operative mortality and the incidence of peri-operative infarction is less.

Although the majority are not controlled non-matched series, they however still indicate that patients who are refractory to maximal medical therapy can be operated on with IABP stabilization with a low operative mortality and a low peri-operative infarction rate. Incremental risk factors for death include the subgroup of patients with poor left ventricular function, left main stem disease, left ventricular hypertrophy, unfavourable coronary anatomy, diabetic obese females and concomitant end-stage aortic valve disease.

IABP following myocardial infarction

In Theory, IABP could be used during acute myocardial infarction in order to decrease the size of the infarct, to support the cardiac function, to prevent infarct extension and to reduce complications associated with the event.

Researchers published their clinical experience at St. Louis University with a series of 50 consecutive IABP patients. 33 patients (66 %) underwent IABP due to myocardial infarction. Chest pain was totally relieved in 29 patients (94 %) with improved hemodynamics in 46 of 50 patients (92 %). 19 patients (38 %) died, including 13 of the 33 patients admitted with acute myocardial infarction.

Effects on ischaemic pain were impressive; pain was abolished within minutes for 11 patients and hours for one patient. Only one hospital death occurred in group I. Of the 14 patients in group II, 8 hospital deaths occurred.

The same group of investigators in a randomised clinical study looked at the effects of IABP on post-myocardial infarction pump failure and showed no beneficial effects on definable end points. Therefore, in patients with acute infarction IABP is not employed except as a supportive measure to be followed by a myocardial revascularization procedure; when for example there is development of cardiogenic shock or if any of the mechanical complications following myocardial infarction have occurred. Once there are reasons for revascularization, IABP may be beneficial in decreasing the size of infarction and decreasing operative mortality.

In patients with acute myocardial infarction researchers reported results with 40 patients treated with IABP for cardiogenic shock following myocardial infarction. Group I was treated with IABP and Group II with IABP and coronary artery bypass grafting. In hospital mortality between group I and II was 71 % versus 47 %. The portion of Group II that underwent treatment within 16 h from the onset of symptoms had a lower mortality (25 %) than the portion of Group II that underwent surgery more than 18 h after the onset of symptoms.

IABP for ventricular arrythmias

In patients with acute myocardial ischaemia when tachyarrhythmia is refractory to second or third line antiarrhythmic therapy IABP treatment should be instituted followed by cardiac catheterisation and coronary artery bypass grafting.

Almost all the ventricular dysrhythmias due to ischaemia are temporarily controllable with medication; therefore few patients would require IABP prior to a revascularization procedure. There is, however a role for using IABP in patients who have an unstable rhythm due to myocardial infarction early after myocardial revascularization.

Patients with ventricular aneurysms and arrhythmias with triple vessel disease amenable to bypass grafting have shown good survival results, however arrhythmia has persisted in 30 % of the cases unless some form of aneurysm repair is carried out.

IABP support for acute ischaemic mitral incompetence

Most frequently involves the posterior papillary muscle and the responsible coronary artery by 80 % is the right coronary artery. According to researchers early mortality is high in these patients (21 %).

IABP should be used in patients who have slipped into cardiogenic shock following post-infarction MR. This would allow haemodynamic stability in order to permit left ventricular catheter studies to be followed by mitral valve replacement. Concomitant bypass improves early and late survival.

IABP support for acute ischaemic rapture of ventricular septum

In the majority of cases with cardiogenic shock pulmonary congestion ensues. Deterioration of the patients clinical condition is dependent upon the extent of involvement of the right ventricle and also the function of the left ventricle. Researchers reported on the extremely poor outcomes, with in-hospital mortality rates of about 45 % for surgically treated patients and 90 % for those treated medically.

IABP treatment during ischaemic rupture of the ventricular septum, increases the mean aortic pressure and cardiac output and decreases the right ventricular and pulmonary wedge pressure.

Patients should be operated upon as quickly as possible and a delay in surgery can lead to multi-systemic organ failure. These patients are at high risk for operative mortality and even with prompt surgical management, operative mortality remains significant because of heart failure and risk of fatal haemorrhage. A meta-analysis of 17 series from 1991 to 2009 reported five-year survival rates ranging from 33 % to 65 % especially if concomitant revascularization procedure had been advocated.

IABP support during percutaneous coronary intervention (PCI)

The incidence of utilization of IABP in the course of cardiac catheterisation is reported by the International Benchmark Registry to be as high as 1 in 5 as an adjunct to high-risk PCI.

Various authorities around the world have adopted a policy of "standby" IABP during angioplasty procedures in high-risk patients. Treatment with balloon may be the most effective measure in the first few minutes following complicated angioplasty.

Relative criteria have been developed for selection of patients who should be considered for prophylactic IABP before PCI:

- Multi-vessel angioplasty in-patient with hypotension,
- Angioplasty of the only functional coronary artery
- Left main coronary artery angioplasty unprotected by a patent graft.

Various rare indications for intra-aortic balloon pump

Bridge to cardiac transplantation

IABP mainly reduces the afterload thus improving the performance of the failing heart. In a series among 274 heart transplant patients, thirty-seven (28 %) required IABP as a bridge to transplantation.

High risk cardiac patients who are undergoing general surgical procedures

Two patients presented who underwent intraperitoneal surgery under the support of intraaortic balloon pump (IABP). In one patient, the IABP was inserted urgently because of the development of chest pain with significant ST depression on arrival in the operating room.

IABP support in paediatric population

The major problems encountered here are:

1. The small size of the aorta.
2. High elasticity of the aorta, which precludes effective balloon pumping.
3. Small stroke volume, which precludes balloon augmentation.

Researchers reported rather disappointing early experience with IABP support for heart failure following repair of congenital defects in infancy. However, recent advances in paediatric IABP technology have made its use feasible for children of all ages with acceptable morbidity. In selected groups of children with predominantly left ventricular failure, IABP has been an effective and lifesaving adjunct to conventional medical treatment of refractory low cardiac output. These developments are especially relevant to emerging countries where the cost of ECMO/VAD is prohibitively high; the use of IABP may be a more cost-effective modality in appropriate patients.

Pulmonary artery balloon pumping

In theory would be indicated for patients with pulmonary hypertension such as after embolectomy or mitral valve replacement. Acute infarction involving the right ventricle would be a relative indication. Despite the obvious theoretical advantages, in reality the results are equivocal.

During sudden cardiac arrest

Combination of IABP with external compression during resuscitation theoretically improves coronary and cerebral perfusion.

Inability to be weaned off cardiopulmonary bypass/post cardiotomy cardiogenic shock

As early as the beginning of 1970s researchers realized that a major indication for use of an intra-aortic balloon pump is cardiac dysfunction with low cardiac output after heart surgery. The group of patients in whom IABP is deemed beneficial following unsuccessful separation off the cardiopulmonary bypass machine, include:

1. Patients with severe left ventricular muscle dysfunction and low ejection fraction who need an extensive operative procedure, which does not improve the cardiac performance immediately.
2. Patients requiring reoperations (redo-grafts) while they are suffering from an acute left ventricular dysfunction due to an unstable coronary syndrome.
3. When the ejection fraction in percent is lower than the end-diastolic pressure in mmHg.
4. Patients with severe long standing aortic stenosis and compromised ejection fraction especially when there is a need for associated procedures such as aortic root enlargement or coronary artery bypass grafting.
5. Patients with severe ischaemic mitral incompetence and dilated poor left ventricular function.
6. Patients with large left ventricular aneurysms and low ejection fraction.
7. Patients with left main stem coronary disease and an acute myocardial infarction

in progress.

8. Post-operative right ventricular dysfunction.

Emergency use of IABP after cardiac surgery should be considered, when: all the causes of incomplete revascularization have been eliminated & there is a difficulty to wean from heart lung machine after attempting for 30 min at flow rates above 500 ml/min, with hypotension and low cardiac index despite increasing requirements of inotropic support (Dopamine > 10 mcg/Kg/min).

Utilization of IABP as an emergency measure for postoperative cardiac failure has consistently produced a survival rate of around 70 % by various groups. A 2010 study found a cumulative survival for a group of 2697 patients requiring IABP support post-operatively was 85.2 % at 4 years. [17, Rank 5]

Complications of IABP

IABP complications are resulted during difficult insertion and malposition, prolong IABP stay and due to patient's comorbidity such as peripheral vascular disease, small size patients, use of sheath of IABP and Diabetes.

A study identified IABP malposition to be a common finding on post insertion CT scans. Anatomic to balloon length mismatch was found in 68.2 % of the cases, with subsequently severe adverse effects.

Injuries resulting during IABP action could be overlooked unless catastrophic clinical implications are encountered; an important analysis reviewed a total of 45 necropsy patients who have had an IABP inserted and who died within 105 days of the time of balloon insertion. Dissection of the aortoiliac axis occurred in nine patients and in none of them was the dissection suspected before death. In 4 out of those 9 patients, insertion occurred without resistance. In one out of the 3 patients that they had developed arterial perforation no complication of balloon insertion had been developed. In 2 out of the 3 patients that they had developed thrombosis intravascularly no clinical suspicion rose prior to death. Clinically silent arterial emboli occurred in 3 patients. They concluded that out of the 20 complications (in 16 patients) only 4 (20 %) had been suspected before death.

By enlarge, complications are reported to be primarily associated with the insertion process and prolonged balloon pumping, rather than removal or post removal monitoring.

Obviously, due to the nature of the IABP, the main complications relate to vascular injury, with studies suggesting vascular ischaemic complications of between 8–18 % with major limb ischaemia reported to be less than 1 %.

In a study published by, cold pulse-less foot was detected in 29.5 % of the cases. The ischemia resolved either with removal of the balloon or with thrombectomy. One patient developed gangrene and required amputation.Thrombocytopenia, defined as platelets <150,000/mL or >50 % decrease from baseline, occurred in 57.9 % of patients.Among patients undergoing IABP, thrombocytopenia is generally mild, appears to be unrelated to concomitant heparin use, and is not associated with an increased risk of major bleeding or in-hospital death.

Rupture of the IABP is rare but can cause gas embolism and potential entrapment of the balloon within the arterial tree. However it is very rare, possibly less than 0.5 %. The proposed mechanism involves mechanical disruption of the balloon against an atherosclerotic plaque or extensively calcified aortic wall with resultant perforation and the negative pressure created during deflation traps blood within the balloon. The blood rapidly reacts with the helium causing a hard clot formation, which together with the tortuous atherosclerotic aortic environment results in entrapment of a semi-deflated balloon.

Finally, Complications of thrombosis and infection are related to the duration of IABP therapy while the limb ischemic problems are more a function of the atherosclerotic status of the common femoral artery and either the ratio of balloon catheter diameter to arterial lumen, or the difficulty of dealing with a severely atherosclerotic artery with loose plaques or fragility requiring excessive surgical manipulation. [20, Rank 4]

Effect of IABP on Mortality in CABG Patients

Preoperative insertion of intra-aortic balloon pump reduces mortality in elective high-risk coronary artery bypass graft patients. This finding was already suggested by previous meta-analyses but they were challenged by a recent large randomized controlled trial that concluded that the intra-aortic balloon pump was not useful in this context even if it showed a trend toward improved clinically relevant outcomes in the intra-aortic balloon pump group versus 17 (31%) in the control group, operative mortality: 4 (7.3%) in the intra-aortic balloon pump group versus 8 (14%) in the control group.

When compared with other meta-analyses this work includes three recent articles for a total of 402 new patients. We also included sensitivity analyses, almost double the number of patients with respect to previous meta-analyses and, most importantly, our meta-analysis includes articles from four different research groups from four different countries.

The role of the intra-aortic balloon pump has been recently challenged by a study that showed no difference in short- and long-term survival in patients randomized to intra-aortic balloon pump versus standard treatment, recurrent revascularization, or stroke in acute coronary syndrome complicated by cardiogenic shock and planned for revascularization. It should be noted that that study is not included in this meta-analysis because only six patients underwent surgical revascularization.

The intra-aortic balloon pump acts by increasing diastolic blood pressure, directly improving diastolic coronary perfusion and increasing cardiac output and stroke volume by reducing afterload. The ability to act on diastolic pressure has a great importance in clinical practice because previous studies have demonstrated that the augmented diastolic pressure results in a redistribution of coronary blood flow toward ischemic areas of the myocardium.

The value of some trials is to be questioned in the light of the unacceptably high rate of intra-aortic balloon pump-related complications. The most recent trial reported two patients in the intra-aortic balloon pump study group who did not receive the balloon due to technical difficulties and four patients suffering from vascular complications (12%). Strikingly, both in the surgical and nonsurgical population of previously published studies there was a systematic need for crossover from the control group to the intra-aortic balloon pump group (approximately 13 to 17%), which assumes a reproducible methodological bias. [18, Rank 3]

Effect of IABP on Mortality of Patients with Acute Myocardial Infarction

The aim of AMI management is to reduce the mortality by improving or restoring the coronary circulation. Thus far, even with rapidly emerging medical options available, mechanical circulatory support devices are still necessary to provide hemodynamic support when required. IABP has been shown to improve the outcomes of AMI patients with cardiogenic shock by increasing diastolic peak pressure and reducing afterload in the pre-PCI era. In addition, IABP was reported to maintain the hemodynamic stability in selective high-risk AMI individuals under going PCI during short term.The prophylactic IABP support in high-risk patients during selective PCI has also been thoroughly evaluated in a study with a total of 106 patients, suggesting IABP could reduce the level of C-reactive protein and short-term mortality following PCI

However, there has been ongoing controversy on IABP application on AMI patients with or without cardiac shock since the 1990s. Although IABP results in a hemodynamic benefit on afterload reduction and coronary perfusion improvement, the effects on cardiac output are modest and not sufficient to reduce mortality. As shown in a recent meta-analysis, preoperative insertion of IABP reduced mortality in selective high-risk coronary artery bypass graft patients.IABP may play a role as a bridge or transition in short term but not on increasing long-term survival rate, which are also affected by subsequent physiopathologic progression and treatment following AMI.

Before the IABP-Shock II Trial, which did not find improved 30-day, 6-month, or 12-month survival rate after the implantation of IABP, researchers showed that IABP support could reduce afterload, as measured by a significant reduction in BNP in 2010. However, they also revealed that mechanical support, such as IABP, failed to prevent the initiation and development of systemic inflammatory response syndrome (SIRS) and multi-organ dysfunction syndrome (MODS), which lead to the high

mortality of AMI patients with cardiogenic shock as assessed using Acute Physiology and Chronic Health Evaluation (APACHE) II score.There was a meta-analysis supporting this in the importance of prognosis assessment in patients with AMI complicated with cardiogenic shock. Although APACHE II score was not applied in the meta-analysis, it reported a significant reduction of in-hospital mortality in AMI with cardiogenic shock, while AMI patients with high-risk and cardiogenic shock may not benefit from the use of IABP in terms of in-hos
pital mortality, rate of reinfarction, and recurrent angina.Nevertheless, this study might be inherent biased due to the combined analysis of RCTs, prospective and retrospective observational studies.

Most of current meta-analyses and recommendations for IABP application were mainly based on nonrandomized data due to the difficulties in conducting a randomized clinical trial in the emergency setting of AMI. According to the absence of meta-analysis on prospective randomized studies, it is of great value to reassess the therapeutic effectiveness of IABP for circulatory support in AMI. Therefore, we carried out the current updated meta-analysis but failed to reveal a substantial benefit from IABP therapy on reducing the short- and long-term mortality, in AMI with or without cardiac shock. The potential limitation of our study is that IABP-SHOCK II trial may have relatively larger weight.

Although there was no significant difference on the short-term mortality regardless of whether IABP-SHOCK II trial was included or not, the long-term mortality was improved without IABP-SHOCK II trial. However, the results are consistent with another recently published meta-analysis, which also showed that IABP was not found to improve 30-day mortality among patients with AMI in RCTs, no matter patients had cardiogenic shock or not. As we know, cardiogenic shock is commonly rapidly progressive and usually fatal. Despite of the advances in coronary revascularization, cardiogenic shock as a complication of AMI still remains as a huge clinical challenge with high mortality. It eventually results in SIRS and MODS due to peripheral hypoperfusion with microcirculatory dysfunction of ischemia sensitive tissues and organs. This would happen in various percentage of patients with mild, moderate, or severe cardiogenic shock, which could preclude the statistical processing. Therefore, further studies should include hemodynamic measurements or laboratory inflammatory markers within a scoring system to divide AMI patients into more accurate subgroups.

In addition, safety is another important issue in consideration of IABP application. Although the sheathless catheter insertion technique and catheters with smaller profiles were developed, the use of IABP may produce a high rate of complications, such as hemorrhage, recurrent ischemia, stroke, and reinfarction. Although no differences regarding hemorrhage were observed in IABP-Shock II Trial, conflicting conclusions were reported in a meta-analysis, in which IABP was found to significantly increase the risk of moderate-to-severe bleeding.In a meta-analysis, it was also found IABP was associated with an increased rate of bleeding, possibly associated with the use of multiple antithrombotic agents with aggressive anticoagulation regimen in acutely MI patients.

Besides, the use of IABP was also the strongest independent predictor for major bleeding due to femoral artery cannulation, prolonged duration of IABP support, IABP-related thrombocytopenia and renal impairment, which were consistently demonstrated by other study populations, especially in patients who had developed or were anticipated to develop cardiogenic shock. Researchers further pointed out that IABP insertion in the urgent setting in response to intraprocedural hemodynamic instability confers a higher risk of bleeding compared with selective insertion for stable patients. In terms of other safety issues, they observed significantly increased risk for recurrent ischemia in IABP group than in the control group. Although it seems more closely related to the premorbid status of patients, these findings may add additional support on a more conservative strategy for using IABP in acute phase of MI with or without cardiogenic shock.

As mentioned earlier, AMI is not only associated with compromised cardiac contractile function, especially in patients with cardiogenic shock. Therefore, other than mortality, more comprehensive assessment of hemodynamic changes and inflammatory markers of patients with AMI may serve as better end point for IABP application. In addition, there were <10% of patients in control group accepting

IABP or LVAD support in IABP-SHOCK II trial, which might interfere the analysis of mortality in our study. In terms of the timing of IABP insertion, it was too difficult to control in real clinical settings and to be included for analysis in most studies. Future RCTs with larger numbers of patients and rigorous design are required in the future. [26, Rank 3] **Preoperative Prophylactic IABP in Severe LV Dysfunction Patients**

Preoperative prophylactic IABP insertion was associated with reduced postoperative 30-day mortality in severe LV dysfunction patients who underwent OPCAB. Furthermore, prophylactic IABP insertion resulted in significant reduction of postoperative LCOS incidence and shorter postoperative hospital stay.

From the perspective of pathophysiology, the positive effect of IABP insertion is believed to increase coronary blood flow while simultaneously decreasing myocardial oxygen demand. Consequently, preoperative prophylactic IABP assistance provides better hemodynamic stability in crucial times of higher oxygen demand when the heart is displaced in OPCAB procedures.

Although there are certain advantages in theory, the results have been controversially debated in clinical practice. Some studies have shown a positive effect of preoperative prophylactic IABP insertion in improving the outcomes of high-risk patients. The strongest evidence supporting preoperative IABP insertion for high-risk patients undergoing CABG comes from published meta-analysis studies. However, many contemporary studies have challenged the effectiveness of preoperative IABP in high-risk patients undergoing CABG. Worse outcomes were shown in a recent propensity-score matching study, in which the preoperative IABP insertion in patients undergoing CABG after acute myocardial infarction was associated with increased in-hospital morbidity, greater transfusion requirements, and longer postoperative ICU stay.

The results of previous studies have been controversial for several possible reasons. First, there is no standard definition of a high-risk patient. Various conditions, including severe LV dysfunction, left main disease, diffuse coronary disease, and reoperation, have been suggested for preoperative prophylactic IABP insertion.

Second, the criteria for prophylactic IABP insertion have not been well defined. A distinction is lacking between therapeutic use for patients with preoperative cardiogenic shock or hemodynamic instability and prophylactic use for patients with preoperative hemodynamic stability. In many previous studies including patients with hemodynamic instability, the indication has been more likely for therapeutic, rather than prophylactic insertion. Third, the results were also possibly affected by the severity of the patients who were selected to receive preoperative IABP support. Finally, most of the procedures were conducted in CABG patients. IABP insertion before surgery was suspended during CPB. The benefit from IABP support was relatively low.

Various studies investigated for the clinical effects of preoperative prophylactic IABP insertion in patients with severe LV dysfunction that underwent selective OPCAB. The IABP group of patients received preoperative prophylactic IABP support to increase the safety of OPCAB procedures. The patients who received preoperative IABP support for hemodynamic instability, cardiogenic shock, and emergency operations were excluded. Comparatively, IABP was still working during OPCAB procedures in our study. These patients were more likely to benefit from preoperative IABP insertion. Therefore, preoperative prophylactic IABP insertion was associated with a lower rate of conversion to on-pump CABG, which has been associated with increased in-hospital mortality

The preoperative prophylactic IABP insertion in our study was not associated with an increased rate of IABP-relationship complications (that is, limb ischemia requiring surgical intervention, severe bleeding at the IABP insertion site, and embolism). The incidence rate of IABP-related complications was low, similar with a previous study. Therefore, IABP insertion is safe in those high-risk patients.

This study was subject to the limitations inherent in any retrospective, observational study from a single center. The nonrandomized design might have affected our results, owing to unmeasured confounds, procedural bias, or detection bias. Despite the benefits of propensity matching, it is possible that there are additional confounds that were not accounted for in our adjustment algorithm. The whole study depends on the accuracy of propensity score matching and many pitfalls may be hidden. Second, it is generally believed that the experience of the surgeon can influence the results of OPCAB. Six experienced cardiac surgeons performed the OPCAB procedures in this study. However, our hospital is an international center for cardiovascular clinical and research.

All of the surgeons followed the same standard OPCAB procedure of our hospital. Furthermore, this study was also limited to patients undergoing isolated OPCAB. Patients requiring concomitant cardiac surgical procedures, and/or those with mechanical complications of acute myocardial infarction, such as acute mitral regurgitation or myocardial rupture, were excluded from this study. Therefore, the results of this study cannot be extended to these extreme high-risk patient populations. Finally, the present study was conducted in the setting of a high-volume tertiary cardiovascular center in a developing country; therefore, the results might not be generalizable to other centers in different situations. [8, Rank 4]

Combination of IABP and Mechanical Ventilation for the Treatment of Cardiogenic Shock after Acute Myocardial Infarction

The IABP + mechanical ventilation group tended to present with more severe cardiogenic shock than the IABP group, as demonstrated by a lower mean arterial BP, systolic BP and a greater incidence of Type 1 respiratory failure. Type 1 respiratory failure is defined as $PaO2 < 60$ mmHg and the mean ± (SD) PaO2 for the IABP + mechanical ventilation group was 49.9 ± 5.1. Nevertheless a significant improvement of left ventricular function, as measured by LVEF, was observed in the IABP + mechanical ventilation group following the procedure. By contrast, no difference was observed in left ventricular function before and after treatment in the IABP group. In addition, there were significantly more cases of pulmonary infection and renal insufficiency in the IABP + mechanical ventilation group than the IABP group; analysis showed that these two conditions were significant risk factors for all-cause in-hospital mortality. However, there was no between-group difference in 30-day survival rates. In patients with fragile haemodynamic status, such as those assessed in this study, inappropriate ventilation settings can have severe deleterious effects. Indeed, mechanical ventilation is often referred to as a double-edged sword for patients in cardiogenic shock.Mechanical ventilation with PEEP is universally used in patients who have cardiogenic shock. However, some investigations have shown that PEEP exerts unfavourable haemodynamic effects such as decreased venous blood return which increases right ventricular afterload, decreases left ventricular filling pressure and depresses cardiac output and overall organ perfusion.Nevertheless, moderate levels of PEEP appear to be well tolerated in severe left ventricular dysfunction and cardiogenic shock, and may provide some haemodynamic benefits.Therefore, clinicians should be aware that PEEP can be used for clinical benefits, but high levels should be avoided to minimize the potential side-effects. A significant improvement in left ventricular function was observed in the IABP + mechanical ventilation group. IABP is the most commonly used intervention for cardiogenic shock:it decreases the left ventricular afterload, increases the diastolic coronary arterial perfusion pressure and promotes a redistribution of the coronary blood flow towards the ischaemic myocardium.In addition, an appropriate level of PEEP can improve cardiac output by decreasing the left ventricular afterload and preload.Mechanical ventilation also triggers the respiratory muscles that, during pulmonary oedema, generate more work and absorb a large proportion of the cardiac index.Finally, mechanical ventilation improves pH and oxygenation, thereby offering a good chance of myocardial survival. Survival rates observed in this study (i.e., 34.5% and 48.5% for IABP and IABP + mechanical ventilation groups, respectively) did not corroborate other research, which found rates of 28% and 80% for the IABP and IABP + mechanical ventilation groups, respectively.As stated above, pulmonary infection and renal insufficiency were the main complications reported in the IABP + mechanical ventilation group in this study from our centre and they were significant risk factors for all-cause, in-hospital mortality. Therefore, it is likely that the beneficial effects of improved left ventricular function on in-hospital mortality produced by the combination therapy were counteracted by the high incidence of pulmonary infection and renal insufficiency in this group of patients. The high incidence of pulmonary infection observed in the IABP + mechanical ventilation group suggests that infections develop more easily with this intervention. Indeed, low cardiac output has been reported to be detrimental to the immune system in patients with cardiogenic shock.In addition, ventilator-associated pneumonia (VAP), which occurs >48 h after intubation and mechanical ventilation, is the most common nosocomial infection in the intensive care unit (incidence of 8–28%) in patients receiving mechanical ventilation via intubation.Therefore, researchers postulate that IABP + mechanical ventilation may promote an increase in pulmonary infections, in patients in cardiogenic shock. Prevention and early treatment of pulmonary infections are therefore both important in patients receiving IABP + mechanical ventilation.

Renal insufficiency is reportedly related to organ hypoperfusion in patients in cardiogenic shock.In the present study, patients in the IABP + mechanical ventilation group had more severe cardiogenic shock than patients in the IABP group, which may have accounted for the higher incidence of renal insufficiency in this group. Approximately 7% of patients undergoing percutaneous coronary intervention experience renal insufficiency, a condition which is strongly associated with in-hospital mortality.Therefore, the management of renal insufficiency is one of the main cornerstones in the treatment of cardiogenic shock. Urine production should be measured and in cases of acute renal failure with clinical signs of uraemia, hydropic decompensation, metabolic acidosis and refractory hyperkalaemia, continuous renal replacement therapy should be initiated early.

In agreement with previous findings, the present study showed that successful revascularization was a negative risk factor for all-cause in-hospital mortality. Although early revascularization is increasingly performed, revascularization rates remain unsatisfactory.Clinicians should recognize the benefits of revascularization even if the associated risks are high, especially in patients >60 years old.

The present study was a single-centre, nonrandomized, retrospective study. Nevertheless, randomized clinical trials in cardiogenic shock are difficult to perform and are often more costly than trials in other clinical conditions. Therefore, a randomized study in this critically ill population may not be feasible.In addition, because of the retrospective nature of the study, some variables could not be evaluated, including the mid-term survival rate. Secondly, the patients in the

IABP + mechanical ventilation group had more abnormalities at baseline compared with those in the IABP group. This may have made it difficult to assess the real added value of mechanical ventilation and may have affected the study outcome. Indeed, the rate of successful revascularization in both treatment groups was lower than what could be expected for STEMI. This may have been attributable to the poor condition of the patients, since this present study included patients in cardiogenic shock who were refractory to pharmacological therapy. Finally, the sample size was limited because at our centre only a small number of cases of cardiogenic shock received IABP or IABP + mechanical ventilation therapy. Therefore, further multicentre, randomized, prospective studies with larger sample sizes are needed to confirm our findings.

This study showed that mechanical ventilation with an appropriate PEEP appears to enhance the beneficial effects of IABP on left ventricular function for patients in cardiogenic shock. However, IABP and mechanical ventilation did not decrease in-hospital mortality. The IABP + mechanical ventilation group of patients had greater rates of pulmonary infection and renal insufficiency than the IABP group: factors which were shown to be risk factors for all-cause, in-hospital mortality. [13, Rank 3]

Predictors of IABP Insertion in Coronary Surgery

Recently, several studies have shown that patients undergoing cardiac surgery were older and had more multi-vessel disease, more impaired left ventricular function, and higher incidence of preoperative comorbid illnesses. In patients with left ventricular dysfunction having a higher incidence of associated comorbidities undergoing CABG surgery, it is difficult to wean them from CPB due to impaired cardiac performance after CABG surgery, and the mortality rate is higher. IABP has been widely used during the perioperative period to support patients with preoperative left ventricular dysfunction and low cardiac output syndrome after CABG surgery. The main physiological effects of the IABP are the reduction of the left ventricular afterload and an increase in the coronary perfusion pressure and collateral vessel blood flow secondary to an increase in the aortic diastolic pressure.

The cardiac output increases because of improved myocardial contractility due to increased coronary blood flow and the reduced afterload and preload. Identification of perioperative risk factors in patients undergoing CABG might assist the surgeon in planning the surgery and in the subsequent postoperative management.

In this study, IABP was used in 8.1% of our patients, which is similar to results reported in other studies. Although some studies have shown that survival at follow-up was better for receiving preoperative IABP as compared to intra- or postoperative IABP, other studies have shown that the use of prophylactic IABP in high-risk patients did not lead to any survival advantage compared with the use of intraoperative or postoperative IABP. In this study, preoperative IABP was used in patients with hemodynamic instability having a poor left ventricular function refractory to the maximum medical therapy.

Intra- and postoperative IABP were used in patients that could not be weaned from CPB despite the forced inotropic support; in patients with a low-cardiac output status just after the discontinuation of CPB, supported by high-doses of inotropes; and in patients showing symptoms of arrhythmia but not amenable to anti-arrhythmic continuous infusion with hemodynamic instability. In our study, the prophylactic IABP was not used in any of the patients. Prolonged cardiopulmonary bypass time and prolonged operation time were independent predictive factors of IABP insertion. In our study, the postoperative mortality rate in patients with IABP support was 35.8%, which was similar to that obtained in previous studies.

Several studies showed that advanced age, female gender, smoking, left main coronary artery disease, urgent or emergency operation, prolonged cross-clamping time, and prolonged CPB time were factors affecting postoperative mortality in patients with IABP support undergoing cardiac surgery, but these factors could not be confirmed in our study. In this study, as in others, there was a significant relationship between postoperative renal insufficiency and postoperative mortality. Unlike former studies, it was found that prolonged ventilatory support and postoperative AF were independent predictive factors of postoperative mortality in patients with IABP support.

The morbidity rate related to IABP insertion in our study was 6.7%, which is within the range reported elsewhere (range, 8.7% to 29%). In this study, a pulse-less leg was detected in 9 patients with IABP support, and the problem was resolved after the removal of the IABP catheter in all cases. The low incidence of IABP-related complications is most likely explained by the effect of newer technologies, increased experience of our surgical teams, and more focused attention to IABP-related complications.

In this study, the mean length of ICU and hospital stay was longer in patients with IABP support undergoing isolated on-pump CABG, and these findings were similar to those of previous studies.

This study reported that the 5-year survival was 79.2% in patients with IABP support undergoing CABG, and another study stated that the 4-year survival rate was 85.2%. In this study, although the postoperative mortality of patients with IABP support remained high, the mid-term prognosis was good.

In conclusion, although the postoperative mortality rate of patients with IABP support remained high, the mid-term survival was relatively good for patients surviving the early postoperative period. [19, Rank 3]

Trans-aortic IABP Insertion in Patients with Severe Aorto-iliac Disease

IABP is currently the most widely used mechanical circulatory support in cardiac surgical patients during the preoperative and perioperative period. IABP provides haemodynamic stability by assisting myocardial oxygen supply and demand balance, preoperatively, intraoperatively, and during the critical postoperative period. Intraoperative IABP support is needed for patients who cannot be weaned from CPB. The route choice for IABP catheter insertion during CPB is related to accessibility. Conventionally, IABP catheter is usually positioned in the descending aorta through retrograde femoral catheterization. However, in patients with severe aortoiliac occlusive or aneurysmal disease, or small peripheral arteries, femoral route is not possible. In these circumstances, there are several alternative methods to provide counterpulsation.

Alternative routes for IABP catheter insertion include the subclavian, axillary, brachial, innominate, or iliac arteries. Availability of small IABP catheters can broaden the indication for these methods of insertion in an increasing number of patients encountered in daily cardiovascular practice. The catheter can also be inserted intraoperatively using a transaortic route including the ascending aorta or the proximal portion of the aortic arch. Of these alternate approaches, transaortic insertion is the most frequently used and constitutes a rate of 1.9% to 6.2% of all IABP procedures.

Transaortic route is a suitable alternative way to allow IABP insertion in patients with severe aortoiliac diseases. Researchers did not encounter a problem or complication related to this procedure used in failure to wean from CPB. Transaortic route is a good second choice (class I level, C evidence) for intraoperative placement of an IABP in patients with severe aortoiliac disease or prior abdominal aortic or femoral artery operation. In this option, the IABP catheter may be inserted directly into the ascending aorta or indirectly through a graft anastomosed to the ascending aorta and brought into the subcutaneous tissues in the jugulum or xiphoid region.

The techniques of transaortic IABP insertion have evolved over the past four decades. There is no available ideal technique. This technique should permit a rapid and safe IABP insertion combined easily with its removal and minimal or no residual synthetic material within the mediastinum. In patients needed IABP support during cardiac surgery, an open sternum facilitates direct insertion into the ascending aorta with the balloon catheter tip lying distally in the descending aorta. Direct catheter insertion includes a technique that used pledgeted or concentric pursestring sutures to secure the balloon catheter in the ascending aorta. This graftless technique offers the advantage of rapid balloon placement through the ascending aorta under direct vision. However, it has the disadvantage of requiring a repeat sternotomy for IABP catheter removal. Additionally, there is always the possibility that a thrombus on the balloon catheter might be stripped off by the aortic wall during its removal.

A variety of techniques for inserting the IABP through a graft sutured to the ascending aorta have been reported. These techniques can eliminate the necessity of resternotomy, and the IABP catheter is removed in the surgical ICU under local anesthesia. The use of a graft may help prevent frictional resistance during balloon removal. A technique for insertion of an IABP catheter indirectly into the aorta was described, in which a polytetrafluoroethylene vascular graft of 10 mm in diameter is anastomosed to the ascending aorta under a partial occlusion clamp and tunneled behind the sternum below the xiphoid process. Other authors also reported similar techniques. Researchers described a technique for transaortic IABP insertion that can be performed in a rapid and atraumatic fashion in 14 patients. In their method, they used a short (4 cm) Gore-Tex vascular graft of 6 mm in diameter and performed the anastomosis without a side-biting vascular clamp by using partial-thickness bites on the aortograft suture line and the synthetic graft was brought out through the sternotomy incision. They also removed IABP catheter without the need to resternotomy.

The technique that was described is an alternative that obviates the need for resternotomy to remove the IABP catheter. Their technique is unique in that video-assisted thoracoscopic surgery is used, obviating the need to tunnel the IABP through the sternum in the above-described technique by Burack and associates. This method can potentially reduce the incidence of sternal instability and sternal wound infection. In our study, we used indirectly a separate saphenous vein graft anastomosed to the ascending aorta for balloon insertion to provide IABP support in patients who have difficulties for weaning from CPB. In the technique described, there is no need to return the patient to the operating room. The simple suture set is enough at the bedside in surgical ICU. In all of our patients, the removal of IABP catheter did not require repeat sternotomy.

There are reasons for lack of space in the ascending aorta including very short aortas, anastomoses of multiple saphenous vein grafts, the aortotomy suture lines for aortic valve surgery, or the aortic perfusion or de-airing cannulas. These reasons can make the ascending aorta an unsuitable route. In these situations, it is impossible to apply the side-biting clamp to the aorta for additional Synthetic graft implantation because of the absence of free space. In these settings, Researchers described a technique in which a woven Dacron graft of 12 mm in diameter is sewn to the ascending aorta without the use of a partial occlusion clamp using partial-thickness sutures in the aortic wall. In our study, we could easily find sufficient anastomotic area for a separate saphenous vein graft anastomosis by applying the partial occlusion clamp even when the aorta is crowded with multiple saphenous vein grafts. With this alternative method, it was observed that there is no increased risk of mediastinal contamination and sternal wound infection.

The base of the balloon should lie approximately 2 cm below the left subclavian artery. Researchers recommended a simple technique to achieve correct transaortic IABP catheter insertion and positioning without the need for special equipment. The external pressure is applied to the left subclavian artery to avoid displacement of catheter. Thereafter, balloon position is guided by means of palpation into descending thoracic aorta through the opened pleura. Thus, by this manipulation aberrant cannulation to the cerebral arteries or left subclavian artery is prevented during the insertion of the catheter. In our study, we also made a similar application. Transesophageal echocardiography is often used to guide appropriate IABP positioning in the descending thoracic aorta in the operating room. As well, epiaortic ultrasound can be used to confirm the position of the catheter.

Transaortic IABP insertion is associated with considerable morbidity and mortality. Possible complications related to this route include aortic dissection, bleeding at the anastomosis or directly aortic insertion site, cerebral or peripheral embolism, myocardial infarction, mediastinal or graft infection, balloon rupture, aberrant cannulation of the subclavian artery, or improper positioning. These problems can be minimized by careful surgical techniques. Transaortic IABP insertion should be avoided in patients with aortic dissection, a severe calcified ascending aorta, or obvious ultrasonographic evidence showing potential embolic debris in the ascending aorta.

Researchers reviewed 39 patients who required transthoracic IABP insertion. Five patients (13%) sustained complications potentially related to the procedure including balloon rupture in 2 patients (5%), graft infection in 1 (2.5%), and cerebrovascular accidents in 4 (10%). The overall survival was 44% (17/39). There were no deaths directly related to the balloon placement or removal. In a series of 8 patients, they encountered the complications related to transaortic IABP including graft infection, aberrant cannulation of the left subclavian artery, left coronary artery embolism, and inability to close the sternum due to mechanical tamponade. In this study, there were no complications and mortality related to transaortic IABP. [22, Rank 4]

Effect of Trans-brachial Intra-Aortic Balloon Pumping for High Risk Percutaneous Coronary Intervention

The protective effect of elective placement of IAB pump before revascularization for short-term circulatory support in patients with high-risk coronary anatomy and impaired LV function is well established.Currently, an increased number of elderly patients with several comorbidities, including severe peripheral vascular disease, are referred for coronary revascularization. The traditional placement of IAB via the common femoral artery may be contraindicated or impossible in patients with severe atherosclerotic disease of the iliac arteries or abdominal aorta or in patients with suprainguinal vascular bypass grafts. Several alternatives to the femoral approach have been developed, including surgical insertion into the axillary artery or grafts to the ascending aorta, but these techniques require anesthesia and are time consuming and, thus, unsuitable in most patients who are hemodynamically unstable. Some reports underscore the feasibility of surgical or percutaneous placement of IAB in patients with vascular bypass grafts to the lower extremity arteries. In contrast to the safety of coronary procedures via aortofemoral synthetic vascular grafts,IAB placement through vascular grafts may be associated with a high rate of limb ischemia and a potentially increased incidence of graft infection.In a report of 9 patients who had percutaneous IAB placement through mature bypass grafts developed limb ischemia and 2 of them required thrombectomy of the occluded grafts.

The development of smaller IAB catheter sizes allows the use of alternative arterial approaches for IAB placement. Recently, the percutaneous insertion of IAB via the brachial approach has been proposed as an effective and safe alternative in patients with peripheral vascular disease undergoing coronary artery bypass surgery. Researchers had used an 8-Fr IAB, which had been removed early because of hand ischemia. Herein, we report our experience of IAB insertion via the left brachial artery in a patient with critical coronary anatomy, severely impaired LV function and bilateral aortofemoral bypass grafts. To the best of our knowledge, this is the first report of a successful percutaneous coronary intervention of an unprotected trifurcating distal left main stenosis, assisted by a 7.5-Fr IAB inserted percutaneously through the brachial artery without causing upper limb ischemia.

From a technical standpoint, access to the brachial artery is readily attainable, and adequate hemostasis can be achieved after the removal of the IAB catheter, because manual compression of the brachial artery is easy. They used a 7.5-Fr sheath to insert the IAB, and we did not witness any hand ischemia. The principal limitation of the transbrachial approach is the small caliber of the brachial artery and the potential risk of ischemic complications of the upper extremity. This limitation can be overcome by the recent availability of 7 Fr IAB catheters, by inserting the catheter with the sheathless technique and by careful anticoagulation. The importance of close monitoring for hand ischemia cannot be overemphasized. It seems that pulse oximetry is a reliable way to monitor hand perfusion. In addition to pulse oximetry, catheter was placed into the left radial artery for continuous recording of the radial pressure waveform.

The timing of IAB catheter removal is crucial, because prolonged pumping via the brachial artery may theoretically increase the risk of arm ischemia due to thromboembolism. They withdrew the IAB 4 hour-postprocedure, after hemodynamic stability had been confirmed. However, reports from patients who underwent bypass surgery indicate that the IAB catheter can remain in the brachial artery for as long as 90 hours without complications.

Although brachial artery atherosclerosis is rare, the prevalence of subclavian artery stenosis is up to 6% in patients with coronary artery disease.Researchers reported that an interarm systolic pressure difference of >10 to 20 mm Hg has a low sensitivity and positive predictive value but a high specificity and negative predictive value for identification of subclavian stenosis. If a transbrachial IAB insertion is planned, blood pressure in both arms must be measured. Ideally, in patients with an interarm pressure difference >10 mm Hg or with known peripheral vascular disease, the subclavian anatomy has to be defined with an angiogram of the aortic arch or a selective subclavian angiogram, before IAB insertion. If contrast nephropathy is a concern, pressure recording during a simple pull back from the aorta to the subclavian artery of a brachially inserted catheter can rule out significant subclavian disease.

They inserted the IAB via the left brachial artery, because this avoids all the cerebral arteries except the left vertebral artery and may theoretically decrease the risk of cerebrovascular complications. However, the right brachial artery can be also considered, because there are no reports of neurological complications in patients who had an IAB placed via the right arm. In patients undergoing bypass graft surgery, the right brachial may be preferable, because it allows harvesting of the left radial artery, if needed.

In our patient and in previous reports using a transbrachial IAB, pumping was synchronized with the ECG, because of concerns that the pressure waveform would not be a reliable trigger. The pressure sensor at the tip of the catheter points away from the direction of propagation of the aortic pressure waveform, theoretically, may interfere with correct triggering. However, the correctness of this hypothesis needs to be determined.

In conclusion, this case demonstrates that in patients with critical coronary anatomy and impaired LV function who are at high risk for complications if an IAB catheter is inserted via the conventional transfemoral route, placement of the IAB via the brachial artery before coronary revascularization may offer an effective and safe alternative for ventricular support. However, larger prospective studies are needed to evaluate this alternative approach and to further define the technical challenges that may influence its efficacy and safety. [26, Rank 3]

Addition of Intra-Aortic Balloon Pump (IABP) during Peripheral Venoarterial Extracorporeal Membrane Oxygenation (VA ECMO) Support

Venoarterial extracorporeal membrane oxygenation (VA ECMO) is increasingly used in various clinical acute settings such as extracorporeal cardiopulmonary resuscitation (ECPR) or cardiogenic shock refractory to conventional treatment. There is concern that VA ECMO might change the CBF and impair cerebral autoregulation, resulting in neurologic dysfunction. A clinical study demonstrated that intra-aortic balloon pump (IABP) support in patients after cardiac surgery caused a considerable increase in the flow velocity in the middle cerebral artery. In clinical practice, the addition of an IABP during VA ECMO support is believed to improve coronary bypass graft flows and cardiac function in critically ill patients.

IABP has been successfully applied as an adjunct to VA ECMO in patients with cardiogenic shock. Despite the beneficial effects on cardiac performance, the effects of this combination on the CBF are conflicting. One recent clinical experience paper suggested that an IABP obstructed VA ECMO flow in the aorta in patients on peripheral VA ECMO. End-diastolic reversal of blood flow in the cerebral arteries has been observed in some patients with IABP, which likely suggests that the flow velocity in the right middle cerebral artery did not increase with IABP. Transcranial Doppler ultrasound (TCD) is a noninvasive technique that allows for repeatable bedside assessments of the CBF velocity (CBFV) during cardiac and vascular surgery. Previous studies showed a positive relationship between the CBF and CBFV. The effect of an IABP on the CBF during VA ECMO support has not been examined by TCD in humans.

VA ECMO is effective for the treatment of acute cardiac failure, however, the neurological morbidity has become a significant concern for many patients. At one academic medical center, combined ischemic and hemorrhagic stroke affected 7% of the adult patients supported with ECMO and significantly increased the odds ratio of death. Brain death occurred in 7% to 21% of the cases of ECMO-treated adults in some ECMO centers. In 2009, the national Extracorporeal Life Support Organization (ELSO) registry reported that 21% of 295 adults treated with ECPR experienced brain death. Additionally, approximately one-half of the survival patients showed evidence of cerebral injury. CBF reduction (inadequate perfusion) and non-pulsate blood flow during VA ECMO might play a role in the pathogenesis of this complication.

VA ECMO and IABP are well-established treatments in patients suffering postcardiotomy cardiogenic shock. Most clinicians ignored the critical question of brain perfusion during the combination of these two treatments. There are many reports regarding the effect of IABP on cerebral circulation. The outcomes are unclear. In a study of animal models with cardiogenic shock, when the cardiac output was reduced by one-third and the cerebral perfusion was reduced by 80%, the IABP support caused a further 10% reduction in the CBF. In human studies, researchers noted an overall reduction of 11.6% in the ocular blood flow measured by ocular pneumoplethysmography in 56 patients on IABP assistance. Similarly, a reverse CBF occurring at the end of the diastole was observed. In a model of VA ECMO-treated cardiac arrest, the authors tested an often encountered clinical combination of VA ECMO with IABP. They found that when used with the femoro-femoral VA ECMO approach, IABP did not significantly change the CBFV.

A clinical study reported that because of an early systolic reversal blood flow, no net increase occurred in the total flow in the common carotid artery with IABP support. These results indicated that rapid deflation of the IABP decreased the pre-ejection CBF, and cerebral perfusion might be inadequate or unchanged. In our study, although this type of reverse phenomenon was not observed in any of the patients, the outcome might be dependent on the antegrade blood flow. And this phenomenon was supported by the results which reported that IABP significantly increased the antegrade mean flow in the middle cerebral artery in patients after cardiac surgery.

During the peripheral VA ECMO support, the blood ejected from the heart theoretically would perfuse the heart, brain, and upper extremities. It was reported that the CBF was determined by the cardiac function by analyzing the effects of the systolic cardiac performance on the intracranial hemodynamics in nine infants undergoing ECMO. In a study, using the radioactive microsphere method showed that the CBF velocity was decreased in newborn lambs after the initiation of VA ECMO support at low flow rates. Higher flow rates could stabilize cerebral hemodynamics. These findings suggested that CBF is dependent on cardiac output or the intensity of the ECMO support.

IABP was employed in most of the VA ECMO setups with the aim of reducing the after load to improve the coronary perfusion and maintain a pulsatile blood flow. Previous studies have suggested an improved clinical outcome of VA ECMO support combined with IABP in patients with cardiogenic shock. There are concerns that an intermittent aortic occlusion by the IABP balloon might diminish the available cerebral blood. No studies have reported the cerebral flow during the concomitant support of VA ECMO and IABP in adults by TCD, as was done in this study. The mean CBF was significantly lower in VA ECMO combined with IABP support than in VA ECMO alone during myocardial stunning (a pulsate pressure lower than 10 mmHg) when there was slight antegrade flow ejected by the heart. The CBF values were significantly higher in VA ECMO combined with IABP than with VA ECMO alone during the spontaneous cardiac function period. The effect of IABP on CBF during VA ECMO support appears to vary with the spontaneous cardiac function state.

No significant differences in this study were found in the response of the mean CBFs during the combination support and VA ECMO. The authors commented as to the specific condition between the statement of the spontaneous cardiac and that of the VA ECMO and IABP support. The effect of IABP on the CBF might be different for severe cardiac failure and spontaneous cardiac function during VA ECMO support. When the data were analyzed between the different cardiac functional states, the data of the mean CBF were divided into two groups (P group and N group) by the cardiac function state (determined with pulsate pressure after turning off IABP during the VA ECMO support).

These results demonstrated that in a severe cardiac dysfunction situation (a pulsate pressure lower than 10 mmHg), IABP might have an unfavorable effect on CBF during the peripheral VA ECMO support. The implementation of IABP during the early stage of the ECMO support resulted in a significant decrease of the CBF. Clinically, some patients had essentially no ventricular cardiac output with 'ventricular stun' during VA ECMO support. The pulse pressure of the pericallosal artery is frequently lower than 10 mmHg. The TCD ultrasonogram of the cerebral blood velocity tracing showed a flat waveform. Under such conditions, VA ECMO provided retrograde blood flow from descending to ascending across the IABP.

The diastolic inflation of the intra-aortic balloon might intermittently compromise the retrograde non-pulsatile ECMO flow to the brain during the concomitant use of ECMO and IABP. This finding might explain the reason that IABP in late diastole caused a drop in the CBFV during severe cardiac failure. The recovery of the heart results from the appearance of the antegrade aortic flow during VA ECMO support. The addition of IABP significantly increased the mean CBF under such conditions. Additionally, the use of an IABP to maintain pulsatility during VA ECMO support is uniformly agreed upon in some studies. The pulsatility effect of IABP probably led to improved CBF perfusion and contributes to cerebral autoregulation recovery. [31, Rank 4]

First Line Support by IABP in Non Ischemic Cardiogenic Shock

The first-line support by IABP in non-ischaemic CS improves organ perfusion and stabilizes the patient for at least 24 h, as shown by decreased lactate levels in all patients. After 24 h of IABP support, the patients with urinary output > 2,000 mL and a negative fluid balance were more likely to be responders who could recover or could be maintained on IABP support until LVAD implantation or heart transplantation.

IABP versus Other Forms of Mechanical Circulatory Support

IABP has been used since the 1960s, and for a long time it was the only available mechanical device in CS. However, IABP has not improved prognosis in CS complicating AMI. Refractory low-output heart failure not caused by the acute coronary syndrome represents a subpopulation of CS patients, accounting for less than 10% of all indications for mechanical circulatory support. Only few reports describe successful use of IABP support as bridge to recovery, LVAD, or transplantation in small groups of patients with NYHA class IV heart failure not related to the acute coronary syndrome deteriorating following CS. Although the definitive treatment of refractory heart failure is LVAD implantation or heart transplantation, these complex therapies are associated with increased mortality in INTERMACS class 1 and 2 patients.

On the other hand, it has been shown that the prognosis of patients with severe hypoperfusion bridged to heart transplantation by IABP was similar to that of electively transplanted patients. Thus, stabilisation of patients with short-term circulatory support devices is necessary. This provides time for the selection of suitable candidates and the evaluation of contraindications for advanced mechanical support and transplantation. The level of support is higher by pVAD and ECMO than IABP, but a meta-analysis comparing pVAD with IABP found no difference in 30-day survival in CS patients. The presence of concomitant RV failure has been associated with early escalation to advanced mechanical circulatory support in patients supported by IABP. The advantages of IABP compared to pVAD or ECMO consist in a large availability, a reduced complexity of professional training, the possibility of a rapid insertion in the ICU without the need for fluoroscopy, and a low complication rate.

In a population, IABP support was the last treatment option in 7 patients, who died during support or had major contraindications to heart transplantation or LVAD. Escalation to ECMO was chosen by a multidisciplinary team for 2 patients after 3 and 7 days of IABP support, respectively. These patients underwent later heart transplantation. IABP support remained necessary and provided haemodynamic stability until LVAD implantation or heart transplantation in 9 of our patients, in agreement with other reports. However, 9 patients could be weaned from IABP, of which 7 could be discharged on optimal medication and were alive at the 1-year follow-up. In a previous report, researchers described the strategy of weaning from mechanic and inotropic support in low-output heart failure patients and reported a high long-term survival in patients able to tolerate β-blocker therapy at discharge.

Monitoring IABP Response

Elevated blood lactate is an important marker of severe systemic hypoperfusion leading to abnormal cellular oxygen metabolism. At 24 h, researchers found a significant decrease in lactate levels in the whole cohort, but lactate was not significantly lower in IABP responders than non-responders. On the other hand, higher levels of C-reactive protein and bilirubin baseline values were observed in IABP non-responders than IABP responders, showing that the success of IABP is less likely to occur in the presence of inflammation and multi-organ dysfunction; in these patients, more advanced mechanical support should be considered. Already at 24 h, and persistently at 48 h, the improvement in urinary production with a negative fluid balance was a useful clinical marker of response to treatment, although serum creatinine levels did not significantly improve.

This is an interesting clinical observation that received less attention in previous reports about IABP in non-ischaemic CS. One study on ultrasound spectral Doppler estimation of renal flow velocity reported higher renal blood flow during IABP support. Although they did not routinely perform haemodynamic measurements in the present study, it was hypothesized that the decrease in LV afterload by IABP increases right to left flow and leads to decreased right-sided congestion and increased renal perfusion, which result in enhanced diuresis.

A study in patients with end-stage non-ischaemic heart failure shows a 1-year survival rate of 63%, which was identical to survival rates stated for patients receiving IABP for CS from AMI. This finding is in line with another retrospective IABP-CS study, but in contrast to the TandemHeart-CS study, which reported a better survival in patients with non-ischaemic cardiomyopathy. However, patients categorized as having "non-ischaemic CS" presenting with AMI in the 30 days before study start were excluded in our study, but in fact 6 patients (22%) had an ischaemic aetiology and tended to have a worse outcome; therefore, these 6 patients would have been grouped into the ischaemic cardiomyopathy group in the study by Kar et al. [29, Rank 4]

Intra-Aortic Balloon Pump Counterpulsation

The IABP is a commonly used method of temporary circulatory support in adults. IABP usage in a paediatric population was first described in 1989. However, despite the availability of paediatric size balloons, the usage of IABP for temporary circulatory support in children has not been widespread.

The principle

The IABP is basically an expandable balloon that is inserted into the descending aorta, just distal to the origin of the left subclavian artery. The balloon is periodically filled and emptied of helium gas, which is supplied to the balloon from a cylinder attached to the control console of the pump.

It is essential to understand balloon inflation and deflation. Balloon deflation is timed to the opening of the aortic valve, in systole. Balloon inflation is timed to the closing of the aortic valve, in diastole. The inflated balloon can be considered to be a space-occupying lesion in the descending thoracic aorta. If the balloon were inflated during systole and intra-aortic space occupied, ventricular contraction and outflow would be impeded by the space occupied by the balloon, and hence afterload would increase. In reality, however, the IABP deflates in systole, at the onset of ventricular contraction and with the opening of the aortic valve. The space occupied by the balloon in the aorta is suddenly released at the onset of ventricular emptying. This causes a vacuum effect, or negative pressure in the aorta, thereby reducing ventricular afterload and ventricular wall stress, and improving cardiac performance. [23, Rank 3]

The converse occurs during diastolic inflation of the IABP. During the normal cardiac cycle, following the systolic aortic pressure wave, there is a diastolic elastic recoil that closes the aortic valve as well as provides the pressure head to perfuse the coronary arteries. Inflation of the balloon in diastole creates a space-occupying lesion in the aorta in diastole displacing blood both proximally and distally. This increases the aortic diastolic pressure and hence coronary perfusion.

In paediatric usage, it is the systolic unloading of the left ventricle during balloon deflation that is important. Owing to the resultant afterload reduction, the left ventricle can contract more efficiently and cardiac output can increase by up to 20%. However, it merits emphasis that the IABP only augments cardiac output; some amount of intrinsic function of the left ventricle is required and the IABP augments this. Hence, it is a modality that cannot be used in terminal cardiac failure. It is also to be noted that the right ventricle is not supported by IABP. [33, Rank 5]

Clinical methods

Proper placement and timing of inflation and deflation are the key factors in the efficient utilisation of IABP.

In children, an open surgical insertion of the balloon is employed. Usually, a femoral artery is used, although transthoracic insertion (after cardiac surgery) may be used and may be indicated in neonates. The balloon is usually inserted through a small polytetrafluoroethylene patch placed on the femoral arteriotomy. Proper placement of the balloon, just distal to the origin of the left subclavian artery, is essential for proper functioning of the IABP and for avoiding potentially catastrophic complications. The position of the balloon can be assessed by simple measurement, fluoroscopy, post-insertion chest radiograph or preferably by echocardiography. Surgically placed balloons ranging from 2.5 to 7 ml are available for infants and children (up to 18 kg). The criterion used in selecting an appropriate-size catheter has been detailed elsewhere.

The timing of balloon inflation and deflation is extremely important. This may be performed by either using electrocardiographic tracing or echocardiography. It must be noted that smaller paediatric balloon catheters differ from adult catheters in that they do not have a central pressure-monitoring lumen. Hence, timing of the balloon on the basis of aortic pressure waveform is not an option in smaller children. Using electrocardiography, inflation should occur along the ascending T wave (ventricular repolarisation = diastole), and deflation is timed before the R wave (which signifies the onset of ventricular contraction).

However, the timing of IABP using electrocardiography in children has been shown to have certain limitations. Recent reports have emphasised M-mode echocardiography as the tool to ensure proper timing of balloon inflation and deflation. A parasternal echocardiographic image provides a good view of both the aortic valve leaflets and the balloon. Using aortic valve opening and closing as reference points, balloon inflation and deflation can be timed accurately.

The patient generally starts receiving intravenous heparin to prevent thromboembolic complications, to maintain an activated partial thromboplastin time of around 1.5–2 times the control.

The magnitude of augmentation may be adjusted in two ways. The pumping ratio can be changed; this is the ratio of augmented beats to unaugmented beats (for example, 1:1, 1:2, etc). Alternatively, the balloon inflation volume can be adjusted, which would hence alter the level of afterload reduction. In general, on initiation of IABP support, ratios of 1:1 or 1:2 are selected, along with the maximum balloon volume.

Weaning from the IABP begins when haemodynamic stability is maintained (as assessed by clinical, biochemical and echocardiographic parameters) following the reduction of pharmacological support to minimal levels. The pumping ratio is then gradually changed from 1:1 to 1:3 or 1:4. Then, after a period of observation, the balloon may be removed.

In the past, the use of IABP has been associated with much morbidity and complications. However, currently, increased familiarity with insertion technique, better instrumentation and awareness of possible complications has decreased the incidence of major complications. Some complications8 are related to groin dissection (haematoma, lymph leak, wound infections, pseudoaneurysm), distal limb ischaemia (thrombosis, embolism) or are due to misplacement of the balloon (intrathoracic/intra-abdomenal aortic rupture, ischaemic damage to bowel/kidney/spinal cord).

In the past, three factors were thought to preclude the use of IABP in children. Firstly, the paediatric aorta was thought to have greater elasticity than the adult aorta. So most of the energy generated during balloon filling was thought to be transferred to the expansile aorta and, as a result, diastolic augmentation would be dampened. However, this has recently been disproved. Secondly, there were also concerns regarding the efficacy of using the IABP in the paediatric population with its higher incidence of arrhythmias, making optimal timing very difficult. Thirdly, it has generally been assumed that IABP usage in children is associated with an increased frequency of complications. Perhaps that was the case before the advent of catheters designed specifically for paediatric use. However, in the two most recent reports of IABP usage in children, the incidence of complications was only 6.9% and 12.5%. [15, Rank 2]

Indications and results of IABP use in children

In the absence of widespread usage of IABP in paediatric cardiac centers worldwide, literature reports on paediatric IABP have been sporadic. In a study, which is the earliest experience of IABP use in children, there was a 43% survival among a group of 14 children. It was reported on patients aged 5 days to 18 years; the smallest child weighed 4.2 kg. The survival in children <3 years of age was 75%. However, overall survival was only 25%. They studied children with left ventricular dysfunction after cardiac surgery and reported 44% survival among those managed with IABP. Researchers reported the successful utilisation of IABP support in a 2 kg infant. Among the series of patients, 37% were long-term survivors. However, most of these reports dated from the years 1980–93. Much has evolved since then, especially advances in intensive care monitoring, treatment, antiobiotic availability and specifically intra-aortic balloons and consoles specifically designed for paediatric use. While interpreting these results, it is important to bear in mind that IABP provides support only to the left ventricle. Hence, its use would be indicated in disease conditions in which left ventricular failure occurs. These include, for example, anomalous origin of the coronary artery from the pulmonary artery, transposition of great arteries, left ventricular outflow obstruction, aortic and mitral valve diseases, and IABP has been used with nearly 100% success in these patients. Where disease is biventricular in nature, with a component of pulmonary hypertension, or in which right ventricular pathology predominates—for example, tetralogy of Fallot or after complex conduit repairs. Although patient numbers are small, IABP has been used successfully to support children with acute myocarditis and cardiac trauma, which are self-limiting causes of cardiac failure. And this experience compares well with the 80% survival of children with myocarditis managed by ECMO.The results of IABP use after a Fontan procedure have been disappointing. This is not surprising since the efficiency of the Fontan circulation is based on the postoperative level of pulmonary vascular resistance and not on systolic cardiac function. When its use has been successful after a Fontan procedure, it has been in those rare situations when the pulmonary vascular resistance has been normal and altered cardiac function proven to be the cause of the dysfunction. The rate of complication following IABP use has been acceptable. Researchers reported an incidence of 6.9% (2 of 29 patients), including sepsis in one patient and transient ischaemia in the other. Neither complication required IABP removal. Researchers reported a 12.5% (3 of 24 patients) incidence of IABP-related complications—two involved transient limb ischaemia and one patient developed mesenteric ischaemia and subsequently died. Apart from this, they encountered septic and bleeding complications but did not relate these to IABP usage. [3, Rank 3] **Management of Intra-Aortic Balloon Pump Entrapment**

Due to the nature of the IABP, the chief adverse sequelae involve vascular injury; studies suggest that vascular ischemic sequelae occur at a rate of 8% to 18%, while major limb ischemia occurs less than 1% of the time. Rupture of the intra-aortic balloon is rare but can cause gas embolism and entrapment of the balloon within the arterial tree. Balloon rupture was first reported; however, it is very rare, occurring at a rate of possibly less than 0.5%. The proposed mechanism involves mechanical abrasion of the balloon by atherosclerotic plaque or a heavily calcified aortic wall. After perforation, the negative pressure created during deflation traps blood within the balloon. The blood rapidly reacts with the helium, causing a hard clot to form. This clot, together with the tortuous atherosclerotic aortic environment, entraps the semi-deflated balloon.

Entrapment can be avoided by early diagnosis and prompt removal of the ruptured balloon. Balloon rupture can sometimes be recognized by the presence of blood in the catheter between the balloon and the safety chamber; if counterpulsation cannot be sustained, the console will sound the alarm, which enables prompt diagnosis of rupture and appropriate removal of the IABP. However, care should be taken not to rely solely on the alarm, because it was reported that the alarm indicated gas leakage in only 29% of IABP ruptures among patients in their case series. The main indicator of rupture remains blood within the catheter shaft, and this highlights the need for regular review of the shaft during use; 6% of cases of IABP rupture are detected only at the time of removal.

Current management approaches recommend against forceful extraction of the retained balloon, because the probable result is severe vascular injury. When there is early detection of entrapment, a conservative approach would be the Lambert method. Lambert first reported the use of intraluminal streptokinase with heparinized saline flush for clot dissolution; in his 3 patients, he injected streptokinase into the gas-driven lumen of the intra-aortic balloon catheter and thereby avoided surgery.This approach has since been successfully replicated at other institutions, which shows that injection of a thrombolytic agent (tissue plasminogen activator or streptokinase) into the gas lumen of the balloon catheter can dissolve the clot, enabling evacuation of the balloon chamber and normal removal of the intra-aortic balloon catheter.

If the detection of the "entrapped clotted balloon" is recognized late (>60 min), the thrombus is unlikely to resolve with thrombolysis. We therefore recommend CT imaging and open vascular exploration with femoral, femoroiliac, or abdominal aortotomy. In particular, to avoid massive bleeding at extraction, an entrapped catheter should be removed tip-first (preferably) through a proximal arteriotomy. [19, Rank 5]

Because there is a significant potential for morbidity and death associated with IABP entrapment, it is useful to evaluate risk factors. It was reported that independent predictors of major complications associated with IABP use included female sex, peripheral artery disease, body surface area (<1.65 m2), and age >75 yr. Researchers also found that the risk of complications associated with IABP use was highest among women and patients with diabetes mellitus, and that infectious sequelae were greatly reduced if insertion of the IABP took place in the operating room. Researchers reported the additional modifiable risk factor of use of the introducer-sheath technique for IABP insertion and recommended sheathless insertion in high-risk patients, particularly those with peripheral artery disease and diabetes mellitus. It is difficult to know the specific risk factors for balloon entrapment due to the scarcity of cases; however, it is reasonable to think along the lines

In the evaluation of balloon rupture, several risk factors have been identified. The balloon itself is susceptible to damage if a guidewire is not used or if there is forceful insertion against resistance; insertion of the guidewire at an angle greater than 45° predisposes the balloon to kinking at the posterior arterial wall; and inadequate wrapping and insufficient aspiration of air from the balloon can damage the membrane, while excessive inflation can also predispose to rupture. Nevertheless, the main risk remains an atheromatous arterial tree.23

From this perspective, several recommendations can be made in an effort to reduce the risk of IABP rupture. Routine arteriography of the aorta and iliac vessels can be carried out at the time of cardiac angiography in high-risk patients to accurately identify vessels distorted by atherosclerotic disease and thereby enable preoperative planning of IABP insertion approaches.Researchers provided the most comprehensive advice regarding risk management. They advocated use of the smallest possible balloon size, use of a sheathless IABP insertion technique, and removal of the IABP at the earliest opportunity.

They also showed the unreliability of plain chest radiography in the determination of IABP position and recommended a low threshold for CT imaging (dependent upon clinical judgment) in application to patients with an IABP and a rising serum lactate level, regardless of IABP positioning on the chest radiograph. They further advised considering the use of CT imaging or TEE for the definitive evaluation of IABP placement in patients who exhibit clinical signs suggestive of IABP malposition, and especially in patients with significant underlying atherosclerotic disease who are at risk of visceral compromise independent of IABP use.Researchers advocated using the lowest augmentation setting to achieve the desired cardiac support, thus reducing the risk of contact between the balloon and the arterial plaques at higher settings. [39, Rank 1]

Vascular Complications Following IABP Implantation

The most common vascular complication related to IABP insertion is limb ischemia. The occurrence rate of limb ischemia increases in patients who have risk factors such as peripheral vascular disease and diabetes mellitus. For these reasons, careful assessment of the aorto-femoral vascular tree should be carried out during early diagnosis and intervention to prevent limb loss. It should also be noted that minor limb ischemia can normally be relieved by IABP removal, whilst this is not the case when major limb ischemia occurs, indicating that the ischemia is initially most likely caused by intermittent obstruction.

In fact, some patients will suffer from limb amputation as a consequences of irreversible limb ischemia due to IABP insertion. This is a very rare and serious complication, so careful physical examination is vital to identify early vascular changes and treated immediately before they become established. Emergency revascularization via a thrombectomy can stabilize the patient to avoid further complications.

Bleeding and hematoma have also been reported to occur in several studies, with varying rates. In most cases, bleeding is related to the insertion site and can vary from mild to severe. It can lead to thrombotic complications which may require transfusion or surgery. Many studies have stated that IABP duration time increases the risk of moderate and major bleeding if it used for a long period of time, even if it is more than two days. Furthermore, sheathless insertion is found not to be associated with high bleeding rate.

Mesenteric ischemia is a rare event, but is considered a potentially life-threating condition which can lead to serious conditions, such as gangrene of the bowel wall. However, only a small proportion of patients had mesenteric ischemia during IABP insertion in the included studies, due to the fact the majority of the research in this field has been carried out in animal studies or are reported in case reports, both of which were excluded in this review. Early diagnosis is important in any patient suspected of having mesenteric ischemia to prevent further complications.

Studies have investigated the association between intra-aortic balloon catheter size and visceral flow. In a number of studies, we have compared the use of a shorter balloon and compared this with the standard size catheters. Final results from these studies have concluded that the short balloon decreased mesenteric blood flow to a lesser extent when compared with the standard-size balloon, without losing IABP beneficial effects. In fact, it even improves visceral flows in comparison with the conventional IABP catheter.Furthermore, in an additional study, Gelsomino et al. investigated the effect of IABP weaning strategy on visceral flow and found that mesenteric blood flows decreased in both forms of weaning. These data indicate that the weaning strategy should not affect the occurrence of this complication, although further clinical research would be required to validate this.

There is a lack of published information regarding the risk of pseudoaneurysm after IABP. The literature tends to only mention the number of patients without exploring the related risk factors. Once again, this should be a focus of future work

In the studies reviewed, most procedures were carried out using the femoral artery for insertion of the IABP catheter. However, a number of studies used alternative approaches. The subclavian artery approach could be associated with a lower morbidity rate. However, there are some things that should be taken into considerations. It is more time-consuming than the femoral approach and, therefore, is not recommended in the emergency setting. Additionally, there is still a chance of developing vascular complications, such as stroke and limb ischemia, due to the fact that the balloon catheter traverses the arch of the aorta. Studies, therefore, are needed to investigate whether this approach may reduce the risk of complications.

In assessing the vascular complications of IABP, several risk factors must be taken into consideration, such as female gender, smaller diameter catheters, peripheral vascular disease and diabetes mellitus. Complications, in general, due to IABP tend to be more common in females due to the smaller size of the femoral artery, so whether this increased risk could be overcome by utilizing alternative access points remains to be seen.

Several studies have linked vascular complications with diabetes mellitus and peripheral vascular disease. Therefore, careful vascular assessment is required when inserting IABP catheters into patients with these diseases to reduce the risk of vascular complication, as has been reported in many studies.

Sheathless insertion and smaller-size catheters can minimize the risk of vascular complications. It has been previously shown that there is a significant decrease in the rate of major vascular complications with IABP insertion in the last five years and this has been due to the increased use of catheters with smaller diameters. Moreover, the use of 6 Fr catheters has shown a great benefit in minimizing the risk of vascular complications, but further studies are required to cover the complications risk of using a smaller-sized catheter. Finally, long treatment time with an IABP catheter is considered an independent risk factor for the development of vascular complications. The longer duration of IABP support seemed to increase the risk for the of occurrence vascular complications. [22, Rank 2]

Contemporary Application of IABP for Cardiogenic Shock

The intra-aortic balloon pump (IABP) is the most widely used mechanical circulatory support (MCS), with an implantation rate in USA of around 50,000 per year.

However, recent studies have challenged the role of IABP support in cardiogenic shock (CS) following ST-elevation myocardial infarction (STEMI) and, independently from these results, on the basis of previous registries, the use of IABP support in CS has been downgraded in the most recent guidelines of American College of Cardiology/American Heart Association (ACC/AHA) and European Society of Cardiology (ESC). In addition, definitive evidence in other fields of application of IABP, like as peri-procedural support in high-risk percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG), is still inconclusive.

The group of patients with postcardiotomy shock is worth of further comments. Postcardiotomy shock is a rare complication of cardiac surgery, associated with a high mortality rate. However, a more accurate classification is needed. Postcardiotomy shock has an incidence of 2–6% after cardiac surgery, but only 0.5–1.5% are refractory to inotropic and IABP therapy. While refractory postcardiotomy shock carries a dismal prognosis without MCS systems ensuring full cardiac function replacement, more uncertainty exists as regard to its not-refractory presentation. Therefore, due to the current lack of criteria allowing, at the time of shock onset, for an accurate discrimination of the patients' course, caution should be used in interpreting our results. In addition, postcardiotomy shock is substantially orphan of large studies, and its management, particularly in terms of implantation of MCS, suffers from a great interinstitutional variability.

The use of IABP, in this context, should be a preliminary step. Current acquisitions on pathophysiology of CS offer a sound certainty that high doses of inotropes are detrimental on heart recovery. Therefore, if the end-organ perfusion is not ensured by a medium dose of inotropic support, IABP should be implanted without delay.

Current recommendations on IABP support arise from studies focused on a well-defined target population, specifically CS post AMI. The only robust RCT conducted on IABP efficacy in CS failed to found any difference in early and long term mortality in the group of IABP-supported patients. This study has raised some criticisms pays the penalty for a homogenous cohort of patients at the expense of the realistic representation of unselected CS patients cohort. Recently, researchers summarized current indications of IABP support: on the basis of the most recent updates, AHA/ACC guidelines on CS after AMI recommend the use of IABP as a class IIA/A indication, whereas ESC guidelines state that IABP may be considered as a MCS (IIB/B). The last European guidelines on myocardial revascularization further downgraded the routine use of IABP in CS associated to AMI to a class III.

However, having this device a strong pathophysiological basis for its benefits, and being clinicians extensively confident in this technique, the negative results might be related to other factors, such as severity of shock, timing of implantation and management.

In the overall population, the multivariable analysis identified the development of AKI, the need for prolonged mechanical ventilation the postoperative period and the inotropic score at the moment of IABP implantation as factors associated with mortality.

The dismal effect of AKI in the prognosis of cardiac patients is nowadays a sound acquisition, but in this case the development of AKI is even of greater interest, as it shows that the amount of hemodynamic support is probably not sufficient and should prompt further interventions. Instead, the threshold of inotropic score we have identified sets a new paradigm for the timing of implantation. No previous studies suggested a threshold of pharmacological support triggering IABP implantation.

The interaction between LVEF variation and IABP counterpulsation is controversial. Our study suggests that the clinical improvement after IABP placement is unrelated to a LVEF increase. Even if this finding was apparently surprising, this is not a new acquisition. Indeed, a substudy of the SHOCK trial showed similar results and a seminal experience demonstrated that, in patients with left ventricular failure, IABP did not improve LV performance indexes.

The overall IABP-related morbidity of study (10.5%) is similar to previous reports. This feature supports the benefits of technological improvement in the devices, and reinforces the extensive use of IABP even in centers not able to provide the full panel of MCS.

Our study has the strength to represent, at the price of the heterogeneity of the population included, a “real world” picture about IABP implantation in a high-volume center. Our findings suggest a new consideration of this type of mechanical support at the time of transition from pharmacological therapies to full mechanical support.

This study has many limitations: the prospective design and the absence of control group do not allow for any inference about mortality rate nor a comparison to a baseline population without IABP. The relatively small sample size may also have contributed to the absence of any difference in terms of mortality between two greatly different groups. Moreover, the heterogeneity of the population and the relatively small number of patient included limited the power of the analysis. [40, Rank 4]

Clinical Outcomes of IABP Use in CABG

Postoperative recovery in elderly patients takes a longer time than in younger patients. Postoperative atrial fibrillation requiring medical treatment, and other complications occur more frequently in the elderly; the total intubation time is also longer for this group. Therefore, delayed recovery in the elderly may simply be due to the aging process affecting all organs. For this reason, elderly patients may need more mechanical support in cases of low cardiac output following cardiopulmonary bypass.

While the number of COPD patients was higher in the older group, the number of diabetes mellitus patients was lower in the older group. In addition, EuroSCORE values were higher in the elderly patients. The mortality rate was higher in elderly patients; however, there were no statistically significant differences between the patients who had emergency surgery in both groups.

It has been reported that IABP decreases the mortality rates of low-cardiac output and severe myocardial ischaemia patients in the pre-operative period, provides support for patients who failed to wean from cardiopulmonary bypass during the intra-operative period, and prevents low cardiac output and medically refractory arrhythmias in intensive care units in the postoperative period. In this study, IABP was used in cases of low cardiac output, persistent angina pectoris, or arrhythmia due to myocardial ischaemia in the pre-operative period.

In previous studies, the use of pre-operative IABP in high-risk patients was reportedly more advantageous than peri-operative IABP support. Researchers compared the use of pre-operative and peri-operative IABP in high-risk patients in their study. Their results indicate that the pre-operative use of IABP was advantageous for early and long-term mortality.Theyshowed that in a meta-analysis involving 1 034 patients, the use of pre-operative IABP in high-risk patients reduced mortality rates.Researchers reported that when shock, urgent surgery, haemodynamic instability, and MI in the last three days were excluded, the use of pre-operative IABP did not have a positive effect on morbidity and mortality rates; however, the length of the hospital stay was shorter in these patients.

Researchers proposed a scoring system that predicts the need for IABP support in high-risk coronary artery bypass patients.According to this study, heart failure, re-operation, emergency operation, left main coronary artery disease, patients over the age of 70 years, moderate and poor left ventricular function, and recent myocardial infarctions are independent risk factors for the need for IABP support. As a result of the study, the benefits of IABP support in patients with high-risk scores were emphasised. In clinical practice, researchers did not use a risk-scoring system for prophylactic IABP support. In this study, they aimed to determine the pre-operative risk factors for mortality and other clinical outcomes.

In previous studies, emergency surgery, a history of myocardial infarction, prolonged cardiopulmonary bypass, and concomitant peripheral artery occlusive disease were all found to be significant determinants of mortality in primary isolated CABG patients.Furthermore, risk-scoring systems were generated. They showed that the mortality rate of the older patient group was higher than that in the younger group. However, the logistic regression analysis indicated that the only independent risk factor for mortality was a prolonged cardiopulmonary bypass time.

In addition, subgroup analysis revealed different results. For example, in the older patient group, chronic renal failure and prolonged cardiopulmonary bypass were identified as factors that affected mortality rate. In younger patients, female gender, diabetes mellitus, emergency operations, higher EuroSCORE values, prolonged cardiopulmonary bypass time, and prolonged stay in the ICU were independent risk factors for mortality. In elective operations, advanced patient age and prolonged cardiopulmonary bypass time were identified as factors that affected mortality rates.

Complications with the intra-aortic balloon pump were described in previous studies: limb ischaemia, thrombocytopaenia, arterial rupture or dissection, and sepsis and local infections. Complication rates have been reported from 26 to 50% in different studies. The risk factors for IABP complications were stated as increased age, female gender, duration of IABP treatment, presence of diabetes mellitus, and having several risk factors (e.g. obesity, smoking, hypertension, cardiogenic shock, inotropic support, low cardiac output, increased systemic vascular resistance, and ankle–brachial pressure index < 0.8). In a study, the IABP complication rate was higher in older patients compared to younger patients (25 vs 12.2%). Mild thrombocytopaenia was the most frequently detected complication. When thrombocytopaenia is detected, IABP therapy is terminated immediately so that fewer bleeding complications occur. [41, Rank 5] **Physiological Principles of IABPs**

Heart failure is a progressive and fatal disease that affects more than 23 million people worldwide, and will affect more than 8 million people in the USA by 2030. Despite major advancements in medical and device treatments for heart failure in recent decades, the incidence of heart failure continues to rise. This epidemic has a major impact on patient quality of life, while imposing heavy costs on the healthcare system. According to the American College of Cardiology/American Heart Association, advanced congestive heart failure (CHF) is referred to as stage D when patients continue to have symptoms at rest despite optimal guideline directed medical therapy. In the USA, more the 250,000 patients suffer from advanced CHF refractory to maximal medical therapy.

The most recent guidelines update reiterate that cardiac transplantation remains the gold standard therapy for patients with stage D heart failure.However, donor heart availability remains the major limiting factor, resulting in a large number of patients waiting long periods of time before transplantation. As a result, mechanical circulatory support (MCS) devices have been increasingly used in the acute setting as a ‘bridge’ in order to sustain organ function and stabilise haemodynamics while patients remain on the transplant waiting list or undergo left ventricular assist device (LVAD) surgery. These MCS devices include intra aortic balloon pumps (IABPs), micro-axial flow catheters, and centrifugal flow pumps. IABPs are commonly used for temporary circulatory support in patients with advanced heart failure. IABP is traditionally placed percutaneously through the transfemoral artery approach. The major limitation with this approach is ambulatory

Restriction can promote deconditioning, particularly in situations of prolonged circulatory support. This restriction is frequently seen in advanced CHF patients waiting long periods of time prior to cardiac transplantation. A subclavian artery approach IABP insertion is an alternative to femoral artery IABP, which allows patients to be ambulatory during the pre-transplant period. In this review, we aim to summarise the physiology of IABP, the evidence for its use in advanced CHF, and the efficacy and safety of subclavian artery IABP insertion. [44, Rank 4]

An IABP is usually placed in a retrograde fashion through the femoral artery and is positioned distal to the left subclavian artery in the descending thoracic aorta. Inflating and deflating the balloon in synchrony with the heart rate helps augment diastolic blood pressure and theoretically can increase coronary arterial perfusion, thereby augmenting myocardial oxygen delivery. During systole, the balloon quickly deflates thereby reducing afterload and therefore decreasing myocardial oxygen consumption and workload.Volume shifting of approximately 40 ml per heart beat by the IABP increases left ventricular stroke volume and cardiac output by up to 1 litre per minute, with the largest increases seen in patients with severely reduced cardiac output. Patients who continue to have evidence of end-organ dysfunction, haemodynamic compromise or right ventricular overload despite IABP therapy usually require MCS with higher cardiac output, such as the Impella device.

IABP vs LVAD

Recent clinical trials have failed to show a clear benefit of IABP support among patients with acute myocardial infarction, cardiogenic shock or high-risk percutaneous coronary intervention. However, despite these findings, IABP remains the most widely used MCS with more than 50,000 implants per year in the US alone. IABP support has been shown to be safe and effective in patients with acute decompensated dilated cardiomyopathy as an urgent method of cardiac support to maintain adequate organ perfusion until cardiac transplant or destination LVAD.

Current guidelines assign a Class IIa recommendation for the use of MCS in carefully selected patients with stage D CHF as a 'bridge to recovery' or 'bridge to decision'.

Currently, with the widespread availability of LVAD, approximately 50 % of patients are supported with such devices at the time of cardiac transplantation. Continuous-flow LVAD has been shown to improve survival, functional capacity and quality of life in most patients. However, LVADs have been shown to have similar perioperative mortality, length of hospital stay, renal failure requiring dialysis or early acute rejection compared to IABPs in patients undergoing heart transplant. At the time of listing for transplant, patients who underwent IABP support (compared to LVAD) had significantly higher serum creatinine, lower BMI, lower proportion of blood type O and more functional impairment requiring full assistance with activities ofdaily living.

This study suggests that patients who have IABP support are generally more unwell and less mobile, which is likely to further exacerbate patient deconditioning. Long-term IABP support has been shown to be effective as a bridge to LVAD implantation in critically ill end-stage CHF patients and was not associated with increased haemorrhagic complications.[7] Patients with mild cardiogenic shock can be adequately supported long-term with IABP until LVAD or heart transplant surgery; however, those with severe cardiogenic shock usually cannot maintain adequate organ perfusion with IABP support. These patients with severely reduced cardiac indices usually require MCS with higher flow rates, such as the Impella axial flow pump. [46, Rank 3]

Ambulatory Intra Aortic Balloon Pumps

A technique of transthoracic IABP insertion has been previously described, predominantly with the use of a short conduit to allow placement of the IABP in the ascending aorta, axillary or subclavian artery. This insertion method was first described by Mayer in patients with aortoiliac occlusive disease. More recently, this technique has been further refined, allowing patients to have an IABP placed percutaneously via the upper extremity in the cardiac catheterisation laboratory by either interventional cardiologists or cardiac surgeons. The trans-brachial artery insertion method has been shown to be safe and effective in unstable CAD patients prior to urgent coronary artery bypass surgery.

Multiple studies have shown the effectiveness of ambulatory IABP in advanced heart failure patients waiting for advanced heart failure therapies, namely LVAD implantation or heart transplantation. Researchers studied 50 patients with end-stage CHF undergoing left axillary-subclavian artery IABP support as a bridge to heart transplantation.Of these 50 patients, the majority (84 %) underwent successful heart transplantation with an excellent (90 %) 90-day post-transplant survival. The most commonly encountered minor adverse event was IABP malposition, occurring in 44 % of patients, which was easily rectified with fluoroscopic adjustment.

All of these patients were allowed to sit upright and 16 patients were able to ambulate to receive dedicated physical therapist-assisted ambulation sessions to prevent deconditioning. The remaining 34 patients had nursing-guided ambulation. This study showed significant improvements in both renal and liver function and decreases in pulmonary hypertension before and after IABP insertion. The median time of ambulatory IABP support was 15 days in patients who underwent heart transplantation alone, with maximum support duration of 152 days in one patient who underwent dual heart-lung transplantation. Another similar study by Tanaka et al. showed a 93 % success rate with subclavian artery IABP as a bridge to transplant, with no mortality related to the balloon pump. These two studies clearly highlight the safety and efficacy of long-term use of ambulatory IABP in the advanced CHF population as a bridge to transplant or LVAD. [42, Rank 4]

Physiology of IABP Counterpulsation

Intra-aortic balloon pump counterpulsation (IABPC) for the management of cardiogenic shock in acute coronary syndrome is a safe and under-utilized technique despite recommendation in European and American guidelines. It remains shrouded in mystery with many general physicians and secondary care providers unaware of its place in the management of cardiogenic shock.

Raising awareness and understanding of this interventional process is vital for the management of myocardial infarction patients. In critically ill patients IABPC can not only be life saving with timely introduction but can provide haemodynamic stability to patients prior to more definitive measures being put in place. Recognizing the possible need and benefits from such a procedure should be the responsibility of all medical physicians as the onset of cardiac events is one that can occur in any setting.

Cardiogenic shock is an inadequate perfusion of organs as a result of cardiac impairment. This can occur after the sudden occlusion of a large coronary artery, resulting in myocardial ischaemia and necrosis. The resulting hypotension leads to multiorgan failure and death. Early reperfusion of the occluded artery by percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) has been shown to improve outcomes in cardiogenic shock. Mechanical circulatory support devices can provide stability until re-vascularization has taken effect which can be particularly lifesaving in the context of acute mitral valve rupture or ventricular septal defect (VSD). The timing of such intervention is vital and early recognition of patients who will need such circulatory support will provide an opportunity for concurrent PCI and IABP insertion, which often yields more favourable outcomes.

Myocardium is supplied by the coronary arteries which carry oxygen-rich blood from the root of the aorta. The large surface epicardial arteries subdivide into smaller subendocardial vessels which supply myocardium. During ventricular contraction, known as systole, the subendocardial coronary vessels are compressed due to high ventricular pressures causing coronary blood flow to stop. As a result most myocardial perfusion occurs during ventricular relaxation, known as diastole. The principle of intra-aortic balloon pump conterpulsation is to improve the ventricular performance of a failing heart by increasing myocardial oxygen supply and reducing myocardial oxygen demand. [46, Rank 5]

Insertion and Operation

The catheter is inserted via the femoral artery under fluoroscopic guidance and positioned in the proximal descending aorta, typically a few centimetres distal to the origin of the left subclavian artery. Pumping is dependent on aortic pressure and the electrocardiogram and can be automated by circuitry within the mobile console.

IABPC optimizes coronary perfusion by timing inflation with the diastolic phase of the cardiac cycle. It is within the diastolic phase that coronary perfusion takes place. Therefore, rapid inflation during this period raises the pressure within coronary arteries allowing for improved coronary blood flow and myocardial oxygenation. The deflation of the balloon occurs prior to systole when the aortic valve opens. This reduces cardiac afterload, increases stroke volume and reduces tension in the myocardial muscle, thus reducing myocardial oxygen demand. The outcome is improved overall cardiac function.Systolic blood pressure reduces by approximately 20% associated with an increase in aortic diastolic pressure by approximately 30%. Subsequently, coronary perfusion may improve the flow beyond critical stenoses

How IABPC Helps in Myocardial Infarction

In 1968, researchers reported improved blood pressure and urine output in patients stabilized with IABPC before and after surgical re-vascularization. For many the use of IABPC was limited to cardiothoracic surgery due to technical difficulty with catheter size, placements and high risk of complications. Technological advancement has led to the availability of a percutaneous insertable IABP which interventional cardiologists began to test in high-risk PCI patients. They conducted a cohort study of 181 patients with either cardiogenic shock post-myocardial infarction (MI) or unstable angina. Of the patients with unstable angina, 42 received haemodynamic stabilization, and despite initially being deemed unfit for surgery, went on to be successfully re-vascularized by CABG. Remarkably, complication rates were not found to be statistically significant. This landmark study demonstrated short-term benefits of IABPC in pump failure and refractory ischaemia, but long-term prognosis essentially unaltered. The improved coronary perfusion and haemodynamic support offered can potentially 'buy patients time' and optimize conditions for subsequent re-vascularization.

A randomized controlled study demonstrated benefit from IABPC to patients receiving re-vascularization through CABG, PCI or thrombolysis, though the difference failed to reach statistical significance. Criticisms of the study included lack of defined clinical endpoints and information regarding haemodynamic compromise were not made available for this study. In contrast, it was concluded that the treatment of a patient presenting with cardiogenic shock by means of thrombolytic therapy, IABP and then transfer for urgent re-vascularization by means of PCI/CABG was associated with lower in-hospital mortality than standard medical therapy.

Researchers investigated the use of IABPC in patients with acute ST elevation myocardial infarction (STEMI) leading to cardiogenic shock. Of the seven randomized trials included in one half of this analysis (1009 patients) the 30-day survival benefit was deemed non-significant. This concurred with the observation of no improvement in left ventricular ejection fraction (LVEF). There were 43 deaths recorded in the IABPC group versus 45 in those not receiving and ventricular support. Although the patients included in this study were deemed high-risk this was not standardized throughout the study, which is difficult given the heterogeneity of the patient cohort.

The authors concluded there was no clear evidence-base for the use of IABPC in high-risk acute myocardial infarction (AMI) patients. In addition, the risk of bleeding and stroke were also raised (2% and 6% respectively). However, this study does not state that patients in the acute setting do not benefit from IABPC, which is often the drawn conclusion. On the contrary, the aid of haemodynamic stability not only reduces the need for higher dependency care, intubation and reduced inotropic requirements but may also lead to reduced hospital stay. In addition, those patients with STEMI meeting indications for CABG have a prognostic benefit from surgery.

In the CRISP AMI trial (counterpulsation to reduce infarct size pre-PCI acute myocardial infarction), 337 patients were randomized in a multicentre study to either primary percutaneous coronary intervention (PPCI) therapy and IABP therapy or PPCI alone in patients without cardiogenic shock to assess outcomes on infarct size. Those allocated to the IABPC arm had this initiated pre-PCI and continued for at least 12 hours postprocedure. This study found no significant difference in final infarct size as assessed by cardiac magnetic resonance imaging, between the two arms of the study, 42.1% in the IABPC and PPCI group versus 37.5% in the PCI only group. This suggested that in patients presenting with acute anterior STEMI without evidence of cardiogenic shock, IABC together with PPCI compared with PPCI alone did not result in reduced infarct size.

Researchers suggested that although IABPC is effective in optimizing haemodynamic support in patients, this is only one element of acute cardiovascular care. Effective destination therapy, i.e. CABG, PCI or cardiac transplant are what alter long-term prognosis. Hence, IABPC use as a bridge, minimizing inotropic demands may be justified until definitive intervention is achieved. This aspect is again vital to the general medical setting. Patients deemed unfit for definitive intervention can arguably be considered for IABPC with the aim to evaluate the clinical status of the patients once cardiac function is optimized. This treatment allows for optimization of medical therapy in the interim. [49, Rank 4]

IABP as an Alternative Method of Cardiac Support

The lack of high-level evidence supporting the use of IABPC has led to a search for alternative therapies. Left ventricular assist device (LVADs) functions by acting as a surrogate pump to support the damaged left ventricle. These devices are usually situated inside or outside the body. A cannula is inserted into the left ventricle and an outflow graft is passed over the diaphragm and joined to the root of the aorta. This drains blood from the left ventricle to the pump, and is subsequently returned to the ascending aorta. LVADs are used far less frequently than IABPC and their use is presently limited to end-stage heart failure as a 'bridge to recovery' in those patients awaiting cardiac transplant.

Studies have focused on the use of LVADs in heart failure and patients with impaired cardiac function. In one study the use of LVAD improved New York Heart Association (NYHA) scoring of patients.This was evidenced by nearly 30% of the patients going from class IV to class II. However, the co-morbidities and adjuvant medical therapy were not made apparent for such patients who showed such a significant improvement.

Further data support the fact that LVAD can potentially improve LVEF and functional status.Even though these studies do not show evidence base for the use of LVAD in patients post-AMI and impaired LVEF, they do point to the potential benefit upon optimization of alternative therapy in such patients. Possible early consideration of such devices in patients with AMI and possible cardiogenic shock with impaired LVEF may well benefit from early assessment and implantation of such devices. This may lead to earlier discharge from hospital and return to functional status.

Very few individual trial data exist that actively compare LVAD to IABPC. This is mainly due to the fact that at present they are used for varying interim measures. However, it was concluded that patients who received LVAD instead of IABPC indeed had no survival benefit and in fact had higher bleeding complications. Any immediate superior haemodynamic superiority provided by LVAD is arguably offset in the long term. This hypothesis was supported by the early termination of the Prospect II trial that aimed to compare the Impella LVAD to that of IABPS in high-risk PCI patients. There was no statistical benefit with regard to adverse events between the two mechanical devices. However, a significant confounding variable of atherectomy was conducted in patients implanted with the Impella device leading to the termination of the study due to futility of the endpoints reached. [45, Rank 3]

Despite the recommendations for IABPC use in international guidelines, the literature has led to divided opinion on the true efficacy of using such devices. The use of IABPC lacks robust multiple randomized controlled trial data for long-term survival outcomes in cardiogenic shock. However, observational data suggest that there is a clear role as an adjuvant or 'bridge' therapy.

Treating cardiogenic shock is incredibly difficult in the medical setting, especially outside the CCU. The damaged heart needs to be rested, yet without a sufficient mean arterial pressure there is multiorgan under-perfusion. Inotropic support is associated with many complications including arrhythmia, peripheral limb and gastrointestinal tract ischaemia. Although inotropic support has evidence in treating septic shock it is associated with a markedly poorer outcome in managing cardiogenic shock. IABPC can markedly reduce inotropic demands and assist in keeping mean arterial pressures elevated. Although its use and management is yet confined to Coronary Care and Cardiothoracic units, its discussion for use is one that should span the breadth of all medical specialties. Just as dialysis is known to the realms of all medical fields it is also the duty of the caring physician to be aware that IABPC exists to provide patients with a mode of cardiac stabilization that if not leading to PCI or surgery will offer patients a route to minimizing cardiac damage and possibly hospital discharge.

Future studies for IABPC should aim not only to decipher more definitively the role of IABPC in an acute setting but should also look to expand to evaluate whether such use is beneficial in patients with decompensated heart failure and use in other types of shock, e.g. septic shock. Owing to the differing pathophysiology of cases such as septic shock, one must begin with phase one trials in order to gain evidence of the possible beneficial effects that could be applied to a human model.

What we can say with some confidence is that IABPC should be considered in all patients with haemodynamic instability secondary to AMI, leading to cardiogenic shock. This method of cardiac support can be offered to patients in the CCU setting with little risk to the patient and with minimal methods of monitoring. It remains to be seen whether IABPC can be used in patients with acutely unstable cardiac disease with the sole aim to medically stabilize the patient and then treat medically without further intervention. This will be left to the discretion of the treating physician and specialist cardiologist unit. [44, Rank 3]

IABPC usage is not without complication. The complications can be extremely serious with arterial and aortic damage including dissection.These complications are not always evident during the time IABPC is in situ. Some of these complications become apparent when patients return to their general medical ward for further medical treatment and rehabilitation. It is therefore vital that all medical doctors are aware of such possible complications. Embolization, thrombocytopenia, balloon rupture, trapping of gas and infection are all early identified complications.Prolonged use of IABP therapy coincided with a greater risk of serious complication.

Incorrect placement by the operator can cause limb ischaemia (a too proximally placed IABP can occlude the origin of the left subclavian and compromise arterial blood flow to the left hand and IABP placed too distally can block the renal arteries and contribute to renal hypoperfusion, low urine output and renal failure). Traditionally, IABPC use was routinely combined with full heparin anticoagulation introducing the risk of heparin induced thrombocytopenia. However, many centres now only load an initial heparin bolus, further minimizing the risk of HIT to an absolute minimum. One of the largest retrospective studies to date, the Benchmark Registry documented that of the 16,909 patients in the study only 2.6% suffered any major complications.

Researchers analysed high-risk features that were associated with increased incidence of IABPC complications. This included female gender, patients known to have peripheral vascular disease, diabetes, stroke/TIA, patients with a body surface area less than 1.8 m2 and cardiac index less than 2.2 L/min/m2. They found that patients with one or more of the above risk factors had a significantly higher incidence of IABPC-related complications compared with a cohort lacking the above risk factors (15% versus 3%). As such, these authors devised a risk-scoring system to allow clinicians to predict the risk of IABPC-related complications. With this model, they found that the risk of complications significantly increased with the addition of an extra risk factor in the individual patient such that a patient with four risk factors had a 75% risk of complication.Overall, however, the complications seen during the early development of IABPC have markedly decreased. The latest devices can be inserted percutaneously without a sheath, reducing the risk of arterial complications. [41, Rank 2]

Effects of IABP on Acute Myocardial Infarction

Intra-aortic balloon counterpulsation pump(IABP) can increase blood flow in the coronary artery and the brain while reducing afterload and cardiac oxygen consumption. Researchers first reported the clinical application of IABP. Because IABP can quickly improve the effect of patients' clinical symptom, so this technology causes people's attention. Although numerous percutaneous circulation support equipments are applied, the effect of IABP in adjuvant therapy of AMI patients is still controversial. Some previous studies show that IABP benefits for high-risk patients with AMI, but most of these studies are non-randomized and retrospective, with serious selection bias and poor credibility. However, in some other studies, the effectiveness of IABP in adjuvant therapy for severe patients with AMI has not been ensured.

Existing research shows that IABP increases blood supply to the coronary artery and the brain, reduces afterload, and eventually decreases cardiac oxygen consumption . It can thus be considered as an adjuvant method for treatment of AMI. The difference in results for short- (1–2 months) and long-term (6–12 months) follow-up indicates that treatment of AMI with IABP may be associated with some slow, compensatory mechanism of myocardial repair, but the specific mechanism is still not clear.

A study showed that in 2 months, the granulation scar tissue in the infarct area changed into connective tissue. In 2–3 months, the infarct area changed into a complete, acellular fibrous scar. These changes in scar tissue are consistent with the effect of IABP on mortality in this meta-analysis and suggest that IABP treatment may be affected by some unknown factors associated with scar formation. More experiments should be conducted to determine the mechanism. Although IABP can reduce AMI patient mortality in the first 6–12 months, it also increases the risk of bleeding. This mechanism is also not clear, thus further studies are needed.

Since 1980s, IABP is widely used in clinic. AMI is commonly seen in internal medicine, and about 7%~10% of AMI patients with CS has high mortality rate, through timely and effective treatment is performed. Coronary artery recanalization is the key to treat AMI, but in theory IABP can be used to better ensure sufficient blood supply and improve cardiac function of patients so as to save more myocardium and eventually further reduce the adverse consequence of AMI for patients. But, in the process of actual clinical research, the role of IABP is still controversial.

Although similar meta-analyses have been published, their conclusions differ from those provided here. In a meta-analysis based on six RCTs (two of which included patients with percutaneous left ventricular assist devices in the control group), no convincing benefit was observed with IABP therapy in AMI patients with CS . Another meta-analysis concluded that IABP did not reduce mortality in AMI patients without CS, but the data were not divided into subgroups based on follow-up duration. Briefly, those analyses concluded that IABP might not benefit AMI patients. However, in this analysis, we came to the opposite conclusion when the data were stratified by different durations of follow-up. Without analyzing different follow-up time, a meta-analysis showed that IABP can not improve LVEF or reduce the occurrence of angina or infarction on AMI patients without CS. However, IABP reduced the mortality of AMI patients with CS, but it increased the incidence of stroke and bleeding.[13, Rank 4]

IABP in Management of Coronary Vascular Disease

The management of patients with coronary vascular disease can be challenging especially in patients with severe left ventricular dysfunction and critical left main or severe triple vessel disease . Postoperative periods may also be characterised by low output cardiac state with attendant morbidity and mortality and thus action needs to be intensified to forestall these.

The use of the IABP with some pharmacological agents may influence the eventual size of the infarcted segment of the myocardium by preventing the extension of the myocardial infarction as a result of improved coronary blood flow. The insertion of IABP is an invasive procedure with several potential complications; as a result, its usage should be accurately tailored to high risk patients with persistent low cardiac output state in order to prevent the attendant high mortality and morbidity. [20, Rank 5]

Impact of IABP on Prognosis of Patients with AMI

The mortality rate of acute myocardial infarction (AMI) remains high. Although coronary revascularization, including percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG), has been widely used in clinical practice, the mortality for AMI with cardiogenic shock (CS) is still 40%-50%. Intra-aortic balloon counterpulsation (IABP) is the main circulatory assist device used in high-risk PCI, CABG, or AMI with CS, and can increase coronary blood flow, reduce left ventricular afterload, and improve cardiac function.

The impact of IABP on the prognosis of AMI patients is controversial. Many previous clinical randomized controlled trials (RCTs) had shown that IABP plus PCI or CABG could help improve the prognosis of AMI patients, and reduce in-hospital mortality.It was reported that IABP could significantly reduce the mortality of AMI with CS.With further in-depth studies, the impact of IABP on the prognosis of AMI patients was called into question. The results of a large-scale RCT published recently were in contrast with the above findings, and indicated that IABP did not reduce 30-day and 1-year mortality in AMI patients with CS.More than half of the studies in the meta-analysis by Romeo were observational, which might bias the results. [12, Rank 3]

IABP is widely used in treating AMI patients. However, whether IABP can improve the prognosis of AMI patients remains controversial. But another recent meta-analysis by Ye showed that IABP did not improve the two-month mortality of AMI patients with or without CS.The meta-analysis of this study showed that IABP did not reduce the in-hospital and 30-day mortality in AMI patients, and not reduce 6-month mortality.

The combination of different therapies, such as TT, PCI, or CABG might have different effects on IABP in AMI patients. The results of the prospective observational National Registry of Myocardial Infarction 2 study and ALKK-PCI showed no prognostic improvement in AMI patients with CS treated by IABP combined with PCI.Numerous studies have shown that mortality in AMI patients receiving TT combined with IABP was significantly reduced. However, our meta-analysis indicated that IABP did not reduce the in-hospital and 30-day mortality in AMI patients receiving TT, possibly because most studies included in the meta-analyses were observational studies instead of RCTs, which might bias the results. This meta-analysis only included three small-scale RCTs, and only 63 and 59 patients were included in the IABP and non-IABP groups, respectively. Therefore, large-scale RCTs are still needed to further confirm the impact of IABP on AMI patients received TT.

The implantation of IABP would delay PCI, which might be the cause of increased mortality in the IABP group. IABP could help increase coronary perfusion and maintain hemodynamic stability, thus possibly reducing infarct size and improving the prognosis. However, the results of clinical RCTs concluded the opposite to the above speculation. The Counterpulsation to Reduce Infarct Size Pre-PCI Acute Myocardial Infarction study included a total of 337 AMI patients without CS, and randomly divided them into IABP (before PCI) and control (PCI) groups. The results suggested that IABP did not reduce AMI infarct size. This might be related to the fact that the preparation time for PCI in the IABP group was significantly longer than that in the control group. [28, Rank 5]

The use of a left ventricular assist device or more vasoactive drugs in some patients in the non-IABP group could increase cardiac output and improve tissue perfusion, thus affecting prognosis. Thiele reported no difference in the systemic inflammatory response index and the tissue perfusion index between the two groups; this was likely related to the significantly increased use of vasoactive agents in the control group.Additionally, 8.5% of the control group in the Perera study received IABP. The proportion of the above studies accounted largely for the proportion of study, which might be the reason for no prognosis improvement in the IABP group.

The beneficial effects of IABP differed among AMI patients. The improvement in coronary blood flow depended on the severity of stenosis.The results of one study in 239 AMI patients who received IABP showed that those with sustained ischemia post-PCI or post-CABG benefited from IABP.A research study on the IABP effects in 499 AMI patients with CS demonstrated that the mortality in those with rapid systemic hypo-perfusion reversal (after IABP treatment for 30 min) was significantly reduced.Further study is needed to verify more clinical indications to provide a reference for clinical practice.

IABP might possibly improve the long-term prognosis of some AMI patients. The SHOCK long-term prognosis study revealed that the 6-month mortality was significantly improved. A study also confirmed that IABP could help reduce the 6-month mortality in AMI patients without CS. However, some recent studies showed that IABP did not improve 6-month or 12-month mortality in AMI patients, possibly because the AMI patients included in the above studies all had CS.

This study shows that the in-hospital and 30-day mortality in the IABP-before-PCI subgroup was reduced, and also 6-month mortality, suggesting that the timing of IABP may be very important. Perera confirmed that IABP before PCI did not reduce 30-day mortality, which may be related to several factors, such as significantly increased procedural complications, 12% received rescue IABP, and longer IABP duration in the control group. [33, Rank 4]

Supporting IABP after Myocardial Infarction

In patients with acute myocardial infarction researchers reported the outcomes on 40 patients who received an IABP therapy for cardiogenic shock after an infarction. Group I received IABP therapy and Group II IABP and aortocoronary bypass. Hospital mortality rates in Groups I and II were 71% and 47% respectively. The part of Group II that underwent therapy within 16 hours after the occurrence of the symptoms had lower mortality rate (25%) than that of Group II that underwent operation later than 18 hours after the symptoms were manifested (71%). Patients with acute refraction (coronary dissection or refraction due to plaque fissuring) of a minor branch of the left coronary artery due to percutaneous intervention would benefit from the IABP insertion followed by urgent revascularization. Placement of an IABP in patients following myocardial infarction was most frequently indicated for cardiogenic shock (27.3%), hemodynamic support during catheterization and/or angioplasty (27.2%) or prior to high-risk surgery
(11.2%), mechanical complications of acute MI (11.7%), and refractory post-myocardial infarction unstable angina (10.0%). [50, Rank 4]

Patients treated with IABP in our study who met the criteria of CS had a 30-day survival of 64 %, which is in line with the recent IABP-SHOCK II trial, showing a

30-day survival of 61 %. These survival rates are high when compared with other, older studies, most likely because of the high percentage of early revascularisation (90 %). The IABP-SHOCK II trial was the first randomised controlled trial on the use of IABP in patients presenting with AMI complicated by CS where reperfusion was achieved mostly by PCI and showed no reduction in short-term mortality.

Nonetheless, these results question if IABP deserves its place as routine treatment of patients with AMI complicated by CS, but do not exclude a beneficial effect in some patients. The challenge is to find a way to distinguish between those patients and not abandon such a potentially life-saving treatment regardlessly. At least, it can be expected that a beneficial effect of augmented diastolic pressure only plays a role in case of PI with exhausted autoregulation. In case of CS without PI, improved coronary blood flow is unlikely. [47, Rank 3]

IABP as Treatment of Persistent Ischemia

Use of IABP after successful epicardial reperfusion complicated by PI (no-reflow phenomenon), or after failed PCI, is an area which has not been investigated extensively. This no-reflow phenomenon is attributable to a variety of factors, including micro-embolisation, spasm, intramyocardial oedema and other entities incompletely understood, but leading to enlargement of the area of myocardial necrosis.

In a number of these patients, dramatic relief of ischaemia occurs after insertion of IABP, most likely due to afterload reduction and augmentation of myocardial blood flow. Since coronary autoregulation is completely exhausted in these patients, myocardial blood flow is directly dependent on perfusion pressure. Because of that exhausted flow reserve, a positive effect of augmented perfusion pressure is well conceivable. [46, Rank 2]

Both the ACC/AHA (2012) and the European Society of Cardiology guidelines strongly recommended IABP as a bridge to reperfusion for patients suffering from AMI complicated by CS, recommendations derived from several observational clinical trials. However, these recommendations have been challenged because of several recent meta-analysesand RCTs, which demonstrated that IABP for patients with AMI complicated by CS was not associated with reduced mortality, but with high potential risks of major bleeding and stroke. The IABP-SHOCK II trial, a randomized, open-label, multicenter trial involving 600 patients with CS following AMI who underwent early revascularization, demonstrated that IABP did not increase either 6- or 12-month survival rates compared with no IABP use. All these over-mentioned meta-analyses for IABP application did not include all available relevant citations and there was none of them grouped meticulously which might cover the beneficial efficacy of IABP on special patients. [38, Rank 5]

Conclusion

IABPs are commonly used for temporary circulatory support in patients with advanced heart failure, particularly as a bridge to heart transplant or LVAD. Ambulation and physical conditioning of such patients are often paramount when awaiting major surgery and recovery; ambulatory restriction can be detrimental in cases of prolonged circulatory support. Through continued innovation and advancement in the field of heart failure and circulatory support, improvement in clinical care, as well as patient quality of life, is self-evident. As the use of ambulatory IABP becomes more prevalent, future studies should aim to measure its impact on health-related quality of life, as it may be useful in assessing the effectiveness of such acute interventions. [20, Rank 5]