Mechanical left ventricular support using a 50 cc 8 Fr fibre-optic intra-aortic balloon technology: a case report

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Abstract

Introduction: More than four decades have passed since the first clinical use of an (IABP) to improve the clinical scenario for patients with chronic left ventricular failure. The original IAB catheter size was 15 French (Fr), requiring an open surgical insertion and removal. This therapy has now become the most widely used mechanical device for failure of the left ventricle. The introduction of an 8 Fr fibre-optic IAB catheter with a 50 cc diastolic blood volume displacement has further increased the potential clinical impact of this technology. This new catheter can be used for all patients over 162 cm in height, allowing a broader spectrum of patients to benefit from increased diastolic blood volume displacement and fibre-optic pressure monitoring. The catheter has been designed on an 8 Fr shaft platform, potentially reducing the incidence of vascular complications. We present our case report on the world's first implant of this 50cc 8 Fr IAB catheter.

Case Report: Cardiac investigations on a 53-year-old man showed the patient to have ischaemic dilated cardiomyopathy with a left ventricular ejection fraction (LVEF) of 25%. An 8 Fr 50cc Sensation PlusTM IAB catheter was inserted pre-operatively, prior to coronary artery bypass grafting.

Results: The world's first insertion of this 8 Fr 50 cc IAB catheter was a complete success, with no complications. The patient's pre-, peri- and post-operative courses were as we expected and event free, underpinned by IABP support.

Conclusion: This new 50 cc, 8 Fr IAB expands the patient group that can benefit from greater diastolic blood volume delivery, improved distal perfusion, more accurate monitoring, subsequent better beat-per-beat support and, finally, the reduced complication rates associated with an 8 Fr shaft.

Keywords

IABP; left ventricular function; left ventricular support; 8 French 50 cc; fibre-optic IAB; diastolic blood volume displacement

Introduction

Kirksey et al. considered intra-aortic balloon (IAB) counterpulsation to be the gold standard for a variety of clinical indications.[1] This technique has become the most widely used mechanical device for failure of the left ventricle (LV).[2] It is important that, as the evolution of cardiac surgery continues, intra-aortic balloon pump (IABP) technology follows suit. In the past 5 years, it has had to advance to deal with the increasing demands on this type of support. We have previously published our experiences with fibre-optic (FO) pressure monitoring. In combination with better timing algorithms, FO has not only met these increasing demands, but has also significantly increased the role of this device as a support therapy.[3] The introduction of an 8 French (Fr) fibre-optic IAB catheter with a 50 cc diastolic blood volume displacement has further increased the potential clinical impact of this technology. This new catheter can be used for any patient over 162 cm in height. This means a

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broader spectrum of patients can benefit from increased diastolic blood volume displacement and fibre-optic pressure monitoring. This 50 cc IAB has been designed on an 8 Fr shaft platform which realises the benefits of a reduced incidence of vascular complications.[4]

More than four decades have passed since the first clinical use of an IABP to improve the clinical scenario for patients with chronic left ventricular failure.[5] IABP counterpulsation is applied to reduce left ventricular afterload and myocardial work, to improve diastolic coronary and systemic blood flow and to increase cardiac output.[6] IABP technology has had to evolve as a result of our ageing patient population and its associated increased risks and co-morbidities. It was imperative that this evolution had to not only maintain, but improve its role as a support device that positively influences patient outcomes.

The effectiveness of this therapy is determined by several factors, including the cross-sectional aorta-to-balloon ratio, the ability to track arrhythmias, accurate monitoring, the speed of inflation and deflation as well as true beat-per-beat timing. We previously reported on some of the improvements already made as a result of the introduction of fibre-optic pressure monitoring.[3] The 8 Fr 50 cc catheter is another stage of IABP evolution. We present our case report on the world's first implant of this IAB catheter.

Case Presentation

A 53-year-old man was referred to our institution after initially presenting with several months of severe exertional dyspnoea. The patient reported no chest discomfort, but had asymptomatic low blood pressure. Additional medical history included congestive cardiac failure and epididymo-orchitis. His outpatient medical regime included ramipril, diazepam and furosemide. With a height of 163 cm, the patient would have normally fallen into the traditional 40 cc IAB category. His body mass index was 27.7 kg/m² due to his weight of 73.5 kg.

Cardiac investigations showed the patient to have ischaemic dilated cardiomyopathy with a left ventricular ejection fraction (LVEF) of 25%. Coronary angiography revealed concurrent three-vessel disease. The carotid duplex scan reported moderate atheroma at the bifurcation on the left side and moderate atheroma on the right side. The patient was scheduled for elective cardiac surgery and, in view of his poor left ventricular function, a pre-operative IAB was inserted.

An 8 Fr 50 cc Sensation Plus™ (Maquet Cardiovascular LLC, Wayne, NJ, USA) IAB catheter was inserted pre-operatively and set on an assist ratio of 1:1. The IAB catheter was used in conjunction with the CardioSave IABP hardware (Maquet Cardiovascular LLC). The IAB was in situ for 3 hours prior to anaesthesia, a total of 5 hours prior to cardiopulmonary bypass (CPB). Christenson et al.[7] have previously shown benefits after only 2 hours of pre-operative IAB support; however, our insertion team was available 3 hours prior to anaesthesia, providing this patient with 1 extra hour of pre-operative support (three hours in total). The insertion of the IAB was straightforward and without complication.

Transoesophageal echocardiogram findings by the anaesthetic team revealed mild to moderate functional mitral regurgitation due to the patient's poor LV. The patient had a logistic EuroSCORE of 6.16%.

Coronary artery bypass graft (CABG) surgery was performed in the usual manner. Harvesting of the left internal mammary artery (LIMA) and saphenous vein graft was carried out following a full median sternotomy. The IABP was automatically triggered off the electrocardiogram (ECG). The algorithm successfully filtered interference from the diathermy; subsequently, there were no alarms during the pre-CPB period. Systemic heparinisation was initiated and the ascending aorta and right atrium were cannulated with a 24 Fr straight cannula and a two-stage 36/46 Fr cannula, respectively. When full cardiopulmonary bypass was achieved, the IABP was stopped. A cross-clamp was applied to the aorta and antegrade cardioplegia was given into the aortic root with an induction of 500 ml of warm blood followed by 1000 ml of cold blood (4:1 cardioplegia solution). Smooth cardiac arrest was achieved. The arterial flow was maintained with a cardiac index between 2.0 and 2.4 L/min/m², producing mean arterial pressures between 50-80 mmHg. Mild hypothermia of 33°C was utilised.

The long saphenous vein was grafted onto the posterior descending artery and the obtuse marginal and the pedicle LIMA was grafted to the left anterior descending artery. Once the distal anastamoses were completed, the cross-clamp was released with a spontaneous nodal rhythm. According to the consultant surgeon's protocol, a temporary right ventricular pacing wire was put in place before the proximal ends of the saphenous veins were grafted onto the mid ascending aorta. Pacing was not required during the patient's post-operative course. The IABP was restarted 5 minutes before weaning from CPB, which was achieved on the first attempt.

Once all the cannulae were removed, protamine was administered. The myocardial ischaemic time (cross-clamp time) was 26 minutes and the CPB time was 53 minutes.

The patient was transferred to the Cardiac Intensive Care Unit (CICU) 90 minutes post CPB. The IABP was on a 1:1 support ratio, using the ECG as its trigger. In terms of inotropic support, the patient was on 0.1 μg/kg/min noradrenaline and 5.6 μg/kg/min dopamine.

The post-operative course

Over the next 14 hours, the noradrenaline and dopamine were gradually weaned. The dopamine was stopped 2

hours prior to IAB removal and the background noradrenaline stopped 1 hour after IAB removal.

During the post-operative period, the augmented peak diastolic pressure (APDP) ranged from 68-131 mmHg, the assisted end-diastolic pressure (AEDP) ranged from 39-88 mmHg, the heart rate (HR) ranged from 43-129 beats per minute (bpm) and the mean arterial pressure (MAP) ranged from 55-100 mmHg.

Figure 1 shows these ranges and illustrates the post-operative pressure trends which remained constant in the face of reducing inotropic support.

The IABP was reduced to a 1:2 support ratio at 18 hours post insertion and the patient was extubated after 14 hours of ventilation, which was 2 hours before the IAB was removed.

The patient had no post-operative complications and was discharged from the hospital on day 6. The prescribed

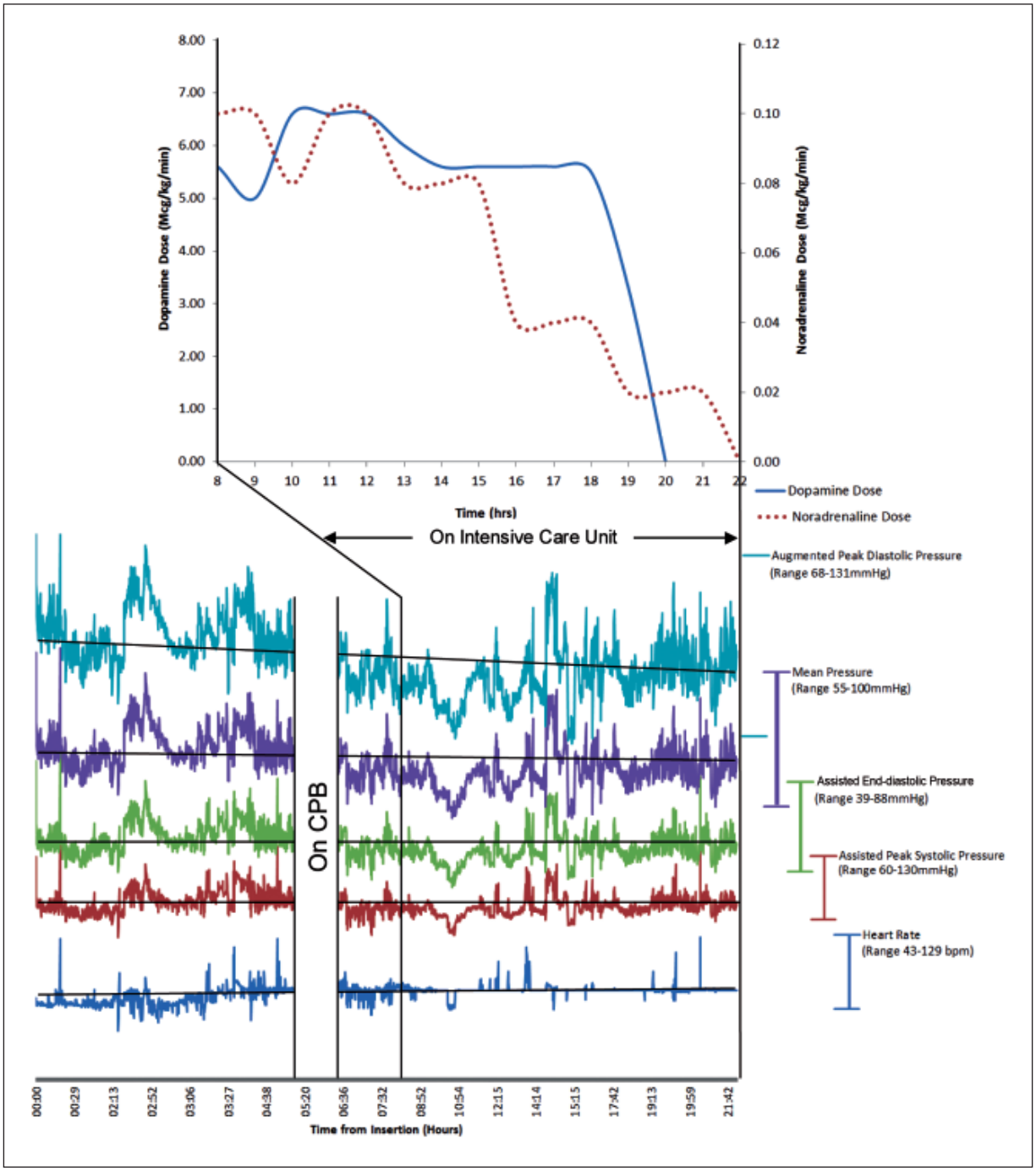

Figure 1. Patient pressure and inotrope use over 22 hours post-IAB insertion

post-operative medications included vitamin B, spironolactone, aspirin, thiamine hydrochloride, diazepam, lansoprazole, paracetamol, furosemide and simvastatin. At the time of submission, the patient was awaiting his 6-week follow-up appointment

Discussion

Intra-aortic balloon pump counterpulsation has clearly evolved. The first IAB catheter size was 15 Fr, requiring an open surgical insertion and removal. The currently available catheters range between 7 and 8 Fr, which allow percutaneous insertion with fewer complications.[8] The most recent development in IABP technology is the new 50 cc fibre-optic catheter. This allows a wider patient group to gain the benefits of larger diastolic blood volume displacement combined with fiber-optic monitoring which, in turn, assists improved software algorithms to provide better beat-per-beat support.

It is important to get the balance correct between obtaining a larger diastolic blood volume displacement and keeping the shaft portion of the IAB sitting in the femoral artery as small as possible. In 2002, Cohen et al. compared the complications associated with catheter shaft size (9.5 Fr against 8 Fr) in 9,332 patients.[4] Data were prospectively collected via a benchmark registry, allowing a worldwide cohort of patients to be analysed. The results showed that the lower calibre 8 Fr shaft catheters were associated with a true reduction in the incidence of vascular complications. Meisel et al. agreed with this, stating that the utilisation of 8 Fr IAB catheters entails an exceedingly low complication rate despite an acute presentation, intense anticoagulant and antiaggregant therapy, frequent co-morbidity, advanced age, severe coronary disease and reduced cardiac function in a large proportion of treated patients.[9] It is clear that an 8 Fr IAB shaft offers a clinical advantage; however, the literature does not discuss the diastolic blood volume displacement of the IAB and its clinical consequence on the patient.

Maquet's own in vitro benchmark testing shows that the 50 cc IAB offers improved unloading and augmentation when compared to a 40 cc catheter. The 25% increase in blood volume displacement is due to the geometry of the balloon membrane. As Figure 2 shows, the 50 cc catheter provides 15% more diastolic augmentation and 58% more systolic unloading than the 40 cc. Maquet have deemed this IAB catheter suitable for patients 162 cm and taller.

As shown in Table 1, previously, patients of 162-183 cm would only have been suitable for a 40 cc catheter and only patients over 183 cm would have been suitable for a 50 cc IAB.[10] Boiangiu et al. reported the use of the predecessor to the Sensation Plus, the Mega IAB catheter.[11] They found the 50 cc catheter increased the cardiac output in 1:1 by 15%. However, the authors did state the benefits of counterpulsation technology were dependent on the balloon-to-aorta cross-sectional area ratio. Augmentation was assessed by measuring the Time Velocity Integral (TVI) with a Doppler. The authors demonstrated that a larger inflated IAB diameter meant that the aorta cross-section to IAB ratio was reduced, subsequently improving augmentation. Along with the increase in volume of blood displaced during inflation, an additional benefit of reducing this ratio may be to improve distal perfusion.[11] The 50 cc IAB expands to 17.4 mm whereas the 40 cc IAB expands to only 15 mm. The theory being that the tighter the IABP-aorta fit the more the propagation of the pulse wave through the aortic wall is modified, although, when fully expanded, the catheter should not exceed 80-90% of the descending thoracic aorta.[10] The Boiangiu paper was supported by Nair's work in 2011, which showed that the larger blood volumes displaced by the 50 cc catheter were associated with greater diastolic pressure augmentation, especially in the smaller patients with a smaller descending aortic cross-sectional area.[12]

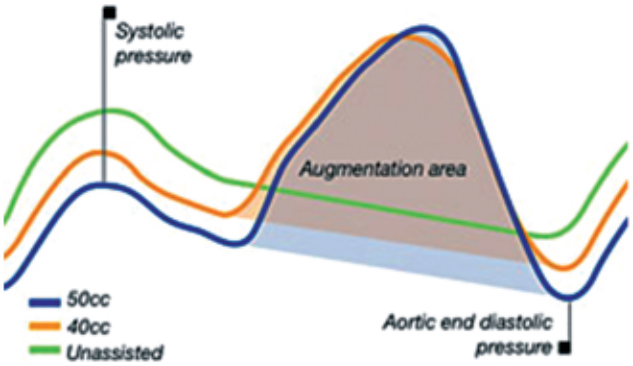

Figure 2. Comparison of the augmentation area of a 50 cc and 40 cc IABP

As concluded in our previous paper,[3] we are of the opinion that, when considering cardiac healthcare delivery as a whole, IABP technology is our most valuable short-term assist device. It may only provide 1.5 to 2.0 L/min of cardiac output assist, but it is involved in many patient interventions. The aforementioned fibre-optic technology, better algorithms and the now widely available increased diastolic blood volume displacement reinforce this opinion.

Table 1. IAB Sizing Chart

Patient Height (cm)	Recommended IABP (cc)
<152	25
152-162	34
162-183	40
183	50

Conclusion

Our case report on the world's first insertion of the 8 Fr 50 cc fibre-optic Sensation Plus IAB was a complete success with no complications. The patient's pre-, peri- and post-operative courses were as we expected and event free, underpinned by IABP support. This catheter expands the patient group that can benefit from greater diastolic blood volume, improved distal perfusion, more accurate monitoring, subsequent better beat-per-beat support and, finally, the reduced complication rates associated with an 8 Fr shaft.

In terms of future research, we intend to quantify and compare the time velocity integral and stroke volume across 34, 40 and 50 cc IAB in order to confirm Boiangiu's[11] and Nair's[12] theories on the reduction of the IAB to aortic cross-sectional area ratio, which is imperative for increasing diastolic augmentation. As Kantrowitz[5] stated, any new idea, if it is to succeed, requires the courage and depth of understanding of its inventor to pursue the thought through to its conclusion.

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Conflict of interest statement

The authors have no conflicts of interest to declare.

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