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Short Review

Versatility of the Axillary Intra-Aortic Balloon Pump in Adult Cardiac Surgery

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Abstract

The axillary intra-aortic balloon pump (ax-IABP) has been proposed as an alternative to the femoral IABP, particularly for patients with comorbidities rendering them unsuitable for fem-IABP insertion. Patient mobilisation with the ax-IABP in situ is deemed an additional potential benefit. We reviewed our experience with the ax-IABP. A single-centre retrospective review of all adult patients undergoing cardiac surgery (including heart transplantation) in a UK quaternary cardiac surgery centre between 2017 and 2021 was undertaken. During the study period a total of 232 IABPs were inserted, of which 2.2% (n = 5) were ax-IABPs. Overall in-hospital mortality for this cohort was 19.9% (n = 46). Amongst the five patients who received an ax-IABP, the mean age was 57.4 years, and three patients were female. All patients received an ax-IABP through the right axillary artery via a Dacron side graft. Appropriate positioning was confirmed with real-time fluoroscopy and transoesophageal echocardiography. Operations included heart transplantation (n = 1), coronary artery bypass

grafting (CABG) (n = 1), CABG & mitral valve surgery (n = 2) and CABG & mitral & aortic valve surgery (n = 1). No patient experienced IABP-related morbidity and three patients survived to discharge. In this limited series, ax-IABP has emerged as a reasonable alternative to fem-IABP. Several patients in this series who received an ax-IABP were not suitable for fem-IABP. The absence of IABP-related morbidity in this series supports the usage of ax-IABP as an appropriate alternative treatment for patients requiring IABP support.

Keywords
Circulatory temporary support; mechanical circulatory support; cardiopulmonary bypass; peripheral artery

1. Introduction

The intra-aortic balloon pump (IABP) has emerged as the most frequently used mechanical assist device in contemporary cardiac surgery practice and has traditionally been inserted via a femoral approach (fem-IABP) [1]. Indications for IABP use include refractory angina, prophylaxis in high-risk cardiac surgery patients, failure to wean from cardiopulmonary bypass (CPB) and as a bridge to either decision-making or alternative mechanical circulatory support (MCS) device implantation in patients with cardiogenic shock [2]. Despite some evidence demonstrating improved outcomes in specific patient populations where an IABP is used [3], such findings are not replicated across all studies published on this topic [4].

A number of contraindications to fem-IABP exist, including peripheral vascular disease (PVD), aortic aneurysms and extensive atherosclerosis burden in the abdominal and descending thoracic aorta [2]. Moreover, fem-IABP usage carries a risk of complications and hence its implementation should be considered on a case-by-case basis for each individual patient. Indeed, a recent literature review of twenty studies analysing outcomes in patients receiving fem-IABP reported a complication rate which varied widely from 0.94% to 31.1% [5]. Bleeding, lower limb ischaemia and mesenteric ischaemia emerged as the most frequently occurring complications whilst PVD was shown to be a risk factor for procedure-related morbidity.

These factors have compelled clinicians to seek alternative approaches to fem-IABP insertion and in recent times, particularly in North American centres, insertion of an IABP via the axillary artery (ax-IABP) has become increasingly popular [6]. Indeed, it has been asserted that the ax-IABP possesses a number of advantages over the fem-IABP, foremost of which is the ability for patients to mobilise whilst the device is in-situ [7]. Despite North American series presenting growing numbers of patients with excellent outcomes with ax-IABP [8, 9], there is very little published literature documenting its use in United Kingdom (UK) and European centres with extremely limited patient numbers [10].

The aim of this study was to present our experience of the ax-IABP used in adult cardiac and cardiopulmonary transplant patients in a single UK centre.

2. Methods

2.1 Patients

All patients aged 18 years and over who underwent cardiac surgery (including heart transplantation) and received an ax-IABP between January 2017 and December 2021 at a single UK centre were included in this retrospective observational study. The centre is a quaternary cardiothoracic surgery unit providing both adult cardiac and thoracic surgery in addition to providing cardiopulmonary transplantation and the full range of extra-corporeal membrane oxygenation (ECMO) services for the region. Data were obtained from the local clinical governance databases with any missing data sourced directly from patient case-notes where possible. All data were anonymised prior to use. The unit transitioned to an alternative electronic governance system from 2022 onwards. Issues with data input and collection meant that data quality was less assured from this timepoint onwards, which is why no patient data beyond December 2021 has been included in this series.

2.2 Ax-IABP Insertion

All ax-IABP insertions were performed by a single surgeon using the same operative technique. Under general anaesthesia, a 5 cm right subclavicular incision was made. Axillary artery isolation was achieved after dissection with diathermy of subcutaneous tissue and splitting of the pectoralis major and minor fibres. A 6 mm longitudinal incision was made in the artery followed by an end-to-side anastomosis of a 6 mm Dacron graft to the right axillary artery using 4/0 prolene. The proximal end of the graft was tied with vicryl and silk ties to hold the vascular sheath in place whilst the distal end was tunnelled to the skin. Under fluoroscopic and transoesophageal echocardiographic (TOE) guidance the ax-IABP was then inserted and was activated once satisfactory positioning was achieved. Daily chest radiographs were performed thereafter to ensure that positioning remained optimal.

Ax-IABP removal was also performed under general anaesthesia. The subclavicular incision was re-opened to facilitate removal of the IABP and subsequent tying-off and oversewing of the Dacron graft. The wound was then routinely closed in layers. Ax-IABP removal was either performed as a short, isolated procedure or as part of other procedures such as biventricular assist device (BiVAD) implantation or heart transplantation (HTX).

2.3 Ethics Statement

This work was approved by the steering committee of the Northwest Clinical Outcomes Research Registry (NCORR), which has full ethical approval from the North West (Haydock) NHS Health Research Authority (IRAS 260294). Given the retrospective nature of the work, individual consent for this study was waived.

3. Results

During the study period a total of 232 IABPs were inserted, of which 2.2% (n = 5) were ax-IABPs. Overall in-hospital mortality for this cohort was 19.9% (n = 46). Amongst the five patients who received an ax-IABP, the mean age was 57.4 years, and three patients were female.

3.1 Patient 1

A 48-year-old female was admitted following presentation with a non-ST elevation myocardial infarction (NSTEMI). Coronary angiography demonstrated triple vessel coronary artery disease (CAD) with a chronically occluded left anterior descending (LAD) artery. She developed cardiogenic shock requiring insertion of a left fem-IABP. When this was removed five days later, she again developed cardiogenic shock necessitating re-insertion of the fem-IABP. Imaging demonstrated ischaemic cardiomyopathy with severe left ventricular dysfunction and dilatation with preserved right ventricular function. There was limited left-sided viability and also severe mitral regurgitation. She underwent coronary artery bypass grafting (CABG) ×3 and mitral valve repair with prophylactic insertion of an ax-IABP prior to median sternotomy. Given the anticipated extensive surgery and prolonged recovery, the ax-IABP was chosen rather than the fem-IABP to facilitate early mobilisation despite an expected prolonged need for the IABP. After surgery she was extubated, and her inotropic support was gradually weaned. She began mobilising with the ax-IABP in situ from the 2nd post-operative day (POD) and engaged with physiotherapy. On day 8 she required a short general anaesthetic for ax-IABP removal. She was discharged from hospital on POD 20 and remains alive and well at the time of writing.

3.2 Patient 2

A 39-year-old male was admitted following presentation with decompensated heart failure and end-organ dysfunction secondary to dilated cardiomyopathy. He was known to have sickle cell trait. He was initially treated with inotropes and a fem-IABP and was deemed to be a candidate for HTX. After removal of the fem-IABP he again became haemodynamically unstable and therefore a decision was taken to insert an ax-IABP to facilitate mobilisation during the bridge to transplantation process. A potential long wait for a suitable organ underpinned the selection of ax-IABP so as to allow mobilisation. The ax-IABP improved the haemodynamics and the patient remained stable for five days. He then developed bilateral pulmonary emboli and again became haemodynamically unstable with end-organ dysfunction. He subsequently underwent BiVAD insertion prior to undergoing orthotopic HTX approximately two months later. He recovered well and remains alive at the time of writing.

3.3 Patient 3

A 63-year-old female was admitted following presentation with an NSTEMI. She had significant triple vessel CAD, previous LAD & right coronary artery stents, bilateral iliac artery stents for PVD and severe emphysema whilst continuing to smoke. A transthoracic echocardiogram showed preserved biventricular systolic function. After discussion at the multidisciplinary team (MDT) meeting, she subsequently underwent uneventful total arterial CABG ×3. A few hours later she experienced an asystolic arrest necessitating emergency chest re-opening. Cardiac output was re-established and central veno-arterial (VA) ECMO was initiated alongside inotropic support. Transoesophageal echocardiogram images demonstrated poor cardiac contractility. In order to facilitate ECMO weaning, and in view of the extensive PVD negating femoral access, an ax-IABP was inserted. However, prior to weaning VA-ECMO she became increasingly unwell with abdominal distension. Computed tomography imaging demonstrated extensive bowel ischaemia for which she

underwent laparotomy. Unfortunately the extent of ischaemia was deemed to be unsalvageable, and she was subsequently palliated.

3.4 Patient 4

A 69-year-old female was admitted following presentation with an NSTEMI. Comorbidities included poorly controlled diabetes mellitus (HbA1c > 100), rheumatoid arthritis, pulmonary fibrosis, chronic obstructive pulmonary disease and hypertension. Imaging revealed triple vessel CAD and ischaemic cardiomyopathy with severe left ventricular systolic dysfunction. There was also severe mitral regurgitation. After MDT discussion she underwent tissue mitral valve replacement and CABG ×3 with prophylactic insertion of an ax-IABP prior to median sternotomy due to the severe left ventricular impairment. Given the anticipated long surgery and prolonged recovery, the ax-IABP was chosen rather than the fem-IABP to facilitate early mobilisation despite an expected prolonged need for the IABP. The ax-IABP remained in situ for seven days prior to being removed in theatre under general anaesthetic. Her post-operative recovery was complicated by mediastinitis requiring formal re-exploration in theatre on several occasions. She continued to deteriorate, requiring renal filtration and tracheostomy. Unfortunately she was unable to be weaned from the ventilator and was palliated.

3.5 Patient 5

A 68-year-old man was admitted following presentation with type I respiratory failure secondary to pulmonary oedema. His condition improved with diuretics and oxygen therapy. Comorbidities included hypertension, diabetes mellitus, dual chamber permanent pacemaker for complete heart block and previous closure of atrial septal defect with Amplatzer device implantation. Imaging on this admission demonstrated triple vessel CAD, severe mitral regurgitation and moderate aortic stenosis with mild left ventricular systolic dysfunction. After MDT discussion he underwent CABG x3, tissue mitral valve replacement, aortic root enlargement and tissue aortic valve replacement. It proved difficult to wean from CPB despite high inotropic support and hence a fem-IABP was inserted. The patient was subsequently weaned from CPB. Four days later he developed right limb ischaemia, necessitating removal of the fem-IABP. Angiography revealed previously unknown extensive PVD. Therefore, the patient returned to theatre for insertion of an ax-IABP. He gradually improved and the ax-IABP was subsequently removed in theatre 13 days later. He then made steady progress and was subsequently discharged home after approximately three months in hospital.

4. Discussion

This series has demonstrated that the ax-IABP can be considered as an alternative to fem-IABP in adult cardiac surgical and transplant patients. No repositioning was required and there was no IABP-associated morbidity in this series. Additionally, there were no recorded complications associated with removal of the ax-IABP, such as bleeding or haematoma. A number of patients who were not suitable for a fem-IABP successfully received an ax-IABP. These findings cautiously support increased usage of the ax-IABP in contemporary cardiac surgical practice. Nevertheless, this study is a single-centre retrospective observational series and consequently its results must be considered in that context.

Since the first description of the fem-IABP in the 1960s [11], alternative insertion sites including the subclavian and axillary arteries were also described over the next twenty years [12, 13]. The IABP has subsequently become established as the most frequently used mechanical assist device in contemporary cardiac surgery, utilised in adult cardiac surgery patients both as a prophylactic measure [4] and also in the post-cardiotomy setting. It is also used as part of the surgical management of patients with end-stage heart failure as well as being regularly employed in the scenario of infarct-related cardiogenic shock [3].

There are a limited number of studies specifically examining the role of the ax-IABP in a post-cardiotomy setting, all of which are either case reports or small observational series [9, 14, 15]. These studies all indicated that ax-IABP was favoured over fem-IABP due to the presence of either peripheral atherosclerotic disease or abdominal aortic aneurysms. All described acceptable levels of IABP-related morbidity.

Published literature detailing the role of upper-extremity IABP (comprising either ax-IABP or subclavian-IABP) in advanced heart failure patients has been formally reviewed by Nwaejike et al. [8]. The four studies where all patients received an ax-IABP had a combined cohort size of 85 patients (n = 50, n = 18, n = 13, n = 4), all of whom received an ax-IABP as a bridge to transplant [6, 16-18]. The rate of device exchange or repositioning ranged from 17-64%, seven patients experienced axillary artery thrombus and three patients experienced limb ischaemia. It was reported that the overall majority of patients in these series experienced haemodynamic improvements and went on to receive a cardiac transplant. Median duration of support ranged from 18-35 days.

There are currently no randomised trials examining whether either the ax- or fem-IABP provides any additional benefit in comparison to the other. Fem-IABP is an established practice yet has a number of limitations and contraindications, including the inability for patients to mobilise and the presence of peripheral atherosclerotic disease. The ax-IABP was first described over 30 years ago and is now being increasingly utilised in contemporary practice, particularly for patients with advanced heart failure being treated in North American centres.

The prolonged duration of IABP support in advanced heart failure patients represents one of the key benefits of an ax-IABP over a fem-IABP. It is well recognised that reduced ambulation contributes to increased deconditioning prior to surgery, both of which are associated with adverse post-operative outcomes. Hence, the patient with advanced heart failure receiving a fem-IABP for ‘optimisation’ is simultaneously being deprived of the opportunity to maintain their maximal level of function prior to surgical intervention. Thus, the ax-IABP provides the benefits associated with aortic counterpulsation whilst removing the impediment to mobilisation inherent to the fem-IABP.

In this series, patients received an ax-IABP for a number of different reasons. These included the presence of peripheral atherosclerotic disease, the expectation of a prolonged duration of support prior to transplantation, and extensive cardiopulmonary comorbidities where an inability to mobilise early in the post-operative period was deemed to place the patient at a prohibitively high risk of experiencing post-operative complications. These reasons correlate with the reasons outlined in the existing studies in the literature presenting ax-IABP experiences. Whilst two of the patients in this series did not survive to discharge, reflecting the severity of illness in patients requiring MCS, we report no IABP-related morbidity. Such a finding lends support to recognising the ax-IABP as an appropriate alternative to the fem-IABP in selected patients.

The absence of device exchange or repositioning in this series is also important and is perhaps reflective of our multidisciplinary approach to the ax-IABP, whereby consultant cardiac surgeons, consultant cardiologists and consultant cardiothoracic anaesthetists utilise a number of different imaging modalities including TOE and fluoroscopy to achieve a satisfactory position of the ax-IABP at the time of insertion.

5. Conclusion

Fem-IABP is a safe and established practice for patients undergoing cardiac surgery and heart transplantation who require MCS during their patient journey. However, its limitations and contraindications mean that its use is not appropriate in a certain subset of patients. Alternative approaches, including the ax-IABP, have become increasingly utilised in recent years, although the published literature suggests that ax-IABP usage has not yet been routinely adopted by UK centres. This study adds to the growing body of literature which demonstrate similar clinical outcomes to the fem-IABP, whilst facilitating mobilisation and maintaining a low rate of IABP-related morbidity. As a result of the findings in this and other published studies on this topic, we believe that the ax-IABP is a safe and appropriate treatment for patients requiring mechanical support with an IABP.

Abbreviations

Ax-IABP	Axillary intra-aortic balloon pump
CABG	Coronary artery bypass grafting
CAD	Coronary artery disease
CPB	Cardiopulmonary bypass
ECMO	Extracorporeal membrane oxygenation
Fem-IABP	Femoral intra-aortic balloon pump
HTX	Heart transplantation
IABP	Intra-aortic balloon pump
LAD	Left anterior descending
MCS	Mechanical circulatory support
MDT	Multi-disciplinary team
NSTEMI	Non-ST elevation myocardial infarction
POD	Post-operative day
PVD	Peripheral vascular disease
TOE	Transoesophageal echocardiogram
VA-ECMO	Veno-arterial extracorporeal membrane oxygenation

Author Contributions

MT: Data curation, formal analysis, writing (original draft), writing (review and editing). ZM: Data curation, writing (original draft), writing (review and editing). EA: Writing (review and editing). NN: Conceptualisation, supervision, writing (review and editing).

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Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

Data is available from the authors upon reasonable request.

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