Heart, Lung and Circulation (2019) **28,** 342–347
1443-9506/04/$36.00
https://doi.org/10.1016/j.hlc.2018.03.019

ORIGINAL ARTICLE

Experience With the Axillary Artery as an Arterial Cannulation Site in Patients With Acute Type A Aortic Dissection

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Received 12 December 2017; received in revised form 6 March 2018; accepted 13 March 2018; online published-ahead-of-print 29 March 2018

Background The optimal arterial cannulation site in patients undergoing surgical management of acute type A aortic dissection (ATAAD) remains controversial. The axillary artery is rarely involved in the dissection process, provides antegrade flow in the descending aorta and minimises intraoperative malperfusion. The purpose of this study is to evaluate a single surgeon's experience of axillary artery cannulation for ATAAD repair.

Methods All consecutive patients over a 15-year period having surgical repair of ATAAD were included in this study.

Results There were 55 patients with a mean age of 67 years. The most common risk factors were hypertension (83.6%), connective tissue disease (7.3%) and a bicuspid aortic valve (7.3%). Axillary artery cannulation was performed on 50 patients (90.9%) and was contraindicated in the remaining five patients. Forty-nine patients survived to 30 days with a 10.9% 30-day mortality rate. There was one confirmed stroke (1.8%) and no new malperfusion noted postoperatively. There were no major axillary artery complications or new dissection related to cannulation.
We attribute these results, which are lower than those reported in the International Registry of Acute Aortic Dissection (IRAD) database, to axillary artery cannulation providing antegrade flow in the descending aorta from the outset and reducing intraoperative malperfusion. We believe this technique offers a cerebroprotective advantage and also facilitates selective antegrade cerebral perfusion (SACP) when aortic arch replacement is required.

Conclusion We believe the axillary artery is the ideal cannulation site of ATAAD and helps to reduce mortality and neurological complications in this high-risk group of patients.

Keywords Aorta • Axillary artery • Acute type A aortic dissection • Aortic surgery

Abbreviations: ATAAD, Acute Type A Aortic Dissection; CPB, Cardiopulmonary Bypass; CPR, Cardiopulmonary Resuscitation; CT, Computed Tomography; CVA, Cerebrovascular Accident; DHCA, Deep Hypothermic Circulatory Arrest; DSWI, Deep Sternal Wound Infection; EEG, Electroencephalography; IRAD, International Registry of Acute Aortic Dissection; MRI, Magnetic Resonance Imagine; SACP, Selective Antegrade Cerebral Perfusion; TIA, Transient Ischaemic Attack

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Introduction

Despite many advances in the diagnosis and management of acute type A aortic dissection (ATAAD), this condition remains associated with significant morbidity and mortality. The International Registry of Acute Aortic Dissection (IRAD) reported an overall in-hospital mortality of 23.9% based on a combined series of 682 patients [1]. Rapid surgical intervention is therefore necessary to prevent fatal complications. Moreover, improvements in intraoperative techniques such as the use of axillary artery cannulation facilitating antegrade flow in the descending aorta from the outset and avoiding intraoperative malperfusion have improved outcomes for patients with this potentially lethal condition [2–4].

Due to the potential for neurologic injury, malperfusion, prolonged operative times and bleeding complications, surgical treatment of aortic dissection is considered to be high-risk surgery. Many neuroprotective strategies have been suggested with the optimal method still remaining controversial [3]. Axillary artery cannulation has demonstrated a number of theoretical advantages over aortic and femoral cannulation [5–8]. It avoids manipulation of a diseased ascending aorta as well as the 'sandblast' effect of turbulent flow from the cannula tip in aortic cannulation. It also permits selective antegrade cerebral perfusion (SACP) when circulatory arrest is required. Disadvantages arising from retrograde flow in femoral artery cannulation such as organ malperfusion and the risk of retrograde embolisation by thrombus or atherosclerotic debris are avoided. As a result, many centres have adopted this cannulation strategy as standard practice in aortic surgery [6].

Technical problems and complications related to axillary artery cannulation remain rare. Cannulation related aortic dissection, low pump flow, malperfusion, axillary artery and vein injury, brachial plexus injury and wound infections have all been reported [9]. These complications are rare and some can be minimised with the use of a side graft as opposed to direct axillary cannulation [10].

The optimal cannulation strategy in surgical repair of acute aortic dissection is presently unclear. The purpose of this study is to evaluate a single surgeon's experience of axillary artery cannulation on postoperative outcomes and to reaffirm our belief that this is a safe cannulation site and the best option for ATAAD.

Materials and Methods

Data Collection

Patients were identified retrospectively from a single surgeon's operative record. During a 15-year period (July 2002 to July 2017), a total of 55 patients underwent surgical repair for ATAAD. Fifty of these patients had axillary artery cannulation for cardiopulmonary bypass (CPB), however it was contraindicated in the remaining five patients.

ATAAD was defined as the presence of a dissection flap in the ascending aorta presenting within 14-days of onset of symptoms. All patients were operated on by a single surgeon at Royal North Shore and North Shore Private hospitals. Following approval, the operative database was retrieved and patient records reviewed to confirm operative details and outcomes. All adverse outcomes occurring in the first 30-days postoperatively were recorded.

Operative Technique

Bilateral radial arterial lines were inserted to exclude a significant subclavian artery stenosis (which would preclude the use of the axillary artery) and to monitor for hyperfusion of the right arm. If axillary artery cannulation is possible, the left radial pressure is used to monitor the perfusion pressure during the case as the right is often higher and not an indicator of pressure in the arch distally [6].

A 5–7 cm infraclavicular incision is made 1 cm below the middle and lateral part of the clavicle, extending into the deltopectoral groove. The pectoralis major muscle is separated along the direction of its fibres and the pectoralis minor muscle is retracted laterally or divided. The axillary artery is then identified by palpation and mobilised avoiding the brachial plexus posteriorly. Vessel loops are placed to gain control proximally and distally and the full dose of heparin required for cardiopulmonary bypass (CPB) is administered. An 8 mm Dacron graft is anastomosed in an end-to-side fashion to the axillary artery with a running 5/0 prolene suture. A 24 Fr straight cannula is inserted into the Dacron graft for arterial inflow.

Endpoints

Primary endpoints measured were mortality and neurological morbidity. Mortality was defined as death during the first 30 days after the operation. Neurological morbidity included any patients with permanent neurologic deficit either from stroke or coma or temporary neurologic deficit. Complications of axillary artery cannulation were measured as secondary endpoints.

Statistical Analysis

All data was collated in a password-protected Microsoft Excel spreadsheet database. Data is presented as mean ± standard deviation.

Results

Patients

The entire patient cohort of 55 patients represented 32 men (58.2%) with the mean age of 67 ± 14.2 years. Patient characteristics are presented in Table 1. The most common risk factors for patients with ATAAD in our cohort were patients with hypertension (83.6%), connective tissue disorders (7.3%) and a bicuspid aortic valve (7.3%).

Preoperative clinical findings of the patients in this cohort are presented in Table 2. Two patients had preoperative cardiac arrest and were taken to theatre with continuous cardiopulmonary resuscitation (CPR). Both required urgent CPB and femoral cannulation was performed. Twelve patients had

Table 1 Patient Demographics.

	No.	%
Male	32	58.2
Age (years), mean ± SD	67 ± 14.2	
Age ≥ 75 (years)	21	38.2
BMI, mean ± SD	26.5 ± 4.8	
Hypertension	46	83.6
Connective Tissue Disorder	4	7.3
Bicuspid Aortic Valve	4	7.3
History of CVA or TIA	3	5.5
Peripheral Vascular Disease	2	3.6
Prior Cardiac Surgery	2	3.6

Abbreviations: BMI, body mass index; CVA, cerebrovascular accident; TIA, transient ischaemic attack; SD, standard deviation.

Table 2 Preoperative Clinical Findings.

	No.	%
Cardiac Arrest	2	3.6
Malperfusion	12	21.8
Neurological insult	6	10.9
Antiplatelet Agents	19	34.5
Anticoagulation	8	14.5

Neurological insult = Any neurological injury including syncope, paraesthesia or paralysis.

evidence of preoperative malperfusion with six patients demonstrating any form of neurological involvement.

Operative Procedures

Principle procedures performed are presented in Table 3. Ascending aorta with hemiarch replacement and aortic valve resuspension was the most common procedure performed. Right axillary artery was used as the preferred arterial cannulation site in the majority of patients (90.9%) and was contraindicated in five patients (9.1%) (Table 4). This was because one patient had extension of his ATAAD into the right axillary artery making it high risk for intraoperative malperfusion, another patient had a right forearm atrioventricular (AV) fistula and the remaining three were haemodynamically unstable requiring urgent cardiopulmonary bypass.

Table 3 Operative Details and Principle Procedure.

	No.	%
Ascending Aorta + Hemiarch/Partial Arch Replacement		
Aortic Valve Resuspension	31	56.4
Aortic Valve Replacement	5	9.1
Modified Bentall Procedure	13	23.6
Ascending Aorta + Total Aortic Arch Replacement		
Aortic Valve Resuspension	6	10.9
Operative Details		
DHCA	55	100
SACP	9	16.4

Abbreviations: DHCA, deep hypothermic circulatory arrest; SACP, selective antegrade cerebral perfusion.

Table 4 Arterial cannulation site.

	No.	%
Right Axillary Artery	50	90.9
Femoral Artery	4	7.3
Aorta	1	1.8

All patients, regardless of the procedure undertaken, had surgical repair with the aid of deep hypothermic circulatory arrest. Amongst the cohort, patients had circulatory arrest for a mean ± standard deviation of 25.5 ± 6.7 minutes. Deep hypothermia was employed during repair for all patients, with a mean ± standard deviation temperature of 16.1 °C ± 1.05 °C. Unilateral or bilateral SACP was only used in the six patients requiring total aortic arch replacement and three who had a partial arch replacement. SACP was not used routinely for dissection repair in contrast to elective aortic surgery as clamping dissection arch vessels can create re-entry tears and therefore, was reserved for patients who needed more than an open hemiarch replacement. A mean ± standard deviation time of 58.9 ± 28.4 minutes of SACP was used to assist neuroprotection in these cases.

Mortality and Morbidity

There were six deaths (10.9%) in the 30-day period postoperatively including one intraoperative death (Table 5). The intraoperative death was a patient who presented with severe abdominal pain due to mesenteric malperfusion, who was found intraoperatively to have irreversible

Table 5 Postoperative outcomes.

	No.	%
Mortality (30-days)	6	10.9
Intraoperative Mortality	1	1.8
Acute Renal Failure	6	10.9
Short-Term Haemodialysis	2	3.6
CVA	1	1.8
TIA	3	5.5
Limb Ischaemia	0	0
DSWI	0	0

Abbreviations: CVA, cerebrovascular accident; TIA, transient ischaemic attack; DSWI, deep sternal wound infection.

stomach, small and large bowel ischaemia. The first postoperative death was related to multi-organ dysfunction syndrome secondary to a right ventricular infarct. The second was due to line sepsis in a prolonged ventilated patient with neurological irritability but normal computed tomographic/magnetic resonance imaging (CT/MRI) of brain and electroencephalograph (EEG). The third was related to cardiogenic shock in a patient with pre-existing cardiomyopathy and a left ventricular ejection fraction of 20%. The fourth was related to a major subarachnoid haemorrhage secondary to a known cerebral aneurysm that ruptured on day 10. The final postoperative death was in a patient who was discharged and died suddenly on postoperative day 21 of unknown cause.

There was only one documented postoperative cerebrovascular accident in this cohort and three patients with transient ischaemic attacks. The most common postoperative complication was that of acute renal failure, however, all cases recovered without the need for long-term haemodiaylsis.

Axillary Artery Cannulation and Wound Complications

Complications are presented in Table 6. The most common complications were seroma (3.6%) and haematoma (3.6%). Two patients had chronic pain that eventually resolved. There were no perfusion problems, injuries to the axillary vessels or brachial plexus.

Discussion

Our series reports a low rate of neurological injury and mortality in a high-risk group of patients undergoing surgical repair of ATAAD. We believe that the use of the axillary artery for arterial cannulation plays a major role in these favourable results.

Use of the axillary artery for arterial cannulation in ATAAD has several advantages when compared with central aortic or femoral cannulation. Several publications have shown promising results including reduced intraoperative and postoperative mortality, a neuroprotective advantage, lower rates of malperfusion and fewer reoperation rates, culminating in improved patient outcomes both in the short- and long-term for those with axillary cannulation [11–13].

Table 6 Axillary Artery Cannulation Complications.

Axillary Artery Complications	No.	%
Seroma	2	3.6
Haematoma	2	3.6
Pain	2	3.6
Wound Infection	0	0
Brachial Plexus Injury	0	0
Axillary Artery Dissection	0	0

The axillary artery is rarely involved in the dissection process and can be cannulated directly or through the use a side-arm graft anastomosed to it, providing antegrade flow from the outset, except in the axillary and brachiocephalic arteries. In ATAAD, the ascending aorta is dissected and ensuring perfusion of the true lumen through central aortic cannulation can be challenging. Given that the dissection rarely extends into the axillary artery, cannulation allows arterial flow to be directed into the true lumen, decompressing the false lumen and restoring distal perfusion immediately after CPB is established, reducing rates of intraoperative malperfusion [8,13]. On instigation of cardiopulmonary bypass, it is imperative to monitor line pressure, left radial artery pressure, flow across the aortic arch on transoesophageal echocardiograhy and cerebral oximetry to identify intraoperative malperfusion.

Furthermore, the dissection may extend and involve the common femoral artery, increasing the risk of malperfusion with the use of femoral artery cannulation. Even if femoral cannulation is successful malperfusion may still result as retrograde perfusion against an aortic cross clamp may result in perfusion of re-entry tears, pressurising the false lumen, causing visceral and arch vessel compromise and increased risk of neurological injury [6,14]. This was supported by an autopsy study of ATAAD found that patients who had received femoral artery cannulation had multiple tears, compared with unoperated patients who had only one entry and one re-entry tear. This study recommended that femoral cannulation should be avoided and cannulation should be switched over to central as soon as possible [14]. Subsequently, several studies have demonstrated that arterial perfusion through the axillary artery reduces mortality and improves neurological outcomes when compared with patients undergoing femoral cannulation for ATAAD [8,11,12].

An axillary cannulation strategy for ATAAD also avoids the need to move the cannula during surgery, as would be the case from the femoral artery to the newly sutured aortic graft. Furthermore, it permits the use of SACP if required for more extensive surgery such as total arch replacement, helping tolerate longer periods of safe circulatory arrest by reducing cerebral ischaemic time. This has been associated with improved patient outcomes [3]. We use SACP when aortic arch surgery (total or partial) is required in the repair to reduce cerebral ischaemia, as extended circulatory arrest times are anticipated.

Furthermore, axillary artery cannulation protects the cerebral circulation by deflecting potential atherosclerotic debris from the circulation. This is supported by an animal model by Hedayati et al. (2004) where microemboli were deflected from the ascending aorta and arch towards the descending aorta, preventing its entry into the cerebral circulation [7]. They proposed that altered blood-flow patterns during axillary cannulation help produce retrograde brachiocephalic artery blood flow, providing a neuroprotective advantage when compared with central aortic inflow. Moreover, the cerebral circulation is no longer exposed to potential atherosclerotic debris that it would have encountered during

retrograde perfusion via the femoral artery. Etz et al. (2008) also found that axillary cannulation improved survival and neurological outcomes of patients having repair of atherosclerotic aortic aneurysms [15]. The above benefit of deflecting emboli from the cerebral circulation with axillary cannulation may benefit elderly patients with ATAAD, who often have atherosclerotic aortas.

Cannulation technique of the axillary artery varies. We prefer the use of a side-arm graft technique as it has been shown to be safer with less dislodgement, axillary artery injury and limb ischaemia as compared with the use of a direct technique [10,16]. Importantly, the use of a side-arm graft avoids inadequate perfusion of the vertebral artery during SACP, as in cases with direct cannulation, if the cannula is inserted too far, it may occlude the orifice to the vertebral artery [16]. The side-arm technique takes slightly longer than direct cannulation and has been criticised for bleeding from the anastomosis, but this is rarely a problem with meticulous technique and haemostasis using topical agents prior to proceeding. With bilateral radial artery monitoring, hyperperfusion of the right arm is avoided by snugging on the vessel loop distal to the graft anastomosis.

Absolute contraindications to the use of the axillary artery include a heavily atherosclerotic vessel and known axillary or subclavian artery stenosis. We advocate the use of bilateral radial artery monitoring to ensure adequate flow is present through these vessels to the upper limbs. Relative contraindications include an axillary artery that is involved in the dissection process increasing the risk of intraoperative malperfusion, morbid obesity making exploration of the artery and cannulation a challenge, a very small vessel insufficient to achieve satisfactory CPB flows and circulatory collapse. The side-arm graft technique takes longer to perform than direct axillary or femoral cannulation. Most patients come to the operating room stable and thus, it is possible to use this technique, however if the patient is unstable, we would advocate femoral cannulation or the technique that is fastest to establish CPB. Local complications of axillary artery cannulation documented in the literature are rare and include axillary artery dissection, brachial plexus injury, wound infection, haematoma, seroma and pain [9,10,17,18].

We believe the axillary artery is the ideal cannulation site for arterial inflow in ATAAD. We, as well as others [3,6,8,10–13,15] firmly believe that outcomes of ATAAD repair can be improved with axillary artery cannulation. We do accept that in some situations other cannulation sites may be more appropriate and good outcomes have been achieved with these alternate sites. Intraoperative malperfusion may be precipitated by any cannulation site for ATAAD. The surgeon needs to remain vigilant and flexible with close intraoperative monitoring, as additional or alternative sites of cannulation may be required.

Conclusion

The use of axillary artery cannulation using the side-arm graft technique is a reliable and safe method for arterial inflow during surgical repair of ATAAD. It carries with it a number of advantages when compared with other sites of arterial cannulation, reducing the risk of mortality and neurological complications. Axillary artery and wound complications are uncommon, making this the ideal site for arterial inflow in ATAAD.

Importance of This Study

This study reinforces that the axillary artery is a suitable and safe arterial cannulation site for patients being surgically managed with ATAAD. Despite being a high-risk patient group, use of the axillary artery facilitates excellent postoperative results with low mortality and neurological complications, when compared to IRAD figures. This is the largest known series of side-graft axillary cannulation in ATAAD within Australia, adding to the growing body of evidence supporting axillary artery cannulation, and important for all cardiothoracic surgeons to be aware of.

Limitations

Limitations include the retrospective nature of the study and the small sample size. Nonetheless, this remains one of the largest series in Australia and highlights the safety and efficacy related to axillary artery cannulation in ATAAD.

Acknowledgements

Nil acknowledgements, disclosures or conflicts of interest.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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