Liberal use of axillary artery cannulation for aortic and complex cardiac surgery

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Abstract

OBJECTIVES: Axillary artery cannulation for cardiopulmonary bypass has been described previously as a safe and reliable technique, with a low risk of atheroemboli, avoidance of malperfusion in aortic dissection and facilitation of selective antegrade cerebral perfusion during hypothermic circulatory arrest. The aim of this study was to document the broad applicability of axillary cannulation and its associated morbidity and identify where it was not possible to use planned axillary cannulation.

METHODS: A retrospective review of a single surgeon's 10-year experience of axillary cannulation using the side-graft technique in 184 consecutive patients (age 22–92 years) in aortic and complex cardiac surgery from July 2002 to June 2012.

RESULTS: There were no intraoperative deaths and no major complications related to axillary artery use. There were six postoperative deaths unrelated to axillary artery cannulation. Six patients (3.3%) had minor complications as a direct result of axillary cannulation including seroma, haematoma, chronic pain and pectoralis major muscle atrophy. There were 10 cases where planned axillary cannulation was abandoned, due to inadequate size of the axillary artery in 8 patients and axillary artery dissection and morbid obesity in 1 patient each.

CONCLUSIONS: Axillary artery cannulation is an ideal arterial inflow site in cases where the ascending aorta is unsuitable as it is safe, reliable and reduces the risks of atheroembolization and malperfusion. Major complications are rare with this meticulous technique and it is our standard practice in complex cardiac and aortic surgery.

Keywords: Axillary artery • Aneurysm • Dissection • Aortic aneurysm/surgery • Cardiopulmonary bypass/methods

INTRODUCTION

The standard cannulation site for cardiopulmonary bypass (CPB) arterial inflow at present is the ascending aorta. Neurological complications are a primary cause of morbidity and mortality after cardiac operations, with aortic atheroemboli released during aortic cannulation or decannulation thought to be the most important cause of neurological dysfunction after CPB [1]. Peripheral cannulation is preferable when there is a high risk of aortic atheroemboli or when the ascending aorta is unapproachable, due to reasons including aneurysmal disease, dissection, when CPB must be established prior to redo sternotomy, and in particular when there is a calcified 'porcelain' aorta. Femoral cannulation was previously the standard site for peripheral cannulation, but has been associated with a high rate of mortality and neurological injury [2, 3], due to retrograde flow through an often heavily atherosclerotic abdominal and descending aorta resulting in increased risk of cerebral emboli and malperfusion.

The alternative use of the axillary artery for arterial inflow in complex cardiac operations was first popularized by Sabik *et al.* [4]. Since then it has become an increasingly favoured cannulation site demonstrating a relatively low stroke rate of 0–4% [3, 5–7]. The aim of this study was to investigate axillary cannulation-

related morbidity and its broad applicability and to identify where planned axillary cannulation could not be used.

MATERIALS AND METHODS

Data collection

Patients were identified retrospectively from the surgeon's operative record. During a 10-year period (July 2002 to June 2012), a total of 184 consecutive patients underwent axillary artery cannulation for CPB, operated on by a single surgeon at Royal North Shore Hospital and North Shore Private Hospital. Following ethics approval, the operative database was retrieved. Operation reports and patient records were reviewed to confirm operative details and outcomes, with all adverse outcomes occurring in the first 30-day postoperatively being included.

Patients

The entire patient cohort represented 120 men (65.2%), the mean age was 67 ± 13.5 years. Patient characteristics are

presented in Table 1. All patients underwent axillary artery cannulation using a side-graft technique to either the right ($n = 182$) or left ($n = 2$) axillary artery (due to previous right axillary lymph node dissection and previous right axillary cannulation, respectively). Indications for axillary cannulation included Type A dissection in 32 (17.4%), elective aortic surgery in 100 (54.3%), CPB prior to cardiac reoperation in 15 (8.2%) and porcelain (or heavily calcified) aorta in 37 patients (20.1%) (Table 2). During the study period, axillary cannulation was used for all Type A dissection repairs. Forty-two cases (22.8%) involved a redo sternotomy. One hundred and sixteen cases (63.1%) were elective, 33 (17.9%) were urgent (within 24 h) and 35 (19.0%) were emergent or life-threatening.

Operative technique

Bilateral radial artery pressure monitoring is essential to exclude a significant subclavian artery stenosis, which would preclude the use of axillary cannulation. The left radial pressure is used to monitor the perfusion pressure during the case as the right radial pressure is often higher and hence not a true measurement of the pressure in the arch end distally. It is imperative to monitor the right radial pressure to avoid hyper-perfusion to the arm.

The ascending aorta is routinely palpated and scanned with an epiaortic ultrasound in all patients undergoing cardiac surgery to exclude atherosclerosis. In aortic cases and if there is a high index of suspicion for aortic disease (patients with vessel irregularity or calcium deposition on preoperative computed tomography or angiography or with significant carotid disease), we proceed directly with axillary cannulation in spite of normal ultrasound as this method has its own limitations, including the inability to adequately assess for soft atheroma [5].

A 5–7 cm infraclavicular incision is made 1 cm below the middle and lateral part of the clavicle, extending into the delto-pectoral groove. The pectoralis major muscle is separated along the direction of its fibres and the clavipectoral fascia is removed. The pectoralis minor muscle is then exposed and retracted laterally or divided. The axillary artery is identified by palpation and mobilized by sharp dissection, avoiding the brachial plexus posterior to the artery. Vessel loops are then used to gain proximal and distal control of the axillary artery and the full dose of heparin required for CPB is administered. An 8-mm Dacron graft is then anastomosed to the axillary artery in an end-to-side fashion with a running 5-0 Prolene suture. To achieve haemostasis, an additional 6-0 Prolene mattress suture may be required for the anastomosis. A 24-Fr straight cannula is then inserted into the Dacron graft for arterial inflow [5].

Selective antegrade cerebral perfusion (SACP) is used to minimize cerebral ischaemia time during hypothermic circulatory arrest (HCA) and is used routinely if the HCA time is expected to exceed 30 min [5]. The innominate and left carotid arteries are clamped for short periods for unilateral cerebral perfusion, and the innominate and left subclavian arteries are clamped for longer periods and an additional cannula inserted into the left carotid artery to achieve bilateral cerebral perfusion.

Patients with a calcified aorta undergoing coronary revascularization are almost always operated off-pump with internal mammary inflow and no aortic manipulation. If this is not possible due to haemodynamic instability, then revascularization is

Table 1: Patient demographics

	No.	%
Male	120	65.2
Age (years), mean $\pm$ SD	67 $\pm$ 13.5	
Age $\geq$ 75 (years)	67	36.4
Hypertension	102	55.4
Diabetes mellitus	28	15.2
Peripheral vascular disease	11	6.0
Ejection fraction <45%	46	25.0
Preoperative renal failure	4	2.2
History of TIA	9	4.9
History of stroke	3	1.6

SD: standard deviation; TIA: transient ischaemic attack.

Table 2: Indication for axillary cannulation

	No.	%
Type A dissection	32	17.4
Elective aortic surgery	100	54.3
CPB prior to redo sternotomy	15	8.2
Porcelain (heavily calcified) aorta	37	20.1

CPB: cardiopulmonary bypass.

performed on-pump with a beating heart using axillary cannulation, thus also avoiding aortic manipulation.

Following completion of the operative procedure and termination of CPB, the side graft is clamped close to the axillary artery, divided and oversewn with 4-0 Prolene [5].

Operative procedures

Principal procedures performed are presented in Table 3 and include aortic surgery in 138 patients (75.0%). Forty-two cases (22.8%) involved a redo sternotomy. Total aortic arch replacement was performed in 10 (5.4%), ascending aorta $\pm$ hemi-arch replacement was performed in 126 (68.5%) and descending aorta replacement in 2 patients (1.1%). HCA was performed in 144 patients (78.3%). SACP was used in 40 patients (21.7%). Thirty-five (19.0%) patients underwent emergency operations.

RESULTS

Mortality and morbidity

There were no intraoperative deaths. There were six post-operative deaths (3.3%) unrelated to axillary artery cannulation. One was due to multisystem failure from a right ventricular infarct following redo aortic dissection repair. The second death occurred 3 weeks after the repair of a Type A dissection where treatment was withdrawn due to neurological impairment despite normal computer tomography, magnetic resonance imaging and electroencephalogram and is the only stroke in this

Table 3: Principal procedure performed

	No.	%
Aortic surgery	138	75.0
Total aortic arch replacement	10	5.4
Ascending aorta replacement ± hemi-arch		
Supracoronary	60	32.6
Bentall procedure	66	35.9
Descending aorta replacement	2	1.1
CABG	5	2.7
Valve replacement	25	13.6
CABG + valve replacement	16	8.7

CABG: coronary artery bypass grafting.

Table 4: Postoperative outcomes

	No.	%
Mortality	6	3.3
TIA	9	4.9
Stroke	1	0.5
Sepsis	1	0.5
Myocardial infarction	2	1.1
Acute renal failure (not requiring dialysis)	2	1.1
Limb ischaemia	0	0
Axillary complications	6	3.3
Seroma	2	1.1
Haematoma	1	0.5
Pectoralis major atrophy	1	0.5
Chronic pain (recovered)	2	1.1

TIA: transient ischaemic attack.

series. The third death occurred 3 weeks post-discharge after aortic root and arch replacement for acute Type A dissection where no obvious cause was identified on post-mortem. The fourth death occurred 4 weeks post-discharge after a Type A dissection and CABG. The fifth death was due to a bradycardic arrest following a CABG and aortic valve replacement. The sixth death occurred due to massive sepsis 4-days after an urgent ascending aorta and hemi-arch replacement for 8-cm ascending aorta aneurysm. All the other 178 patients were well and discharged home. Nine patients (4.9%) suffered a transient ischaemic attack (TIA). In-hospital mortality for the repair of Type A dissection was 2 of 32 (6.3%).

Complications directly related to axillary cannulation

Six patients (3.3%) suffered minor complications related directly to axillary cannulation (Table 4). These include axillary wound seroma, atrophy of the pectoralis major muscle due to pectoral nerve injury, axillary wound haematoma and chronic ipsilateral shoulder pain that resolved. Of note, there were no perfusion issues, malperfusion, new dissection, axillary artery injury, arm ischaemia, hyperperfusion injury or brachial plexus neuropraxia.

Cases where axillary cannulation was unable to be used

During the study period, there were 10 additional cases where planned axillary cannulation was abandoned due to inadequate size of the axillary artery in 8 patients and axillary artery dissection and morbid obesity in 1 patient each. The alternative arterial cannulation sites used were the femoral artery in 3 patients, ascending aorta in 4 and aortic arch in 1.

DISCUSSION

This series demonstrates a low rate of neurological injury and mortality in a high-risk group of patients undergoing complex aortic and cardiac surgery. We believe this is a direct result of the use of axillary artery cannulation in patients with diseased ascending aortas.

Axillary artery cannulation has several advantages over femoral artery and aortic cannulation, which has been reflected in improved patient outcomes [2, 3, 7]. First it avoids manipulation of a diseased ascending aorta and the 'sandblast' effect [5] of turbulent flow from the cannula tip in aortic cannulation [3, 8, 9]. In addition, patients with atherosclerotic ascending aortas often have severe ilio-femoral arteriosclerosis, thus making them unsuitable for femoral artery cannulation [6]. In contrast, the axillary artery is invariably free of atheroma [5, 10], making it an ideal site. We have demonstrated the safety and applicability of axillary cannulation in 39 patients with a porcelain aorta.

With antegrade axillary perfusion, the cerebral circulation is no longer exposed to the potential atherosclerotic debris that it would have encountered during retrograde perfusion via the femoral artery and the entire and often diseased abdominal and descending aortas. This is supported by a large study by Etz *et al.* showing significantly lower mortality and stroke rate with the use of axillary cannulation compared with femoral cannulation for atherosclerotic aneurysm surgery. Altered flow dynamics in the aortic arch during axillary inflow may also be responsible for this cerebro-protective effect [11]. During axillary inflow, there is retrograde flow in the innominate artery preventing aortic emboli from entering the right-sided cerebral circulation [11]. The retrograde flow in the ascending aorta and altered flow in the arch also protect the left-sided circulation; as shown by an animal model by Hedayati *et al.* [11] where simulated microemboli were preferentially directed away from both sides of the cerebral circulation, right more than left, during axillary inflow and significantly more than with aortic inflow.

The axillary artery is rarely involved in acute Type A dissection [12] and thus, axillary cannulation is more likely to perfuse the true lumen and minimize malperfusion. Axillary cannulation, which provides antegrade flow from the outset, in Type A dissection, has demonstrated superior outcomes compared with femoral cannulation in terms of lower operative mortality and stroke rate [2, 12]. Retrograde perfusion associated with femoral cannulation is more likely to cause malperfusion because retrograde perfusion may perfuse distal re-entry tears, pressuring the false lumen, and thus reducing the true lumen perfusion, causing visceral and arch vessel compromise and increased risk of neurological injury. This theory of femoral cannulation propagating dissection and creating more re-entry tears via pressurization of the false lumen

is supported by an autopsy study of acute Type A dissection patients, which 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 [13]. The study recommended antegrade perfusion as soon as possible for dissection repair. Axillary cannulation provides antegrade perfusion from the beginning and avoids the need to move the cannula from the femoral artery to the new aortic graft, during the surgery.

Axillary cannulation facilitates SACP, which reduces cerebral ischaemia time and is associated with improved outcomes in aortic arch surgery [14, 15]. Axillary inflow facilitates the de-airing and washout of atherosclerotic debris after completion of the arch anastomoses.

We use a side-arm graft in all cases of axillary cannulation because direct cannulation has been shown to be associated with more complications including inadequate flow, new dissection, malperfusion, dislodgement, axillary artery injury and limb ischaemia [3, 6, 16, 17]. Another concern with direct cannulation is the possibility of occlusion of the right vertebral artery, resulting in cerebral hypoperfusion if the cannula is inserted too far, and there is no left subclavian flow during SACP or HCA [16]. This technique has been critiqued for the increased time required compared with direct cannulation and bleeding from the axillary anastomosis site. However, in our experience, this technique adds ~10 min to operative time, and ongoing bleeding can be avoided with meticulous technique and use of a topical thrombotic agent.

Axillary cannulation is absolutely contraindicated if the vessel is atherosclerotic or if there is axillary or subclavian artery stenosis. Relative contraindications include axillary artery dissection, morbid obesity, very small vessel size, a critical patient with imminent circulatory collapse where access to an alternative cannulation site may be faster. In our experience, the most common reason for abandoning this technique was when the axillary artery vessel was found to be too small intraoperatively. Hyper-perfusion injury to the right arm can be avoided by monitoring the arterial pressure and if this arises, the distal vessel loop can be snared down to decrease flow down the right arm [5].

Importance of this study

While other previous studies have similarly shown low mortality and morbidity rates with axillary cannulation, our study has also highlighted its broad applicability in complex cardiac cases as well as discussing cases where planned axillary cannulation could not be used. This is also one of the largest series of side-graft axillary cannulation documenting its safety and adds to the growing body of evidence supporting axillary cannulation.

Limitations

Limitations of this study include its retrospective nature and small sample size. However, it does contribute to the growing evidence supporting the routine use of axillary cannulation in aortic and complex cardiac surgery.

CONCLUSIONS

Axillary artery cannulation using the side-graft technique is a very reliable and safe method in cases where the ascending aorta is an unsuitable site for arterial inflow in CPB. Axillary artery use has several advantages supported by strong evidence showing improved outcomes in aortic surgery and is the ideal site in elective aortic surgery, Type A dissection and in calcified aorta. Complications directly associated with axillary artery cannulation are uncommon.

Conflict of interest: none declared.

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In cardiovascular practice today, the axillary artery is one of the best alternative cannulation sites in acute type A aortic dissection [1]. It provides potential benefits such as antegrade perfusion of the aorta, low risk of false lumen perfusion in aortic dissection, and the possibility of antegrade cerebral perfusion during aortic arch repair. Indications of axillary cannulation also includes porcelain aorta, ascending aorta and aortic arch aneurysm, coronary artery disease associated with severely atherosclerotic ascending aorta, extracorporeal membrane oxygenation support, and complex redo cardiac surgery such as aortic regurgitation after previous ascending aortic replacement and pseudo-aneurysm after Bentall operation.

We read with great interest the article by Fong and associates [2], regarding liberal use of axillary artery cannulation for cardiopulmonary bypass in aortic and complex cardiac surgical patients. We mostly agree with their considerations. However, we believe that some aspects of the article require further comment.

Direct or graft-interposed axillary cannulation still remains a controversial issue among the cardiovascular surgeons. We routinely prefer direct right axillary cannulation in acute type A aortic dissections in our institute [3]. In our practice, there were no major complications related to this cannulation technique. In our opinion, direct axillary cannulation is not more traumatic, is less time-consuming, and less haemorrhagic during the operation than the graft interposition.

Axillary cannulation is not always free from risk. Complications related to axillary cannulation are becoming associated with increased use of this technique [4]. These include ipsilateral brachial plexus injury resulting in hand weakness and numbness, axillary artery thrombosis, lymphocele requiring aspiration, vascular compromise, compartment syndrome involving the forearm, postoperative bleeding or local wound infection.

Acute intraoperative aortic dissection due to the arterial cannulation into the axillary artery is a rare and devastating complication [5]. It is believed to be due to an intimal flap occurring during cannula insertion. As a strategy to prevent these complications, the arterial cannula should not be advanced too much during the right axillary cannulation. Forced cannulation should also be absolutely avoided. It may cause arterial injury or obstruct the right carotid artery. In our experience, a 20F or 22F flexible cannula was gently advanced 3-4 cm into the axillary artery.

In strategic planning for arterial cannulation, transoesophageal echocardiography (TEE) guidance is useful to ensure correct placement of the cannula. An angiographic, TEE or ultrasound examination plays an important role in preoperative evaluation including aortic branch vessels.

Axillary cannulation is an attractive and useful approach with an extended utilization, and may be safely used in aortic surgery and complex cardiac procedures including redo surgery.

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