Aortic cannulation in complex aortic disease: playing or planning on fear

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Abstract: The quest for the best strategy for arterial cannulation in the setting of complex proximal and arch aneurysm surgery remains elusive. Several cannulation strategies have been proposed to establish cardiopulmonary bypass (CPB) during aortic arch aneurysm surgery. Those strategies have direct influence on patients' post-operative outcomes. In current era of stringent evidence synthesis and with available monitoring tools for different organs and various methods for organ protection, it is imperative that a deliverable strategy for cannulation in complex proximal aortic aneurysm is employed. However, due to scarcity of robust evidence and in a climate where randomized control trials to establish comparative outcomes between central cannulation versus peripheral cannulation are difficult to set up, our understanding is very much limited to observational data and discretional experiences. In this review we aim to illustrate comprehensively the concrete evidence most suitable strategy for arterial cannulation in proximal and arch of the aorta pathology and drawing on the conflicting reports and their correlation to quality outcomes.

Keywords: Aorta; aortic dissection; aneurysm; type A dissection; cannulation

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Introduction

Despite significant advances in perioperative critical care, surgical techniques and availability of device technology, the repair of aortic arch remains without associated morbidity and mortality. The choice of preferred cannulation requires stringent planning and careful understanding of the distorted anatomy one is faced with. However, surgical abilities of an individual surgeon play an important role on depicting outcomes. The ideal cannulation method and perfusion in surgical management of proximal and aortic arch aneurysm or even in the setting of thoracoabdominal aortic pathology remains controversial. Although this is mostly dependent on the type of the aortic pathology and the extent of the aneurysmal disease. Nevertheless, it is not possible to nominate a single best and optimal method for cannulation to establish bypass, circulatory support and safe surgical repair. A conventional and accepted form of arterial cannulation for decompressing the proximal aorta and provision of bloodless field in parallel with safe distal perfusion of the brain, abdominal viscera, the spinal cord, and the lower extremities is the superior method of choice (1). This makes the method of choice a matter of utmost inference where the desired approach has to accomplished not only based on surgical ability but on rational reasoning and evidence which works best in the patient interest. In our

experience, we support the use of proximal cannulation due to its easy approach, simplistic use and utilization for bypass and cerebral perfusion. Utilization of such technique is of advantage as it is performed without causing any significant trauma to the aneurysm itself or the associated existing pathologies. Additionally, this approach allows satisfactory access to the supra-aortic vessels to provide safe cerebral protection; in addition to having a satisfactory proximal and distal aortic pressure control and avoiding unnecessary pressure overload and its adverse effects. However, the presence of atheromatous or chronically dissected segment can contribute to retrograde cerebral embolism and likely malperfusion.

Using central approach through cannulating the ascending aorta and PA to support the circulation and provide antegrade perfusion is of paramount to avoid such aforementioned complications. Another advantage of such approach is the avoidance of unnecessary prolonged DHCA and allowing appropriate organ perfusion. One should note that use of central cannulation is likely limited and can be tricky in certain cohorts of patients as in those with reduced access to the ascending aorta or those with previous cardiac or aortic surgeries. Yet, we can't be conclusive on this approach as we can't generalize this technique to be most suitable to all surgeons which is why every cannulation method should be tailored and planned carefully matching patient best outcome.

Sabik *et al*. in 1995 advocated using the right axillary artery as an alternative cannulation site to the femoral artery in a study that was perceived as a significant landmark in the field of aortic arch repair surgery (2). In the ensuing decades various publications comparing outcomes between central and peripheral cannulation sites generated important data allowing several organisations to establish guidelines on this hotly debated issue. A joint task force between the American College of Cardiology Foundation and the American Heart Association published guidelines in 2010 recommending that for thoracic aortic aneurysms involving the proximal aortic arch and partial arch replacement together with ascending aorta repair, the right subclavian or axillary artery as sites for cannulation is reasonable with an evidence class of 'IIA, level B' (3). This recommendation also cited that subclavian or axillary artery bypasses with a side graft had a reduced associated risk of stroke (3,4). The 2014 European Society of Cardiology guidelines for diagnosis and treatment of aortic diseases also favoured use of central cannulation sites for surgery of the aortic arch, specifically the axillary artery with an evidence class of 'IIA, level C' (5).

Femoral cannulation has been used for over two decades as the method of choice for establishing cardiopulmonary bypass (CPB) in several cases of complex aortic surgery and redo surgeries (6); however, this technique comes with several limitations including exposing the groin as second wound, increased risk of organ malperfusion, retrograde thromboembolism, perfusion of false lumen or retrograde dissection due to reversed flow in the diseased thoracoabdominal aorta (7). Lately, with advancement in surgical practice, proximal cannulation has evolved and considered a safe and reliable technique to provide an alternative to femoral cannulation for establishing CPB. This technique includes either axillary, innominate or even direct aortic cannulations, which has much less risks that are otherwise associated with femoral cannulation; such as lower 30-day mortality rates and less incidence of permanent neurological deficits (8). The major advantages and disadvantages of femoral and proximal cannulations are summarized in *Table 1*.

Axillary versus innominate artery cannulations

Several studies have reported the superiority of proximal artery cannulation over femoral cannulation in terms of better postoperative outcomes (8). Within central cannulation techniques there has been several retrospective studies comparing axillary (AA) *vs.* innominate artery (IA) strategies in aortic surgeries (9). In a study by Preventza *et al*. (10) during elective aortic arch surgeries of 938 patients, there were no differences in reported clinical outcomes between using AA or IA techniques. Similar outcomes were also reported by Di Eusanio *et al*. (11) in 71 patients that underwent elective thoracic aortic surgeries. While Rouchdy *et al*. (12) has reported shorter operative time required when utilizing IA and lower cannulation related complications over using AA cannulation. Finally, in a recent systematic review and meta-analysis by Harky *et al*. (13) concluded no superiority of AA cannulation over IA in terms of postoperative clinical outcomes, but rather a shorter CPB time when using IA cannulation (167±55 *vs.* 173±52 mins, P=0.004). Therefore, the use of IA cannulation can be of advantage during complex aortic surgery without requirement for additional axillary incision.

Minimal access and minimal invasive central aortic cannulation in aortic disease

Minimally invasive aortic techniques have gained

Table 1 Summary of advantage and disadvantage of femoral and proximal cannulations

Cannulation technique	Advantage	Disadvantage
Femoral cannulation	• Safe and quick method to establish CPB prior to opening chest	• High chances of going into false lumen in cases of extended dissection
	• Can reliably access the femoral vessels	• Retrograde perfusion and potential of perfusing the false lumen
		• Increased risk of thromboembolism
		• Higher rate of permanent neurological deficit
Proximal cannulation	• Easily accessible and safe to perform	• Requires assessment of the vessels prior to cannulation to exclude dissection, therefore further or extended imaging needed
	• Can be either axillary, innominate or direct aortic	
	• Associated with lower in-hospital mortality and permanent neurological deficits	• Direct aortic or innominate cannulation can be difficult to achieve in acute dissection cases when it involves neck vessels
	• Can be either direct cannulation or through side graft	
	• Provides antegrade cerebral perfusion	• Requires additional incision for axillary cannulation and thus increased operative time in life threatening cases

momentum in the past decade. In particular, the upper partial sternotomy approach being the most used. Obviously, such technique boosts the advantages of having less pain postoperatively, much shorter hospital stays, earlier resuming of normal daily activities, far better cosmesis, and adequate cost savings. Such transition towards performing less invasive surgical interventions has been pioneered through development of new, innovative arterio-venous cannulation methods; including the use of the retrograde route with femoral artery cannulation and the use of antegrade approach with direct ascending aorta cannulation. However, minimally invasive surgery still has to prove itself as a concept as concerns are tenacious and advantages often are not countable. In many aspects, there is growing evidence for the benefits of minimally invasive access in aortic surgery, for example, in terms of convalescence, measured by ventilation time, mobilization, duration of intensive care unit or hospital stay, and resumption of work (14). Recently, Risteski *et al.* (15) analysed their data of 71 patients that underwent minimally invasive aortic arch surgery for arch aneurysm (58, 82%), dissection (10, 14%) or porcelain aorta (3, 4%). They reported no conversion to full sternotomy in any of the cases; a 4.2% rate of permanent neurological deficit and an acceptable early mortality rate of 5.6%. While the survival rate was 79.2±8.3% at 4 years and cumulative reoperation-free survival was reported to be 76.4±9.4% at 4 years follow up.

Finally, in a recent systematic review by Harky *et al.* (16) comparing minimal access *vs.* full sternotomy in aortic root surgery; they analysed 2,765 patients from eight studies that compared these two techniques. Minimal access surgery was associated with shorter CPB times (P=0.009), shorter ICU and total hospital stay (P=0.0009 and P=0.03 respectively), additionally they had lower operative mortality rates when compared to full sternotomy cases (0.4% *vs.* 1.34%, P=0.02).

Despite the reported positive and enthusiastic reports for proximal arch surgery via partial upper sternotomy, minimally invasive techniques in total aortic arch replacement including the utilization of conventional elephant trunk or FET procedures has not yet been reported. *Tables 2-4* indicates our past arch experience collated from single centre. The outcomes as depicted shows that our outcomes are compatible with international published results.

Discussion

Careful planning and consideration of conventional practice with alternative routes and methods are steps for successful operation with expected outcomes. The debate on the which is the most amenable route or approach for superior cannulation has to be tailored to what suits the patient best given the pathology and anatomy at hand. Tiwari and his colleagues reported their experience using direct ascending aortic cannulation and percutaneous femoral artery cannulation in 235 patients undergoing emergency surgical

Table 2 Demographics of arch cohort

Demographics	Arch operations (n=150)
Age at operation (years), mean [range]	66 [57, 73]
Female gender, n (%)	65 (43.3)
Body mass index (kg/m^2), mean [range]	27.8 [24.7, 30.6]
Previous cardiac operation, n (%)	43 (28.7)
Unstable angina, n (%)	9 (6.0)
MI within 90 days of operation, n (%)	1 (0.7)
NYHA class ≥ III, n (%)	28 (18.7)
Current smoker, n (%)	12 (8.0)
Diabetes, n (%)	13 (8.7)
Hypercholesterolemia, n (%)	58 (38.7)
Hypertension, n (%)	87 (58.0)
Previous stroke, n (%)	8 (5.3)
Respiratory disease, n (%)	21 (14.0)
Peripheral vascular disease, n (%)	34 (22.7)
Renal dysfunction, n (%)	9 (6.0)
Left ventricular ejection fraction 30–50%, n (%)	18 (12.0)
Left ventricular ejection fraction <30%, n (%)	4 (2.7)
Logistic EuroSCORE, mean [range]	16.7 [9.4, 28.2]

Table 3 Operative characteristics

Characteristics	Arch operations (n=150)
Non-elective presentation, n (%)	45 (30.0)
Pathology, n (%)	
Aneurysm	101 (67.3)
Acute dissection	22 (14.7)
Chronic dissection	14 (9.3)
Other	4 (2.7)
Pseudoaneurysm	4 (2.7)
Bicuspid valve	2 (1.3)
Coarctation	1 (0.7)
Intramural haematoma	1 (0.7)
Trauma	1 (0.7)
Concomitant operation, n (%)	
CABG	25 (16.7)
Valve	108 (72.0)
Other cardiac	9 (6.0)
Aortic segments, n (%)	
Root	91 (60.7)
Ascending	126 (84.0)
Hemi-arch	62 (41.3)
Total arch	88 (58.7)
Descending	9 (6.0)
Thoraco-abdominal	1 (0.7)
Conventional elephant truck, n (%)	23 (15.3)
Frozen elephant truck, n (%)	15 (10.0)
CPB time (mins), mean [range]	351 [275, 420]
Aortic cross clamp time (mins), mean [range]	194 [138, 249]
Circulatory arrest time (mins), mean [range]	46 [26, 88]

CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting.

repair for acute type A aortic dissection (ATAAD) (17). They reported that cannulating the ascending aorta in such high-risk cohorts has lower mortality rates when compared to using femoral access. However, no significant differences noted in terms of stroke or long-term survival between both cohorts.

The technique of using Seldinger cannulation has been demonstrated as a safe method with undissected ascending aortic wall (18), yet it's deemed equivocal in the settings of a full- or circumferential dissection. In 2007, Jakob *et al*. (19) reported satisfactory outcomes utilizing direct aortic true lumen cannulation supported by oblique aortic cross-clamping in emergency repair of acute type A dissection (19).

Similarly, Khaladj *et al*. using ascending aortic cannulation achieved with Seldinger technique reported their experience on 122 patients with mortality at 30 days of 15% and 12% for stroke with 17% of them suffered temporary neurological dysfunction (20). Moreover, Reece *et al*. reported a 0% mortality and 21% stroke rate in those patients that underwent direct ascending aortic cannulation; while those who underwent peripheral cannulation reported 17% mortality and 28% stroke rates (21).

In a peculiar way for approaching central cannulation in complex non-elective scenarios, Conzelmann *et al*. performed direct venous drainage initially and opened the ascending aorta, then it was followed by cannulation of the

Table 4 Outcomes

Outcomes	Hemi-arch operations		Total arch operations	
	Elective (n=48)	Non-elective (n=14)	Elective (n=57)	Non-elective (n=31)
In-hospital mortality (%)	3 (6.3)	3 (21.4)	5 (8.8)	6 (19.4)
CVA (%)	1 (2.1)	1 (7.1)	4 (7.0)	1 (3.2)
Paraparesis (%)	0 (0.0)	0 (0.0)	1 (1.8)	1 (3.2)
All reoperation (%)	4 (8.3)	1 (7.1)	5 (8.8)	6 (19.4)
Reoperation for bleeding (%)	4 (8.3)	1 (7.1)	4 (7.0)	6 (19.4)
Renal failure requiring new hemofiltration (%)	0 (0.0)	0 (0.0)	3 (5.3)	2 (6.5)
Prolonged ventilation (>48 hours) (%)	2 (4.2)	2 (14.3)	9 (15.8)	1 (3.2)
Critical care LOS (days), mean [range]	2 [1, 4]	9 [4, 25]	5 [2, 19]	6.5 [5, 14]
Hospital LOS (days), mean [range]	9.5 [7, 12.5]	15.5 [10, 28]	13 [9, 23]	17 [9, 24]

CVA, cerebrovascular accident; LOS, length of stay.

true lumen directly during emergency repair of ATAAD (22). Their reported results were 0% mortality and 21% neurological complications. They concluded that quick, safe and simple establishment of further arterial access can provide advantage while operating on ATAAD.

With modern technology to hand, Inoue *et al*. conducted a study on 32 patients that undergone surgery for ATAAD utilizing direct cannulation of the ascending aorta using the Seldinger technique, however this was guided by epiaortic ultrasound (23). Firstly, they initiated CPB utilizing femoral artery cannulation prior to the direct ascending aorta cannulation. Within their high-risk cohort, the reported mortality was 3.1% and neurological complications was 6.3%.

In that cohort, no complication was reported related to the degree of extension of the dissection, false lumen expansion or development of malperfusion; however, this technique is considered as time consuming and has the increase risk of potential retrograde embolization (23).

We use central cannulation for almost all cases of ATAAD. However, development of malperfusion, dissection of the cannulation site, or injury to nerve plexus can be a concern and it necessitates a different route and approach amongst our armamentarium to dealing with complex elective and non-elective scenarios. Surely, the presence of a thrombus in the false lumen dictate different terms and a modified approach. Hence, in cases with suspected ruptured ascending aorta, the presence of cardiac tamponade and pending cardiogenic shock, avoidance of central cannulation approach is warranted and alternative routes for cannulation is thought for. This may include femoral arterial and venous cannulation to initiate CPB prior to sternotomy.

We advocate minimally invasive surgery on complex aortic disease in selected patients and cases adding the benefit for reduced ventilation time, duration of intensive care unit and hospital length of stay. However, this approach still require mileage to be generalized as a concept to be followed coupled with minimal access approaches. Nonetheless, adversaries to such approaches argues that the potential risk of tamponade in minimally invasive with minimal access aortic surgery could be fatal and detrimental since the pericardium is only partly opened and rapid patient deterioration is unstoppable.

Conclusions

Proximal arterial cannulation adds to the armamentarium for managing complex aortic disease with variance of aortic pathology. Minimal access surgery should be carefully considered with very selective patient cohort as it can provide satisfactory perioperative outcomes and confers no inferiority to full sternotomy in aortic surgeries.

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