Femoral artery cannulation combined with axillary artery cannulation is safe for Stanford type A aortic dissection

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Abstract

Background

The optimal cannulation strategy in surgery for Stanford type A aortic dissection is critical to the patients’ survival, but remains controversial. Different cannulation strategies have their own advantages and drawbacks during cardiopulmonary bypass. Our center used femoral and axillary artery cannulation for Stanford type A aortic dissection. The purpose of this study was to review and clarify the clinic outcome of femoral artery cannulation combined with axillary artery cannulation for the treatment of type A aortic dissection.

Methods

We performed a retrospective study that included 327 patients who were surgically treated for type A aortic dissection in our institution from January 2017 to June 2019. Using femoral and axillary artery cannulation to establish cardiopulmonary bypass in patients with type A aortic dissection. The demographics data and surgical data, clinical results of the patients were calculated.

Results

Femoral artery combined with axillary artery cannulation was technically successful in 327 patients. The cardiopulmonary bypass time was 141.60 ± 34.89 minutes, and the selective antegrade cerebral perfusion time was 14.94 ± 2.76 minutes. The early mortality was 3.06%. The incidence of permanent neurologic dysfunction was 0.92%. Sixteen patients had post-operative renal insufficiency and five patients with liver failure. Two patients ended up with paraplegia.

Conclusion

Femoral artery combined with axillary artery cannulation for type A aortic dissection can significantly reduce the occurrence of malperfusion syndrome and nervous system complications, especially for cerebral protection.

Introduction

Stanford type A aortic dissection (AD) is a surgical emergency with a high rate of medical/surgical complication and mortality\textsuperscript{1−2}. The optimal cannulation strategy in surgery for Stanford type A AD is critical to the patients’ survival, but remains controversial\textsuperscript{3−6}. Because the lesion mainly involves the ascending aorta and the aortic arch, the ascending aorta is often not suitable for cannulation to set up the extracorporeal circulation. Various cannulation techniques to establish a cardiopulmonary bypass
(CPB) for the emergency treatment of AD have been reported. The femoral artery and the axillary artery have become common alternative cannulation sites. Each of these cannulation sites has its own advantages and disadvantages, and the selection strategy is often affected by the range of lesion involvement, surgical methods, peripheral vascular lesions and other factors.

Femoral artery is the classic cannulation site of this kind of surgery. It can be easily performed before sternal opening, avoid ascending aorta cannulation. But many people question the risk of increased mortality, neurological complications, lower limb ischemia, malperfusion syndrome, embolism and other problems.

The axillary artery cannulation can avoid these problems. In recent years, surgeons have begun to use axillary artery cannulation to treat type A AD due to malperfusion with traditional femoral artery cannulation. It provides an effective cerebral protection and is rarely involved in the AD so ensure the true lumen blood supply to the greatest extent, facilitating the implementation of anterograde selective cerebral perfusion for brain protection. Physiological blood flow direction reduces malperfusion complications during CPB and allows anterograde cerebral perfusion during circulatory arrest. However, axillary artery cannulation still has some defects such as insufficient flow, which may affect the perfusion of organs.

We have combined axillary artery cannulation with femoral artery cannulation to overcome the disadvantages of single cannulation. The strategy has been performed at our institution for more than ten years. This study reviewed the mortality and morbidity of type A AD in our hospital from January 2017 to June 2019, and analyzed the safety and efficacy of our combined cannulation strategies.

Material And Methods

1. Patients and methods

Medical records, operative records, and discharge summaries of all patients who underwent type A AD surgery with combined cannulation at our institution from January 2017 to June 2019 were reviewed in electronic medical record system and picture achieving and communication system. Records were noted for cannulation sites, surgical procedures, and overall clinical outcomes were reviewed. We were particularly concerned about postoperative lower limb ischemia, stroke, malperfusion, paraplegia, and death - complications that may be related to the cannulation site and retrograde perfusion.

The ethics committee of our institution, Union Hospital of Fujian Medical University in Fuzhou, China, approved this study protocol, Informed consent was waived as it was a retrospective study.

2. Surgical techniques

All patients were under general anesthesia. In order to avoid a malperfusion, the following measures are taken to minimize the risk: 1. Peripheral vascular condition is evaluated by computed tomography
images, whether there is occlusive disease and whether there is dissection involvement; 2. Peripheral blood pressure monitoring and oxygen saturation detection were used to evaluate whether there was occlusive disease and dissection involvement. The affected arteries should not be cannulated if a significant stenosis and dissection are identified in the preoperative examinations.

We preferred right axillary artery combined with the right femoral artery cannulation. The surgeons were divided into two groups and started at the same time. During femoral artery cannulation, after a purse-string suture is placed on the exposed femoral artery, a femoral arterial cannula is inserted into the femoral artery by using the Seldinger technique. The right femoral artery is usually cannulated if dissection was absent in the right iliofemoral artery. If both sides are dissected, we exercise great care to make certain that our cannula is placed into the true lumen.

If the vital sign was stable, another group continue on anatomy the right axillary artery, the axillary artery exposure for cannulation was obtained through a 4 - 6 cm incision about 2 cm under the Subclavian fossa. The fibers of the pectoralis major muscle were blunt split. The pectoralis minor muscle is retracted laterally. After exposed the axillary artery, femoral artery clamps are used proximal and distal to the cannulation site. After clamping of the vessel and longitudinal arteriotomy, either direct cannulation with an arterial cannula or anastomosed a Dacron graft end-to-side to the axillary artery with a running 5-0 Prolene suture. Flow is evaluated through the cannula by back bleeding, and if adequate, the cannula is connected to the arterial line and secured to the skin.

Median sternotomy was performed, and venous cannulation was performed with a 2-stage right atrial cannula. or with superior and inferior vena cava cannulation if combined with intracardiac operation. The arterial perfusion line was divided into two branches on the operating table, and "single pump and double tube method" was adopted for management, so as to transfer the position of artery perfusion and protect the cerebral at different stages of the operation.

After cannulation, the position of cannulation was confirmed by observing whether there was a clear blood return, whether the pump pressure was normal, and whether there was a significant increase in the pump pressure after pumping 50 ~ 100ml of liquid to eliminate the possibility of insert to the dissection. The arterial pressure of the radial and dorsal foot arteries, transesophageal echocardiography (TEE) and regional cerebral oxygen saturation were routinely monitored by an anesthesiologist.

After the CPB was initiated, we routinely palpated the aorta and compared the pressures of the radial artery and dorsal foot artery, and evaluated the area ratio of the true lumen and false lumen in the descending aorta with TEE to evaluate whether there is a case of malperfusion. We changed the arterial cannulation site if we suspected that the patients had malperfusion syndrome caused by inadequate perfusion.

During surgery, our brain protection methods were deep hypothermia concomitant with selective antegrade cerebral perfusion (SACP). Also, neuro-protective drugs were administered and the head was cooled with a topical ice hat. The axillary artery is rarely dissected, so we can put the cannula inside the
true lumen basically. After establishment of the circulatory arrest, we can find the backflow in the orifice of arch vessels. But if we can find not, we put another cannula inside the orifice of carotid artery\textsuperscript{13-14}. If the dissection involves only the ascending aorta, the ascending aorta and a hemi-arch replacement are usually performed. For patients with arch department involvement, we usually use triple-branched Stent Graft technology\textsuperscript{15}. During core cooling, the left common carotid and innominate arteries were dissociated from the surrounding tissue. After the ascending aorta was clamped, aortic root manipulations such as aortic valve repair and sinus of Valsalva reconstruction were performed. Then the Dacron tube graft was subsequently continuous anastomosis to the aortic root. When a 22°C rectal temperature was achieved, selective cerebral perfusion via the right axillary artery was started at a rate of 10 to 15 mL/kg/min, and femoral artery perfusion was discontinued. Then the left common carotid artery and innominate artery were cross-clamped, next transected the ascending aorta at the base of the innominate artery. The triple-branched stent graft was inserted and properly positioned. Finally, continuous end-to-end anastomosis was performed between the artificial vessels and intraoperative stents. After the dissection operation and after the air was carefully flushed out, systemic perfusion was resumed, and the patient was rewarmed\textsuperscript{16-18}.

3. Definition of clinical parameters

Early mortality was defined as all-cause mortality either in-hospital or within 30 days of surgery. Transient neurologic dysfunction was defined as the occurrence of post-operative confusion, agitation, and delirium without focal neurologic symptoms. Permanent neurologic injury was defined as the new onset of focal injury (stroke) or global dysfunction (coma) after a surgical repair with and without morphological correlates in a brain computed tomography or magnetic resonance image. Early stroke was defined as permanent neurologic injury being evident after the emergence from anesthesia. Delayed stroke was defined as permanent neurologic injury after first awaking from surgery without a neurological deficit. Acute kidney injury was defined as serum creatinine concentrations over 133 $\mu$mol/l or the need of dialysis due to oliguria. Postoperative liver failure was defined as at least having two of the following parameters were concurrently observed: the coagulation abnormality, total bilirubin > 15 mg/dL, liver enzymes levels more than tenfold the upper limit of normal, alteration of consciousness, asterixis.

4. Statistical analysis

Statistical analysis was performed with SPSS ver. 22.0 (SPSS Inc., Chicago, IL, USA). Continuous variables with a normal distribution were expressed as mean ± standard distribution. Nonnormally distributed data were expressed as median.

Results

A total of 327 patients who underwent surgical repair for type A AD in our institution between January 2017 to June 2019. There were 253 male and 74 females with a mean age of 52.16 ± 11.72 years (range, 22 to 87 years). Mean BMI was 24.21 ± 1.92 kg/m². In seven patients (2.14%), preoperative neurologic
symptoms such as transient ischemic attack and transient drowsy mentality had developed. Eleven patients had preoperative renal insufficiency and four patients with hepatic insufficiency. Two patients suffered with paraplegia. The clinical characteristics of the patients are detailed in Table 1.

| Item                        | Data               |
|-----------------------------|--------------------|
| Male/Female                 | 253/74             |
| Age (years)                 | 52.16 ± 11.72      |
| BMI (kg/m²)                 | 24.21 ± 1.92       |
| Hypertension (n)            | 261                |
| Diabetes (n)                | 28                 |
| Neurologic Symptoms (n)     | 7                  |
| Cardiac tamponade (n)       | 13                 |
| Renal insufficiency (n)     | 11                 |
| Hepatic insufficiency (n)   | 4                  |
| Paraplegia (n)              | 2                  |
| Transient leg ischemia      | 3                  |

The ascending aorta was replaced in all cases. The most frequent extent of aortic replacement was ascending aorta and hemiarch replacement combined with modified triple-branched stent graft implantation for repair type A AD. The detailed operative procedures are shown in Table 2. The CPB time was 90 to 334 minutes (mean, 141.60 ± 34.89 minutes), the aortic cross-clamp time was 22 to 169 minutes (mean, 49.05 ± 20.16 minutes), and the selective cerebral perfusion and lower body arrest time was 7 to 25 minutes (mean, 14.94 ± 2.76 minutes). 65 patients with unilateral selective cerebral perfusion and 262 with bilateral selective cerebral perfusion.
Table 2
Intra-operative data

| Item                                      | Data         |
|-------------------------------------------|--------------|
| Surgery strategy                          |              |
| Hemiarch replacement                      | 16           |
| Modified triple-branched implantation     | 311          |
| Cardiopulmonary bypass time (min)         | 141.60 ± 34.89 |
| Aortic cross-clamping time (min)          | 49.05 ± 20.16 |
| Selective cerebral perfusion time (min)   | 14.94 ± 2.76  |
| Cerebral perfusion strategy               |              |
| Unilateral                                | 65           |
| Bilateral                                 | 262          |

The postoperative consciousness time and mechanical ventilation time after operation were 6.71 ± 2.35 and 17.29 ± 2.10 hours, respectively. The postoperative length of stay in the intensive care unit was 55.41 ± 10.16 hours. There were ten (3.06%) early deaths. Three patients died of sepsis on postoperative day 7, 21, and 23, respectively. The other five patients died of multi-organ failure. One patient had a postoperative low cardiac output and died on post-operative day 5. Another one patient died of haemorrhagic stroke on postoperative day 30. Transient neurologic dysfunction was observed in 15 patients (4.59%) and all patients recovered before hospital discharge. A total of 3 patients (0.92%) suffered from a permanent neurologic dysfunction. Hemorrhagic and ischemic stroke was observed in one patient and two patients, respectively. Two patients ended up with paraplegia postoperatively. Five patients with preoperative cerebral malperfusion recovered without postoperative neurologic deficit or sequelae. Sixteen patients experienced postoperative hemodialysis-dependent renal failure (4.89%). Five post-operative acute liver failure was documented (1.53%). No patient required repeat surgery to correct excessive postprocedural bleeding. The incidence of the lower limb ischemia was 3 cases (0.92%). No patients had permanent cannulation-related complications. All related postoperative complications are shown in Table 3.
### Table 3
**Postoperative Data**

| Item                                | TA group   |
|-------------------------------------|------------|
| Early Mortality                     | 10         |
| Postoperative consciousness time (hours) | 6.71 ± 2.35 |
| Mechanical ventilation time (hours)  | 17.29 ± 2.10 |
| ICU stay (hours)                    | 55.41 ± 10.16 |
| Transient neurologic dysfunction    | 15         |
| Permanent neurologic dysfunction    | 3          |
| Paraplegia                          | 2          |
| Hemodialysis-dependent renal failure| 16         |
| Liver failure                       | 5          |
| Lower limb ischemia                 | 3          |

### Discussion

Type A AD surgery is associated with high mortality and high complication morbidity. Establishing a CPB that maintains adequate systemic perfusion is essential to prevent end-organ hypoperfusion during the procedure. Femoral artery cannulation and axillary artery cannulation to establish extracorporeal circulation are widely used in clinical practice and have been extensively reported in the previous literature\(^{19-21}\).

The femoral artery has been used as the primary cannulation site for CPB in cardiac surgery for more than 40 years\(^{22-23}\). Several studies have shown that retrograde perfusion of the femoral artery has the following deficiencies: (1) "Live valve" effect and false cavity blood supply, leading to central nervous system, upper arm, kidney and abdominal organ perfusion disorders; (2) false lumen blood supply and retrograde blood flow flush atherosclerotic plaque on the vascular wall, leading to embolization increase the incidence of stroke; (3) compared with the axillary artery, it is more easily involved by atherosclerosis and extensive interlayer; (4) lower limb ischemia; (5) Anterograde selective cerebral perfusion is inconvenient\(^{24-25}\).

Since 1995, axillary arterial cannulation has been used as an alternative to the femoral artery in patients with type A AD\(^{26}\). Compared with femoral artery cannulation, axillary artery cannulation can significantly reduce central nervous system complications in patients with deep hypothermia. Anterograde selective cerebral perfusion is considered to be the most ideal method for cerebral protection at present, and axillary artery cannulation can be very convenient to coordinate with it for brain protection, which greatly reduces the side effects brought by deep hypothermia and circulatory arrest (DHCA). In this group, 32.9%
of the patients were cannulated in the axillary artery, and none of the patients showed a verifiable
insufficiency of visceral perfusion during the operation\textsuperscript{27–28}. In addition, the advantages of axillary artery
cannulation are also shown in the following aspects: 1. the collateral circulation of neck and shoulder is
rich. Only 15\% of the human beings have no functional circle of Willis. 2. not easily affected by
atherosclerosis and dissection; 3. to avoid retrograde embolism and the expansion of the dissection; 4.
facilitate selective cerebral perfusion.

One disadvantage of axillary artery cannulation is that it takes more time to construct. But Budde et al.
used axillary artery cannulation to establish CPB in 61 patients undergoing elective and emergency
surgery due to proximal aortic pathology. There were no significant differences in postoperative
neurological dysfunction or mortality between the selective group and the emergency group. They
claimed that the routine use of axillary artery cannulation in emergent cases is just as safe and
efficacious as in the elective setting\textsuperscript{29}. However, the biggest disadvantage of axillary artery cannulation is
the insufficient flow, which may affect the perfusion of organs\textsuperscript{12}.

Our center used femoral artery combined with axillary artery cannulation to establish extracorporeal
circulation, providing reliable circulation support for AD repair. Few studies have examined the clinical
outcomes of this cannulation strategy. In this study, 96.94\% (317/327) of the patients undergoing
femoral and axillary artery cannulation survived. In addition, the incidence of permanent neurologic
dysfunction, renal insufficiency, live failure and lower limb ischemia were respectively 0.92\%, 4.89\%,
1.53\% and 0.92\%. Based on the results of our institution, we conclude that femoral artery combined with
axillary artery cannulation results in satisfactory short-term outcomes.

Combined with femoral artery and axillary artery cannulation, with this single pump and double tube
method, the true lumen of AD can be fully perfused to the greatest extent during CPB, avoiding systemic
poor perfusion. In addition, anterograde cerebral perfusion can also be carried out through the upper body
during the circulatory arrest, which greatly ensures the cerebral perfusion and reduces the incidence of
cerebral complications\textsuperscript{30}.

\textbf{Conclusion}

Femoral artery combined with axillary artery cannulation for Stanford type A AD can significantly improve
the prognosis of patients, especially in cerebral protection and reducing the occurrence of adverse
malperfusion syndrome, as well as reducing the time of cooling and rewarming.

\textbf{Abbreviations}

AD  
Aortic dissection  
TEE  
Transesophageal echocardiography
Declarations

Ethics approval and consent to participate

This study complied with the requirements of the Ethics Committee of Fujian Medical University, and adhered to the Declaration of Helsinki. Written informed consent was also obtained from the patient or a relative of the patient.

Consent for publication

Not applicable.

Availability of data and materials

Data sharing not applicable to this article as no data sets were generated or analyzed during the current study.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

L-WC and L-CH and Q-CX designed the study, participated in the operation, and drafted the manuscript. Q-CX and L-CH collected the clinical data and performed the statistical analysis. X-FD and D-ZC provide technical support. All authors read and approved the final manuscript.

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