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Clinical Research

Exploring Differences in Surgical Outcomes Depending on the Arterial Cannulation Strategy for Acute Type A Aortic Dissection: A Single-Center Study

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Background: Type A aortic dissection (AD) and intramural hematoma (IMH) are critical medical conditions. Emergency surgery is typically performed under cardiopulmonary bypass immediately after diagnosis, which involves lowering the body temperature to induce total circulatory arrest. Selection of the arterial cannulation site is a critical consideration in cardiac surgery and becomes more challenging in patients with AD. This study explored the strengths and weaknesses of different cannulation methods by comparing each cannulation strategy and analyzing the reasons for patients' outcomes, especially mortality and cerebrovascular accidents (CVAs).
Methods: This retrospective study reviewed the medical records of patients who underwent surgery for type A AD or IMH between 2008 and 2023, using the moderate hypothermic circulatory arrest approach at a single center.
Results: Among the 146 patients reviewed, 32 underwent antegrade cannulation via axillary, innominate artery, aortic, or transapical cannulation, while 114 underwent retrograde cannulation via the femoral artery. The analysis of surgical outcomes revealed a significant difference in the total surgical time, with 356 minutes for antegrade and 443 minutes for retrograde cannulation ($p<0.001$). The mean length of stay in the intensive care unit was significantly longer in the retrograde group (5±16 days) than in the antegrade group (3±5 days, $p=0.013$). Nevertheless, no significant difference was found between the groups in the 30-day mortality or postoperative CVA rates ($p=0.2$ and $p=0.7$, respectively).
Conclusion: Surgeons should consider an appropriate cannulation strategy for each patient instead of adhering strictly to a specific approach in AD surgery.

Keywords: Cannulation, Aortic dissection, Aortic intramural hematoma, Cardiopulmonary bypass

Introduction

Type A aortic dissection (AD) and intramural hematoma (IMH) are critical medical conditions accompanied by severe pain; they typically result in death if left untreated [1-7]. Over time, the risk of rupture increases. Ruptures may cause circulatory issues and lead to hemopericardium and cardiac tamponade, and a complete rupture inevitably leads to death. Therefore, emergency surgery is typically performed immediately after diagnosis [8]. Even after surgery, the mortality rate remains high, indicating an urgent need for improvements in the surgical technique.

Emergency surgery for these conditions is performed under cardiopulmonary bypass (CPB), which involves lowering the patient's body temperature to induce total circulatory arrest (TCA) [3,4,8]. Subsequently, the aorta is examined, and a graft is used to replace the damaged section.

Typically, patients undergo aortic cannulation for cardiac surgery. However, in cases where severe calcification or a thrombus is found in the aorta, an alternative cannulation site is used. Selection of the cannulation site is particularly challenging in patients with AD or IMH. Patients with AD have both true and false lumens, which complicates the conventional cannulation approach. An aortic cannula may inadvertently enter the false lumen, potentially worsening the AD and increasing the risk of visceral perfusion issues, rupture, and deterioration of the patient's condition [3,4]. However, femoral cannulation increases the risk of dislodging atherosclerotic plaques or thrombi within the aorta, potentially leading to severe complications [1,2,4,8].

Many studies have discussed cannulation methods extensively. In the past, femoral artery cannulation was performed as a standard practice [1,2,4,6,9]. Over time, antegrade perfusion has become preferred to retrograde perfusion via the femoral artery [2,6,10]. Antegrade cannulation includes axillary, innominate artery, aortic, and transapical cannulations. Most surgeons select the approach based on the patient's condition. In addition to these specific considerations, each cannulation method has advantages and disadvantages, which have been highlighted by several studies [8,11,12]. Notably, previous studies have suggested that antegrade perfusion reduces the risk of cerebral infarction [9,10,12].

The current study investigated patients with type A AD or IMH who underwent surgery using the moderate hypothermic circulatory arrest (MHCA) approach at a single center. The study aimed to understand the strengths and weaknesses of different cannulation methods in this specific context by comparing each cannulation strategy and analyzing the reasons for patients' outcomes, especially mortality and cerebrovascular accidents (CVAs).

Methods

Patients

This retrospective study reviewed the medical records of 163 patients who underwent surgery for type A AD or IMH between 2008 and May 2023. From that cohort, 12 patients who had surgery under deep hypothermic circulatory arrest and 5 patients with traumatic aortic disease were excluded. The remaining 146 patients, who underwent surgery under MHCA, were included in the study.

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and the Institutional Review Board of Daegu Catholic University Medical Center approved this study (approval number: CR-23-110-L). The requirement for informed consent from individual patients was omitted because of the retrospective design of this study. Patient survival was determined from medical records, which included details of follow-up appointments. The status of patients lost to follow-up was investigated by consulting the National Health Insurance Service.

Surgical procedures

Blood pressure was routinely monitored in both the right radial and left femoral arteries. Patients underwent surgery using a median sternotomy approach. Before 2018, the femoral artery was the primary choice for arterial cannulation, with an alternative site selected when necessary. However, since 2018, the aorta has been the first choice for arterial cannulation. If the aorta was not circularly dissected as determined by epiaortic sonography, cannulation was performed on the non-dissected aortic wall. As a secondary priority, the medical team considered the condition of the patient when determining the cannulation method.

After the venous cannula was inserted into the right atrium, a CPB was established and systemic cooling was initiated. Once the body temperature reached a state of moderate hypothermia, TCA was induced and an aortotomy was performed. After the aortic arch was inspected, a bilateral antegrade cerebral perfusion (ACP) catheter was inserted into the innominate and left carotid arteries. A cardioplegic solution was infused using the direct infusion method, and aortic graft replacement was performed. After distal anastomosis, an arterial cannula was inserted into the graft, and the CPB was restarted. During the rewarming process, branch vessel and root anastomoses were performed. The aortic clamp was removed after de-airing. Following the administration of protamine to reverse the effects of heparin, bleeding was controlled meticulously, and the wound was closed layer by layer.

Statistical analysis

The statistical analysis was performed using R ver. 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Data are presented as mean±standard deviation. Kaplan-Meier curves were generated to analyze survival rates, and categorical variables were compared using the chi-square test and Fisher exact test. Statistical significance was set at $p<0.05$.

Results

Among the 146 patients included in this study, 32 underwent antegrade cannulation through the axillary artery, innominate artery, or ascending aorta, and 114 underwent retrograde cannulation using the femoral artery.

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In terms of baseline characteristics, the mean ages were 63 years and 61 years in the antegrade and retrograde groups, respectively (p=0.6). The body mass index was 25.1 kg/m^2 in the antegrade group and 24.4 kg/m^2 in the retrograde group (p=0.2). No significant differences were found between the 2 groups in terms of underlying conditions, including hypertension (HTN) (p=0.6), diabetes mellitus (p=0.2), history of CVA (p>0.9), and hyperlipidemia (p=0.3). None of the patients in either group had chronic kidney disease, while one patient in the retrograde group had chronic obstructive pulmonary disease. Notably, the proportions of smokers and patients with HTN were relatively high in both groups (Table 1). The incidence of cardiac tamponade was 12.5% in the antegrade group and 12.3% in the retrograde group (p=1.000). Shock occurred in 12.5% and 15.8% of patients in the antegrade and retrograde groups, respectively, with no statistically significant between-group difference (p=0.857). Patients with a drowsy/stuporous mental status were observed in the antegrade and retrograde groups at rates of 3.1% and 11%, respectively, and the difference was not statistically significant (p=0.3) (Table 1).

No significant differences were found between the groups in the characteristics related to aortic disease. More cases occurred of AD than of IMH (p=0.15) (Table 2).

The analysis of surgical outcomes revealed a significant difference in the total surgical time, with 356 minutes for the antegrade group and 443 minutes for the retrograde group (p<0.001) (Table 3). In terms of the type of surgery, the frequency of total arch replacement was significantly higher in the antegrade group (p=0.031). The times from skin incision to CPB activation and from pump activation to TCA did not differ significantly between the 2 groups (p=0.6 and p=0.4, respectively). However, the mean time from TCA to lower-body perfusion was 56 minutes for antegrade and 64 minutes for retrograde cannulation (p=0.044), while the mean CPB time was 187 minutes for antegrade and 209 minutes for retrograde cannulation (p=0.082). The mean ACP and brain ischemic times did not show significant differences (p=0.3 and p=0.089, respectively), and no significant difference was observed in the TCA starting temperature (p=0.7) (Table 3).

Over the 15-year study period, an increase in the use of antegrade cannulation was observed after 2018 (Fig. 1).

Table 2. Types of aortic disease by group

Characteristic	Antegrade cannulation (N=32)	Retrograde cannulation (N=114)	p-value
Pathology			0.15
Dissection	22 (69)	92 (81)	
Intramural hematoma	10 (31)	22 (19)	
DeBakey type			0.15
1	23 (72)	95 (83)	
2	9 (28)	19 (17)	

Values are presented as number (%).

Table 1. Participant characteristics

Characteristic	Antegrade (N=32)	Retrograde (N=114)	p-value
Sex			0.3
Male	14 (44.0)	61 (54.0)	
Female	18 (56.0)	53 (46.0)	
Age (yr)	63±14	61±14	0.6
Body mass index (kg/m^2)	25.1±3.3	24.4±4.0	0.2
Hypertension	17 (53.0)	66 (58.0)	0.6
Diabetes mellitus	5 (16.0)	9 (7.9)	0.2
Chronic obstructive pulmonary disease	0	1 (0.9)	>0.9
Hyperlipidemia	1 (3.1)	12 (11.0)	0.3
Chronic kidney disease	0	0	
Cerebral vascular accident history	2 (6.3)	9 (7.9)	>0.9
Smoking status	13 (41.0)	38 (33.0)	0.4
Preoperative cardiac arrest	1 (3.1)	1 (0.9)	0.4
Preoperative endotracheal intubation	0	1 (0.9)	>0.9
Cardiac tamponade	4 (12.5)	14 (12.3)	1.000
Shock	4 (12.5)	18 (15.8)	0.857
Drowsy-stuporous mental status	1 (3.1)	13 (11.0)	0.3
Loss of consciousness	5 (16.0)	17 (15.0)	>0.9
Visceral malperfusion	1 (3.1)	10 (8.8)	0.5

Values are presented as number (%) or mean±standard deviation.

Table 3. Results of surgical procedures

Characteristic	Antegrade cannulation (N=32)	Retrograde cannulation (N=114)	p-value
Surgery type			0.031
Ascending and hemiarch replacement	20 (62.5)	92 (80.7)	
Total arch replacement	12 (37.5)	22 (19.3)	
Cannulation site			
Femoral	0	114 (100.0)	
Axillary	7 (22.0)	0	
Innominate	2 (6.0)	0	
Aortic	22 (69.0)	0	
Transapical	1 (3.0)	0	
Operation time (min)	356±107	443±131	<0.001
Skin incision to CPB time (min)	54±25	54±25	0.6
CPB to TCA (min)	29±14	30±15	0.4
TCA to lower body perfusion time (min)	56±28	64±27	0.044
CPB time (min)	187±62	209±69	0.082
ACP time (min)	44±32	48±29	0.3
TCA to ACP time (min)	14±6	16±6	0.089
Temperature during TCA (°C)	25.49±2.47	25.68±2.27	0.7

Values are presented as number (%) or mean±standard deviation.
CPB, cardiopulmonary bypass; TCA, total circulatory arrest; ACP, antegrade cerebral perfusion.

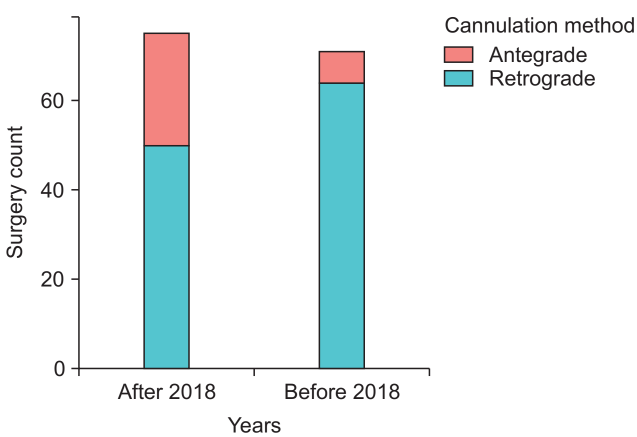

Fig. 1. Ratios of cannulation methods after 2018 and before 2018.

An examination of postoperative outcomes revealed no significant differences between the 2 groups in neurological complications, such as postoperative CVA or spinal cord ischemia. Nor were any significant differences found in the need for continuous renal replacement therapy, re-operation to control bleeding, or extracorporeal membrane oxygenation support. The incidences of pneumonia and visceral organ injury did not differ significantly between the 2 groups. No significant difference in 30-day mortality was seen between the 2 groups. However, the length of intensive care unit (ICU) stay was significantly longer in the retrograde group (5±16 days) than in the antegrade group (3±5 days, p=0.013) (Table 4).

Table 4. Postoperative complications

Complications	Antegrade cannulation (N=32)	Retrograde cannulation (N=114)	p-value
Cerebrovascular accident	2 (6.3)	12 (11.0)	0.7
Spinal cord ischemia	0	2 (1.8)	>0.9
AKI (requiring CRRT)	2 (6.3)	11 (9.6)	0.7
Bleeding control surgery	1 (3.1)	4 (3.5)	>0.9
Mechanical support	0	7 (6.1)	0.3
Pneumonia	1 (3.1)	6 (5.3)	>0.9
Visceral organ injury	0	4 (3.5)	0.6
Length of ICU stay (day)	3±5	5±16	0.013
30-Day mortality			0.2
Survival	27 (84.0)	105 (92.0)	
Expiration	5 (16.0)	9 (8.0)	

Values are presented as number (%) or mean±standard deviation.
AKI, acute kidney injury; CRRT, continuous renal replacement therapy; ICU, intensive care unit.

A survival curve for all patients was generated (Fig. 2). A comparison of the antegrade and retrograde cannulation survival curves revealed no significant difference between the 2 groups (Fig. 3).

Discussion

Many studies have compared antegrade (axillary, innominate artery, or aortic) to retrograde cannulation [1-5,12,13]. In this study, we used patient data to compare the 2 cannu-

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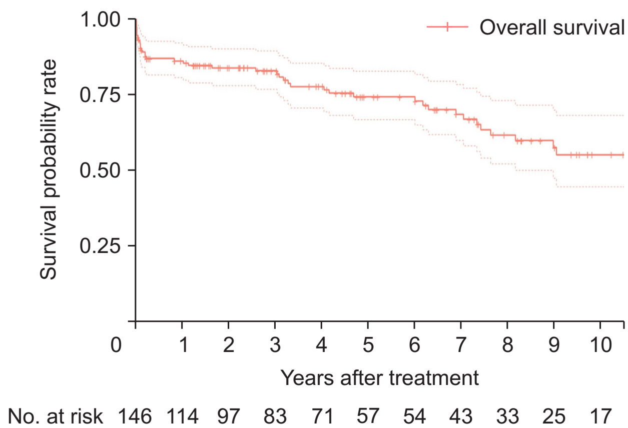

Fig. 2. Kaplan-Meier curve for overall survival.

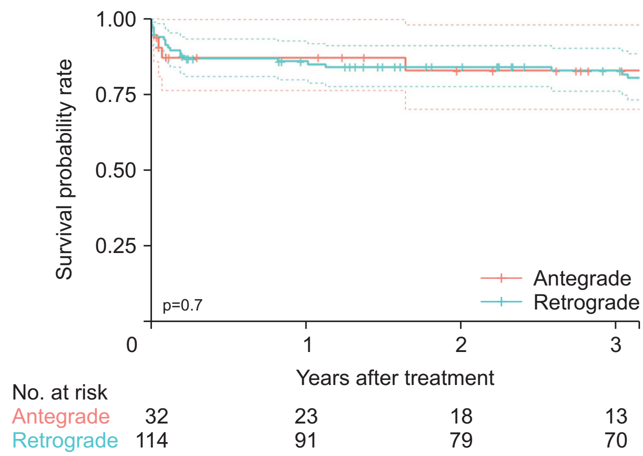

Fig. 3. Kaplan-Meier curves for antegrade and retrograde cannulation methods.

lation methods and determine which approach would be preferable in a typical clinical situation rather than in any specific case.

Recent research findings suggest a shift away from traditional femoral cannulation toward the increased use of axillary cannulation and direct aortic cannulation [2].

Femoral cannulation is associated with a risk of cerebral infarction because of retrograde flow. This can occur when atherosclerosis or plaque is present in the aorta or when thrombus formation in the false lumen is washed out by the retrograde flow. Therefore, antegrade cannulation, which carries a lower risk of cerebral infarction, is increasingly preferred [1,4,5,9,10,12,14]. In a meta-analysis comparing axillary and femoral cannulations, Hussain et al. [14] noted that axillary cannulation was associated with a lower risk of stroke. However, Kamiya et al. [2] reported less atherosclerosis or fewer plaques in patients with dissection, leading to a lower risk of cerebral infarction. Therefore, the authors concluded that avoiding femoral cannulation may not be necessary in such cases.

Despite its increasing popularity, antegrade cannulation is also associated with potential issues. Although axillary cannulation has become more common recently, it is considered less favorable because of access challenges and the risk of injury to the brachial plexus [6,9]. Moreover, malperfusion may be a risk in cases where the blood vessels are small [2]. One concern regarding aortic cannulation is its potential to worsen aortic rupture and dissection, which can have serious consequences.

Reviewing the results presented in the current study, it appears that the data used were appropriate for research since no significant differences were observed in the baseline characteristics, characteristics of aortic disease, or medical history. Interestingly, nearly half of the patients had HTN as an underlying condition, and at the time of emergency room admission, most patients had elevated blood pressure. This could be due to a temporary increase in blood pressure induced by pain, but it also suggests that HTN may not have been well managed in these patients, given the lack of access to regular blood pressure monitoring.

Previous studies have found no significant difference in surgical time between antegrade and retrograde cannulation procedures [5,14]. However, the current study's operative results revealed that antegrade cannulation had significantly shorter operation times than retrograde cannulation. Additionally, noticeable differences were observed between the groups regarding the times for TCA to lower-body perfusion and CPB. It was initially thought that these differences might be due to cooling and rewarming times, with temperature management strategies changing over the study period; however, no significant difference in TCA temperature was found between the 2 groups. Moreover, the number of total arch replacement surgeries, which could potentially extend the surgical time, was not significantly different between the groups, indicating that the extent of a procedure did not influence the results. In line with global trends, our institution has gradually increased the proportion of antegrade cannulations performed over the study period. Therefore, small improvements in surgical techniques implemented over the last 15 years might have contributed to the reduction in surgical time in the antegrade cannulation group. Factors such as post-surgical bleeding control, decannulation methods, and distal anastomosis methods, which have been influenced by technical advancements, likely account for the observed differences. Furthermore, in cases where antegrade cannulation is not feasible, retrograde cannulation may be performed, due possibly to issues with the ascending aorta. This suggests the potential occurrence of other time-consuming processes, such as flap repair or anastomosis site dehiscence. Moreover, in situations where vital signs are unstable, primary venous/arterial cannulation may be carried out in the femoral vessels. This could result in a longer time for managing general issues, such as bleeding control, considering the possibility of a poorer preoperative patient condition in such cases.

Many studies have reported differences in the incidence of stroke following antegrade or retrograde cannulation [1-6,9,13,14]. However, our study found no significant differences between the 2 groups in the incidence of neurological complications, markers of ischemic or embolic injury to visceral organs, or 30-day mortality (Table 4). The main difference noted was a significantly longer ICU stay for the retrograde group. We considered 2 possible reasons for this difference. First, because no differences were observed between the 2 groups in factors that would lengthen the ICU stay, such as pneumonia, it is possible that the longer mean ICU stay in the retrograde cannulation group is a result of subtle neurological issues, such as microembolization or minor ischemic damage to multiple organs. Second, the increased use of antegrade cannulation in recent years has coincided with advancements in critical care management, which may explain the shorter ICU stays for this group. While this is a valid consideration, it remains possible that antegrade perfusion may be more effective than retrograde cannulation in reducing the duration of ICU stays and promoting postoperative patient recovery.

AD is a life-threatening emergency condition, and the early (30-day) mortality rate has been set as the primary endpoint because emergency surgery is a necessary event. In the current study, no significant difference was found in survival rates between the antegrade and retrograde groups. A study by Ram et al. [1] found no significant differences in the survival rate between patients undergoing axillary and femoral cannulations, and other studies observed no significant differences in the survival rate between an axillary cannulation group and a femoral cannulation group [2,6]. The survival curves observed in the current study also indicate no substantial difference in survival between the 2 groups. Both methods showed similar long-term outcomes.

The current study found differences in the mean surgical times and lengths of ICU stays between the antegrade and retrograde groups. Although the primary aim of this study was to assess the benefits of each cannulation method in terms of mortality and CVA, no statistically significant differences were found between the 2 groups. Previous studies have demonstrated the benefits of antegrade cannulation, and actively considering antegrade cannulation has become a generally prevailing trend [9,10,12,14]. However, some studies have demonstrated conflicting results [1,2,6].

It is essential to note that all studies cited above were based not on completely randomized data but rather on case-by-case analyses utilizing data that were subject to biases considered in our study. Considering this aspect, instead of asserting that antegrade cannulation is superior to retrograde cannulation, it might be more reasonable to conclude that optimal cannulation procedures may lead to lower risks of mortality and CVA in patients who undergo antegrade cannulation.

Limitations

The present study has certain limitations. First, since cannulation sites cannot be randomly assigned to patients, selection bias and surgeon preference bias may present issues. Because this study was conducted in one small center with few changes to surgeon staff members and consistent agreement on cannulation strategies during surgical planning, it is likely that the analysis adjusts somewhat for surgeon preference bias. It is also likely that some surgeon preference bias remains. Moreover, due to the extended duration of the study, changes in surgeon experience over the study period were not included as a variable. Second, the number of patients who underwent ascending cannulation was relatively small, which made comparison difficult. Third, because this was a single-center study, its results may not be widely generalizable.

Conclusions

This study found differences in mean surgical times and lengths of ICU stays between groups of patients who underwent antegrade and retrograde cannulations. However, no statistically significant differences were found between the groups in 30-day mortality or CVA. Since the superiority of antegrade cannulation over retrograde cannulation has not been proven conclusively, it would be better to consider a cannulation strategy tailored to individual cases rather than adhering strictly to a specific approach.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

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