Somers *et al. Vessel Plus* 2024;8:15
DOI: 10.20517/2574-1209.2023.48

Vessel Plus

Original Article

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Direct aortic cannulation, a safe alternative to femoral artery cannulation - 17 years of type A dissection surgery experience

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How to cite this article: Somers T, Li WWL, Jongenotter J, Verkroost MWA, Verhagen AFTM, Morshuis WJ, Smith T, Geuzebroek GSC, Heijmen RH. Direct aortic cannulation, a safe alternative to femoral artery cannulation - 17 years of type A dissection surgery experience. *Vessel Plus* 2024;8:15. https://dx.doi.org/10.20517/2574-1209.2023.48

Received: 31 May 2023 **First Decision:** 9 Jan 2024 **Revised:** 5 Feb 2024 **Accepted:** 13 Mar 2024 **Published:** 21 Mar 2024

Academic Editors: Frank W. Sellke, Cristiano Spadaccio **Copy Editor:** Fangyuan Liu **Production Editor:** Fangyuan Liu

Abstract

Aim: Optimal cannulation strategy for acute type A aortic dissection (ATAAD) surgery remains debated. Recent guidelines have advocated antegrade systemic perfusion through right axillary artery (RAX) cannulation, instead of femoral artery (FA) cannulation. However, RAX cannulation can be technically challenging and time-consuming. On the other hand, direct (ascending) aorta (DA) cannulation is a swift procedure that also ensures downstream antegrade flow. In this regard, we assessed whether DA cannulation is a safe alternative to FA cannulation.

Methods: Records of all patients undergoing ATAAD surgery between 2006-2022 at the Radboud University Medical Center were retrospectively reviewed.

Results: In total, 281 patients underwent surgery for ATAAD during the investigated period. Three patients were excluded due to death before the start of extracorporeal circulation and four because of RAX cannulation. Of the remaining 274 patients, 53% (N = 145) received primary FA and 47% (N = 129) DA cannulation, with a success rate of 98% for both approaches. Surgical mortality (combined in-hospital and 30-day) was 9.9% (7.8% DA group *vs.* 11.7% FA group, P = 0.271). New permanent neurological damage was seen in 10.9% *vs.* 6.9% (P = 0.248), respectively. In multivariate analysis, cannulation strategies were not significantly associated with surgical mortality nor postoperative new permanent neurological damage.

Conclusion: DA cannulation offers a safe and fast alternative to FA cannulation in ATAAD surgery. There were no significant differences in mortality and neurological complications. Future studies should focus on the differences between RAX and DA cannulation strategies on postoperative outcomes in ATAAD surgery.

Keywords: Type A dissection, cannulation, axillary artery, direct aorta, femoral artery, extracorporeal circulation

INTRODUCTION

Acute type A aortic dissection (ATAAD) surgery continues to have significant morbidity and mortality rates, despite improved operative techniques over the past decades[1-3]. This includes 18% new neurological complications and surgical mortality rates of 17%-22%, which are mostly related to organ malperfusion (e.g., cerebral, renal, or spinal ischemia)[1,4-7]. Optimal intraoperative organ perfusion can therefore improve ATAAD surgical outcomes.

Femoral artery (FA) cannulation has long been the primary choice for its quick and easy access. This is especially relevant in hemodynamically unstable patients. FA cannulation is, therefore, still used in 28%-46% of the ATAAD cases[2,8-11]. However, retrograde flow may cause organ malperfusion, cerebral embolization, and potentially early dilatation of the false lumen[12]. Therefore, cannulation of the right axillary artery (RAX) with antegrade flow downstream has been increasingly encouraged and advocated to be associated with a significantly lower risk of mortality and stroke compared to FA cannulation in multiple studies and meta-analyses[13-16]. As such, current guidelines advocate the use of RAX cannulation in stable patients above peripheral (femoral) cannulation[7,17]. However, RAX cannulation is often unfamiliar territory for most cardiac surgeons, and can also be technically challenging and time-consuming, particularly important in emergency settings.

Another modality to ensure antegrade downstream perfusion is direct aortic (DA) cannulation in the ascending aorta[4,18,19]. Obviously, this is the routine cannulation location for the large majority of cardiac procedures, and all cardiac surgeons are familiar with this technique. In the guidelines, it carries the same recommendation class as RAX cannulation (class IIa recommendation)[17]. However, manipulation and cannulation in the acutely dissected aorta might instigate reluctancy to utilize this technique. According to a survey among cardiac surgeons in European centers, only 6% of surgeons prefer DA cannulation as their first choice in the acute setting[11]. Furthermore, published data on the safety of this technique are limited. The available reviews and meta-analyses preferentially compare FA with RAX cannulation, and only a minority of the included studies use DA cannulation[13-15]. At our center, DA cannulation is used frequently in ATAAD; therefore, we describe our 17-year experience of ATAAD surgery and compare direct (aortic) cannulation with femoral cannulation regarding postoperative mortality and neurological complications.

METHODS

We performed a retrospective single-center cohort study of patients who underwent ATAAD surgery in the Radboud University Medical Center, Nijmegen, the Netherlands, between January 2006 and January 2023. Patients who died before initiation of extracorporeal circulation were excluded from the analysis. Medical records from all remaining patients were retrospectively reviewed.

Surgical technique

All surgeries were performed by a dedicated aortic surgical team, by either a dedicated aortic surgeon or an experienced cardiac surgeon. The decision for FA or DA cannulation lies with the surgeon, primarily based on experience and preference and after careful examination of preoperative CTA. All patients were opened

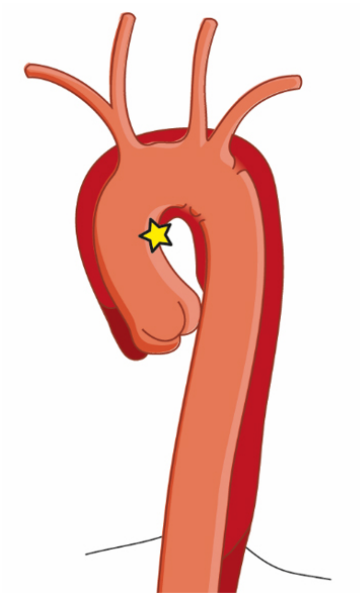

Figure 1. Preferred location of a non-dissected part of the aorta at the lesser curvature of the aortic arch.

through median sternotomy. For DA cannulation, the optimal cannulation site was preferably a non-dissected part in the anterior or lateral ascending aortic wall, determined on the CT preoperatively and with visual inspection intraoperatively (see Figure 1). A purse-string suture was placed superficially, often in the lesser curvature of the proximal aortic arch. Seldinger technique was used to introduce the cannula, following confirmation of the correct positioning of the guidewire in the true lumen through transesophageal ultrasound. In case of FA cannulation, prior to or simultaneous with sternotomy, the groin area was opened, and purse-string sutures placed in the true lumen wall of the common femoral artery, preferably in a non-dissected vessel. Similarly, using the Seldinger technique, a guidewire followed by a cannula was introduced. In the hyperacute setting (e.g., cardiac tamponade), the preferred cannulation strategy is patient-specific and also depends on the availability of one or multiple surgeons. Preferably, the tamponade is relieved and direct cannulation is started, but in unstable cases and with two surgeons, simultaneous femoral cannulation and opening of pericardium can be initiated.

Venous cannulation was introduced in right atrium and followed by initiation of extracorporeal circulation (ECC) and systemic cooling was started. The aorta was cross-clamped, and bilateral near-infrared spectroscopy (INVOS) and radial pressures were monitored to detect possible malperfusion and/or cerebral ischemia. Myocardial protection was achieved after opening of the aorta and administering selective antegrade crystalloid cardioplegia. Supracoronary aortic replacement (SCAR), composite graft replacement, or aortic valve-sparing techniques were used for the repair based on the extent of the dissection and aortic valve function. When a core body temperature (either bladder or rectally measured) of 25 degrees or less was reached (20 degrees or lower in case no antegrade selective cerebral perfusion [ASCP] is used), circulatory arrest was initiated and the cross-clamp released unless DeBakey type II. The distal aortic replacement was performed, again based on the extent, and with the use of bilateral ASCP. The repairs included open distal anastomosis, proximal arch replacement (zone 0), hemiarch (zone 1 or 2) or total arch with or without elephant trunk (ET). Circulation was re-established through a side branch of the prosthesis, the patient rewarmed and the anastomosis between the proximal and distal repair performed. In the case of FA cannulation, this was the moment at which cannulation was switched and the femoral cannula removed.

Outcomes

The primary outcomes of the study are surgical mortality and new permanent neurological damage. Secondary outcomes are acute kidney injury, postoperative dialysis, postoperative wound infection (either sternal or groin), and reintervention for bleeding or post-dissection aneurysm at follow-up.

Surgical mortality is defined as in-hospital mortality (all-cause death occurred during primary hospitalization) plus 30-day mortality (all-cause death including after discharge, but within 30 days of primary surgery). New permanent neurological damage is defined as any neurological symptoms that were not present during presentation prior to surgery but occurred after surgery and were still present at discharge. AKI is defined by the Kidney Disease Improving Global Outcomes (KDIGO) guidelines[20]. Sternal wound or groin infection were defined as any infection requiring antibiotics and/or positive cultures. Reintervention for bleeding is any intervention, either pericardiocentesis, subxiphoid pericardiotomy, or resternotomy, indicated to treat pericardial effusion.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 27.0 (IBM Corp, Armonk, NY) statistical software. Continuous variables are expressed as mean ± standard deviation, and categoric variables as counts and percentages. Fisher's exact test, the $\chi 2$ test, and independent students *t*-test were used for univariate analysis. Logistic regression models were used for multivariate analyses including the variables age, sex, preoperative tamponade, preoperative neurological damage, SCAR with or without clamp, root repair, arch repair, bypass time, clamp time, deep hypothermic cardiac arrest (DHCA) duration, ASCP use and ASCP duration, and arterial cannulation approach (DA *vs.* FA). FA cannulation was used as a reference category. Propensity score matching was performed based on sex, age above 60, ECC time of more than 180 min, unilateral or bilateral cerebral perfusion, and preoperative shock based on previous literature[21-23]. Statistical significance was considered at a P-value of < 0.05.

RESULTS

A total of 281 consecutive patients underwent ATAAD surgery at our center from January 2006 to December 2022. Seven patients were excluded from the analysis, as they died before initiation of extracorporeal circulation ($N = 3$) or underwent primary RAX cannulation ($N = 4$). A total of 274 patients remained for final analysis. The mean age was 62.5 ± 12.5 years, and 43.8% were female [Table 1]. Preoperative tamponade was significantly more present in patients who underwent FA than DA cannulation ($P = 0.033$). The baseline characteristics of all patients are shown in Table 1. Looking more closely into patients who died prior to initiating cannulation reveals all patients died due to aortic rupture after the slow release of sudden tamponade through sternotomy. In one patient, femoral cannulation was initiated, but due to profuse blood loss, it remained impossible to run adequate circulation.

DA cannulation was used in 129 patients (47.1%) and another 145 patients (52.9%) received FA cannulation. Over the last few years, the number of DA cannulation cases has increased compared to FA cannulation. During surgery, the cannulation strategy changed from DA to FA in three cases (2.1%) and from FA to DA in three cases (2.3%). The major reason for the change from FA to DA was the inability to introduce the guidewire or cannula in the femoral artery. The decline or loss of right-sided radial blood pressure or INVOS after aortic cross-clamping was the major reason for the change from DA to FA.

Most patients who received a root-sparing technique also underwent aortic valve intervention, either by replacement (10/179, 5.6%) or resuspension (107/179, 59.8%). There were no significant differences between DA and FA cannulation on aortic valve repair. Root replacements, particularly the Bentall procedure, were

Table 1. Baseline and operative characteristics of patients who underwent acute type A aortic dissection surgery

Baseline	Femoral cannulation	Direct aortic cannulation	Total	*P* value
Number (n)	145 (53)	129 (47)	274 (100)	
Age, years	62.7 ± 12.6	62.3 ± 12.3	62.5 ± 12.5	0.806
< 40 years	6 (4.1)	6 (4.7)	12 (4.4)	0.836
40-59 years	45 (31)	44 (34)	89 (32)	0.588
60-79 years	87 (60)	72 (56)	159 (58)	0.483
> 80 years	7 (4.8)	7 (5.4)	14 (5.1)	0.822
Female	64 (44)	56 (43)	120 (44)	0.904
Preoperative tamponade	35 (24)	18 (14)	53 (19)	0.033
Preoperative neurological damage	7 (4.8)	8 (6.2)	15 (5.5)	0.618
EuroScore II, %	11.7 ± 10.7	8.1 ± 5.3	10.0 ± 8.6	0.155
Operative covariates	Femoral cannulation (*n* = 145)	Direct aortic cannulation (*n* = 129)	Total (*n* = 274)	*P* value
Root replacement	44 (30)	55 (43)	99 (36)	0.035
Valve sparing	4 (2.8)	4 (3.1)	8 (2.9)	1.000
Bentall	40 (28)	51 (40)	91 (33)	0.625
				0.036
SCAR with cross-clamp	4 (2.8)	5 (3.9)	9 (3.3)	0.739
Open distal anastomosis	99 (68)	71 (55)	170 (62)	0.024
Distal aortic anastomosis	28 (19)	17 (13)	45 (16)	0.171
Between IA and LCCA	7 (4.8)	1 (0.8)	8 (2.9)	0.070
Between LCCA and LSA	12 (8.3)	12 (9.3)	24 (8.8)	0.764
Total arch	9 (6.2)	4 (3.1)	13 (4.7)	0.227
Cardiopulmonary bypass details				
ECC time, min	238 ± 72	222 ± 70	231 ± 71	0.063
Cross-clamp time, min	134 ± 49	130 ± 49	132 ± 49	0.530
DHCA	138 (95)	121 (94)	259 (95)	0.618
Duration, min	38 ± 19	36 ± 22	37 ± 20	0.309
ASCP	106 (73)	81 (63)	187 (68)	0.067
Unilateral	10 (6.9)	14 (11)	24 (8.8)	0.248
Bilateral	96 (66)	67 (52)	163 (59)	0.016
Duration, min	39 ± 42	34 ± 38	37 ± 40	0.294
Lowest core body temperature	22.6 ± 2.7	22.6 ± 3.5	22.6 ± 3.0	0.922
> 25 °C	9 (6.2)	4 (3.1)	13 (4.7)	0.768
20-25 °C	54 (37)	30 (23)	84 (31)	0.947
< 20 °C	12 (8.3)	8 (6.2)	20 (7.3)	0.674
Not reported	70 (48)	87 (67)	157 (57)	0.001

Values are mean ± SD or *n* (%). ASCP percentages are related to DHCA. SCAR: Supracoronary aortic replacement; IA: innominate artery; LCCA: left common carotid artery; LSA: left subclavian artery; ECC: extracorporeal circulation; DHCA: deep hypothermic circulatory arrest; ASCP: antegrade selective cerebral perfusion. Significant differences (*P* value < 0.05) are underlined.

performed more in the DA cannulation group (39.5% *vs.* 27.6%, $P = 0.036$) and SCAR with open distal anastomosis but without arch were performed more often in the FA cannulation group (68.3% *vs.* 55.0%, $P = 0.024$). All patients, except one, undergoing SCAR with cross-clamp, equally distributed between direct aortic and femoral cannulation (4% *vs.* 3%, $P = 0.739$), had DeBakey type II aortic dissection. Most patients received ASCP apart from 39 cases (18 DA and 21 FA). However, data regarding the use of ASCP, either unilateral or bilateral, were missing from 48 patient records (30 DA and 18 FA). All procedural details including bypass times and other operative variables are shown in Table 1.

There were no statistically significant differences regarding surgical mortality (DA 7.8% *vs.* FA 11.7%, $P = 0.271$) nor new permanent neurological damage (respectively 10.9% and 6.9%, $P = 0.248$) between both groups. Patients in the DA group required, although non-significant, more pericardiocentesis, subxiphoid pericardiotomy, and resternotomy for bleeding more than 48 h after primary intervention (22.5% *vs.* 13.8%, $P = 0.061$). Additionally, there were no significant differences in the number of patients with AKI and those

with AKI who required dialysis (P = 0.093 and P = 0.561, respectively). Groin infections were reported in 2.1% of the FA group. No leg ischemia was observed after FA cannulation. All other postoperative characteristics are shown in Table 2. Preoperative tamponade was significantly more present in the FA cannulation group, although surgical mortality did not differ significantly within this subgroup (3/18 for DA and 8/35 for FA; P = 0.730). The multivariate analyses for DA canulation were computed using the baseline characteristics and the operative variables as described before, with FA cannulation as the reference category. Permanent new neurological damage (OR 1.518, 95%CI: 0.553-4.167, P = 0.418) and surgical mortality (OR 0.671, 95%CI: 0.244-1.844, P = 0.439) were equally distributed between DA and FA.

Seventy-one patients from femoral cannulation were matched with a similar number of direct aortic cannulation patients. Only reintervention > 48 h after primary intervention was significantly different, favoring femoral cannulation (8 *vs.* 20; P = 0.011).

The median follow-up was 52 months (range 0-193 months). In this follow-up period, there were no significant differences in reoperations between DA and FA, nor significant differences in diameter of the post-dissection descending aorta (see Table 3).

DISCUSSION

This study suggests DA cannulation is a safe alternative to FA cannulation in the surgical treatment of ATAAD patients, offering similar postoperative mortality and morbidity rates. Although the advantages of antegrade flow could not be established in our series, reluctance to manipulate the dissected aorta for canulation does not seem warranted.

Reported studies on DA cannulation in ATAAD surgery are relatively limited. In 2009, Kamiya *et al.* showed comparable outcomes on 30-day mortality (14% *vs.* 23%, P = 0.07) and stroke (4.9% *vs.* 4.5%, P = 0.86) between DA and FA cannulation[24]. More recently, Jormalainen *et al.* completely shifted to DA cannulation in ATAAD patients after they observed similar hospital mortality (13.8% *vs.* 13.5%, P = 0.962) and stroke rates (22.3% *vs.* 25%, P = 0.617).[25] Reece *et al.* even showed DA cannulation has significantly lower perioperative myocardial infarction (P < 0.01) and 30-day mortality (P < 0.05) than FA and RAX cannulation[26]. Kreibich et al performed a similar comparison between DA, FA, and RAX cannulation[27], reporting no significant differences regarding in-hospital mortality and stroke, with significantly shorter ECC and cross-clamp time for DA compared to FA cannulation (198 *vs.* 212 min and 125 *vs.* 148 min, respectively).

Current guidelines advocate cannulation, providing antegrade flow, especially RAX cannulation for stable patients[7,17]. A meta-analysis comprising 715 patients showed a significant reduction in mortality (P < 0.01) and stroke (P < 0.01) for RAX cannulation compared to FA cannulation[14]. In this study, however, malperfusion (a feared complication of FA cannulation) did not differ significantly between both groups (RAX 5.7% *vs.* FA 6.6%, P = 0.67). Another systematic review showed DA cannulation has lower mortality and malperfusion rates compared to FA cannulation, although the stroke rate is higher than that of RAX cannulation[19]. Sabashnikov, on the other hand, showed no significant differences in neurological outcomes when comparing DA cannulation to RAX in their study with 235 patients[28]. Recently, Ramaprabhu *et al.* showed no significant differences between DA and RAX cannulation on mortality, stroke, and overall survival (P = 0.863, P = 0.463, and P = 0.629, respectively)[29]. In both the German Registry for Acute Aortic Dissection Type A (GERAADA) database and the Nordic Consortium for Acute Type A Aortic Dissection (NORCAAD) database, cannulation site did not affect early mortality (15.1% *vs.* 18.8%, P > 0.1 and 19.2% *vs.* 18.9%, respectively)[4,8]. Although non-significant, more AKI was observed in direct aortic

Table 2. Postoperative characteristics of patients who underwent ATAAD surgery

	Femoral cannulation (*n* = 145)	Direct aortic cannulation (*n* = 129)	Total (*n* = 274)	*P* value	PSM FA (*n* = 71)	PSM DA (*n* = 71)	PSM *P* value
Surgical mortality	17 (12)	10 (7.8)	27 (9.9)	0.271	7 (9.8)	3 (4.2)	0.190
New permanent neurological damage	10 (6.9)	14 (11)	24 (8.8)	0.248	3 (4.2)	8 (11)	0.117
Reintervention for bleeding	34 (23)	37 (29)	71 (26)	0.324	14 (20)	23 (32)	0.085
< 48 h	14 (9.7)	8 (6.2)	22 (8.0)	0.294	6 (8.5)	3 (4.2)	0.493
> 48 h	20 (14)	29 (22)	49 (18)	0.061	8 (11)	20 (28)	0.011
Acute kidney injury	28 (19)	36 (28)	64 (23)	0.093	14 (20)	18 (25)	0.422
Requiring dialysis	6 (4.1)	10 (7.8)	16 (5.8)	0.561	3 (4.2)	5 (7.0)	0.666
Sternal infections	4 (2.8)	5 (3.9)	9 (3.3)	0.739	2 (2.8)	3 (4.2)	1.000
Groin wound problems	3 (2.1)	0 (0)	3 (1.1)	0.250	2 (2.8)	0 (0)	0.496
Hospital stay, days	15.9 ± 11.9	17.9 ± 15.4	16.8 ± 13.7	0.215	16.0 ± 12.7	18.6 ± 16.3	0.290

Values are mean ± SD or *n* (%). PSM: Propensity score matching; FA: femoral artery cannulation; DA: direct aortic cannulation.

Table 3. Follow-up characteristics of patients who underwent ATAAD surgery

	Femoral cannulation (*n* = 145)	Direct aortic cannulation (*n* = 129)	Total (*n* = 274)	*P* value
Mean diameter descending aorta during follow-up	38.4 ± 9.5	39.9 ± 10.1	39.1 ± 9.8	0.272
Reoperations for dilatating ascending aorta (root or arch)	2 (1.4)	3 (2.3)	5 (1.8)	0.669
Postdissection reoperation	9 (6.2)	15 (12)	24 (8.8)	0.113
False aneurysm reoperation	3 (2.1)	2 (1.6)	5 (1.8)	1.000

Values are mean ± SD or *n* (%).

cannulation, which has previously been described as more favoring femoral over axillary cannulation due to the close proximity of blood flow and renal artery[30].

Our current study has several limitations. As all patients are only from one clinic, results are difficult to extrapolate. Second, the limited sample size might not be sufficient to detect a significant treatment effect. Another limitation is the retrospective character with non-randomized choice of cannulation strategy, which is based on the surgeon's personal preference and patients' clinical status. In addition, only four RAX cannulations were performed during the study period, making the comparison between DA and RAX cannulation outcomes impossible.

We believe DA cannulation has the best of both worlds: realizing antegrade flow similar to RAX cannulation, while retaining the convenience and familiarity of the technique, as seen in FA cannulation[2,11]. DA cannulation has the advantage over RAX cannulation with lower operating times due to less complexity and more convenience, as shown in other reports[14,27,31]. Future research should focus on DA cannulation for ATAAD patients and compare it to the other techniques offering antegrade flow, especially RAX cannulation.

To conclude, DA cannulation offers a safe alternative to FA cannulation in ATAAD surgery, with no significant differences in mortality, neurological complications, and reoperations. Therefore, the conventional hesitance to touch the dissected aorta is unwarranted. Additionally, DA cannulation obviously obviates the possibility of postoperative groin infections. Future studies should focus more on the

differences between DA and RAX cannulation to determine the optimal cannulation strategy for ATAAD surgery.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study: Verkroost MWA, Verhagen AFTM, Geuzebroek GSC, Smith T, Heijmen RH
Collected all data: Somers T, Jongenotter J
Performed the formal data analyses: Somers T, Jongenotter J, Li WWL
Written original draft and visualized data: Somers T, Li WWL
All authors have reviewed and accepted the manuscript in its current form.

Availability of data and materials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

This retrospective study was approved by the medical ethics committee of the Radboud University Medical Center, according to local regulations, if data is anonymized and cannot be retrieved back to one patient, data may be used without the informed consent of patients.

Consent for publication

Not applicable.

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