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Clinical effects of hybrid debranching technique for acute Stanford type A aortic dissection

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Abstract

Background To investigate the clinical effects and safety of the hybrid debranching technique for patients with acute Stanford type A aortic dissection (AD).

Methods One hundred nine patients with acute Stanford type a AD were selected and divided into observation group and control group according to the different surgical methods. Fifty-five patients in the observation group were treated with hybrid debranching, and 54 patients in the control group were treated with Sun's operation. The operation duration, clamp time, cardiopulmonary bypass duration, volume of blood transfusion, ventilator application duration, duration of stay in the intensive care unit, aortic rupture, second thoracotomy due to hemorrhage, gastrointestinal hemorrhage, stroke, paraplegia, renal failure, and all-cause mortality were recorded. Postoperative follow-up was conducted. The number of cases that underwent follow-up and the number of cases with complete thrombosis of the false aneurysm cavity detected by computed tomography angiography (CTA) was recorded.

Results The surgical success rate was 100% in both groups, and there were no cases with unplanned secondary surgery. Compared with the control group, only the difference in the volume of blood transfusion was not significantly significant between the two groups ($P=0.052$), while the rest of the observation indicators were significantly lower in the observation group than in the control group ($P<0.001$ for all). The proportion of cases with complete thrombosis of the false aneurysm cavity was significantly higher in the observation group than in the control group at 3 and 6 months after surgery ($P<0.05$).

Conclusion In patients with acute Stanford type A AD involving the arch, the hybrid debranching technique was safe and effective. It was recommended for patients with advanced age and a high risk of intolerance to deep hypothermic circulatory arrest.

Keywords Aortic dissection, Aortic arch lesion, Ascending aorta replacement, Aortic arch replacement, Sun's operation, Hybrid debranching technique

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Background

Aortic dissection (AD) is a serious threat to life and health. With the increasing number of patients with diabetes mellitus, hypertension, and hyperlipidemia, the prevalence of AD is also increasing yearly. AD has significant mortality, which increases by 1 to 2% per hour within 24 h [1]. Thus, immediate blood pressure control and surgical interventions are necessary for patients with AD [2]. Among different types of AD, Stanford type A is a catastrophic disease characterized by rapid progression, complexity, and high mortality [3]. Acute Stanford type A AD has been a global problem for the surgical treatment of AD due to the difficulty of the operation, increased incidence of intraoperative hemorrhage, and complications. With the improvement of surgical techniques and the perfection of extracorporeal circulation perfusion technology, artificial vessel replacement of the ascending aorta and aortic arch under deep hypothermic circulatory arrest (DHCA) has become the mainstream surgical method for the treatment of AD [4]. In 2003, Prof. Sun Lizhong of Beijing Anzhen Hospital established Sun's operation in which the total aortic arch replacement + "elephant trunk" stent implantation was conducted under DHCA, resulting in a 5–20% reduction in perioperative mortality. However, DHCA is poorly tolerated in patients with advanced age, high risk, and combined with complex comorbidities. Moreover, thoracic endovascular aortic repair (TEVAR) cannot be conducted in patients with involvement of the aortic arch combined with insufficient effective landing zone. A more rational surgical treatment strategy is always being explored for these patients. With the improvement of the traditional open heart surgery and interventional procedures, the hybrid debranching technique, which combines the above two techniques, was proposed by Bavaria and other experts. The hybrid debranching technique is a new technique combined with TEVAR, making the traditional procedure simpler and safer due to less invasion and avoidance of DHCA [5]. Moreover, the hybrid debranching technique is effective in treating Stanford type A AD [6]. In the present study, the clinical effects were compared between the hybrid debranching technique and Sun's operation in the treatment of acute Stanford type A AD and provided more references for the clinical application of the hybrid debranching technique. The secondary objective of this study is to compare the advantages and disadvantages of the two surgical techniques, and the primary objective is to clarify the clinical effect of the hybrid debranching technique.

Table 1 The general characteristics of the patients

n = 109		Observation group	Control group	*P*
Age(year)		62.81 ± 8.03	48.11 ± 6.13	< 0.01
Gender (Number)	Male	31 (56.36%)	36 (66.67%)	>0.05
	Female	19 (34.55%)	23 (42.59%)	
Smoking History (year)		31.41 ± 4.42	27.11 ± 3.10	>0.05
Drinking History (years)		28.77 ± 6.41	27.40 ± 3.46	
Hypertension		55	44 (81.48%)	>0.05
Diabetes mellitus		30 (54.54%)	20 (37.03%)	
Coronary artery disease		11 (20.00%)	9 (16.67%)	
Cerebrovascular disease		12 (21.82%)	7 (12.96%)	
Chronic pulmonary disease		22 (40.00%)	18 (33.33%)	
The diameter of the aortic artery		47.30 ± 3.11	46.30 ± 5.88	>0.05
The diameter of the false aneurysm cavity		17.31 ± 5.30	15.20 ± 3.91	
The left ventricular ejection fraction		51.21 ± 7.53%	60.11 ± 4.32%	< 0.05

Materials and methods

General data

The data of 109 patients with acute Stanford type A AD treated at the Second Hospital of Hebei Medical University from 2018 to 2020 were retrospectively analyzed (Table 1). According to the different operation methods, they were divided into observation group and control group, in which 55 patients in the observation group were treated with hybrid debranching, and 54 patients in the control group were treated with Sun's operation.

In the observation group, the involvements of the AD lesions were as follows: 15 cases in the celiac trunk, 17 cases in the superior mesenteric artery, 18 cases in the renal artery, 18 cases in the inferior mesenteric artery, and 19 cases in the common iliac artery. The involvements of the lesions in AD in the control group were as follows: 15 cases in the celiac trunk, 14 cases in the superior mesenteric artery, 16 cases in the renal artery, 16 cases in the inferior mesenteric artery, and 13 cases in the common iliac artery. Patients in the observation group were older than those in the control group, and the left ventricular ejection fraction (LVEF) was lower in the observation group than in the control group ($P<0.05$). The differences in the remaining data were not statistically significant between the two groups ($P>0.05$).

Methods

The surgical procedures of patients in the observation group were as follows: general intravenous anesthesia combined with inhalation anesthesia was conducted in the patient. Routine median sternotomy approach incision was conducted, and cardiopulmonary bypass (CPB) was established via the femoral artery–femoral vein cannulation. Meanwhile, hypothermia was steadily managed,

and the rectal temperature was stabilized at 28℃. The ascending aorta was blocked at the proximal end of the innominate artery, the wall of the ascending aorta was dissected, and the ascending aortic valve and coronary artery opening were probed. Under direct vision, cold blood cardioplegia was infused into the coronary arteries for myocardium protection [7]. The currently available mainstream hybrid debranching techniques include Types I, II, III, IVa, and IVb, respectively, and the most practical technique was selected according to the lesion [8]. End-to-end anastomosis was conducted between the ascending portion of the autologous aorta and the proximal end of a four-branch artificial vessel, as well as the arch portion of the autologous aorta and the distal end of the four-branch artificial vessel (product of the MAQUET biocoat artificial vessel series). The most distal branch of the four-branch artificial vessel should be reserved for more than 2 cm as the landing zone of the overmolded stent (the Aortic Overmolded Stent System by Medtronic Co.). After surgery, heparin was neutralized with protamine, and hemostasis was conducted. Then the chest was closed after placing a drainage tube. (Fig. 1)

The surgical procedures of patients in the control group were as follows: general intravenous anesthesia combined with inhalation anesthesia was conducted in the patient. Routine median sternotomy approach incision was conducted, and CPB was established via the femoral artery–femoral vein cannulation. The nasopharyngeal temperature was lowered to 23℃~25℃, and the patient was placed in a prone position. Three branches of the aortic arch were blocked separately. Selective unilateral cerebral perfusion was performed through the right axillary artery, and the flow rate was maintained at 5–10 mL/(kg·min). After circulatory arrest, the aortic arch was cut, and three head vessels were transected. The appropriate type of elephant trunk stent artificial vessel was selected and implanted into the true lumen of the descending aorta. The end-to-end anastomosis was conducted between the artificial vessel and the proximal end of the descending aorta as well as the artificial vessel and the distal end of the four-branch artificial vessel trunk. A 10 mm branch artificial vessel was inserted from the other end of the arterial pumping tube to restore the circulatory perfusion to the lower part of the body. The four-branch artificial vessel was anastomosed with the left common carotid artery, the left subclavian artery, and the innominate artery. The proximal end of the anastomosis was ventilated sequentially, after which the artificial vessel trunk was anastomosed with the ascending aorta followed by ventilation. Exhaust the air of the anastomosis, artificial blood vessels and lifting initiators, discharge the air of the anastomosis, with homeostasis, a drainage tube was inserted, and the operation was finished. (Fig. 2)

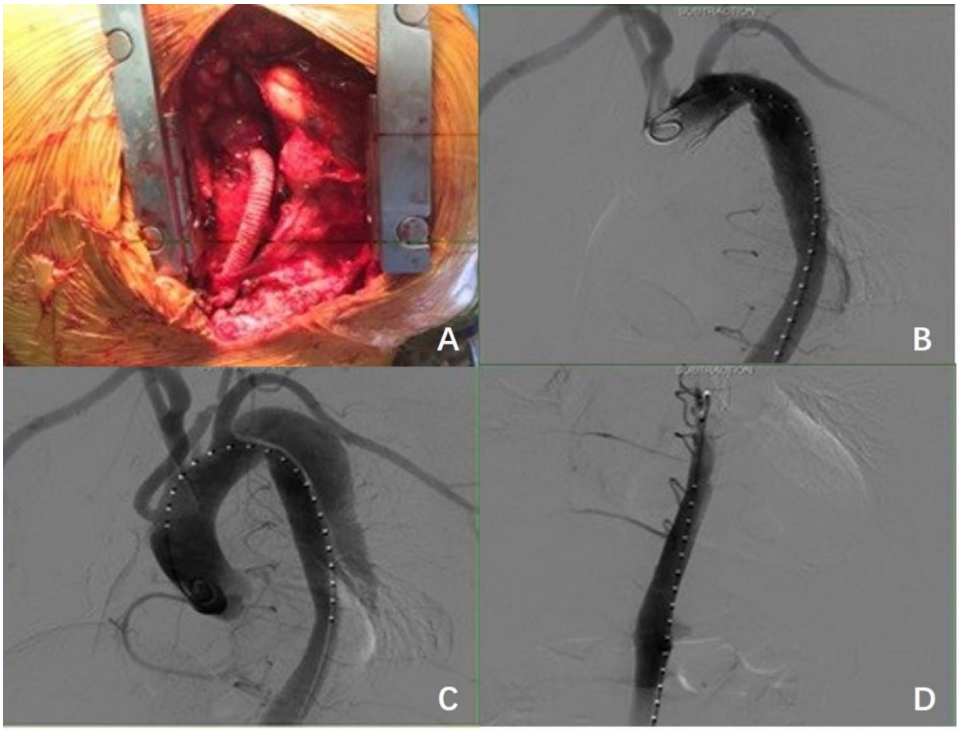

Fig. 1 The hybrid debranching technique (**A**: End-to-end anastomosis was conducted between the ascending portion of the autologous aorta and the proximal end of a four-branch artificial vessel, as well as the arch portion of the autologous aorta and the distal end of the four-branch artificial vessel (product of the MAQUET biocoat artificial vessel series). **B**, **C**, **D**: thoracic endovascular aortic repair (TEVAR))

Observation indicators

The surgical success rate (incidence of no serious complications in the perioperative period) of the two patients was counted. The intraoperative observation indicators were the operation duration, clamp time, CPB duration, the volume of blood transfusion (suspended red blood cells). The postoperative observation indicators included the ventilator application duration, duration of stay in the intensive care unit, aortic rupture, second thoracotomy due to hemorrhage, gastrointestinal hemorrhage, stroke, paraplegia, a renal failure that needed hemodialysis, and all-cause mortality. The follow-up indicators were as follows: the patients were followed up regularly at 3, 6, and 12 months after the operation, and the number of cases that underwent follow-up and complete thrombosis of the false aneurysm cavity detected by computed tomography angiography (CTA) was recorded.

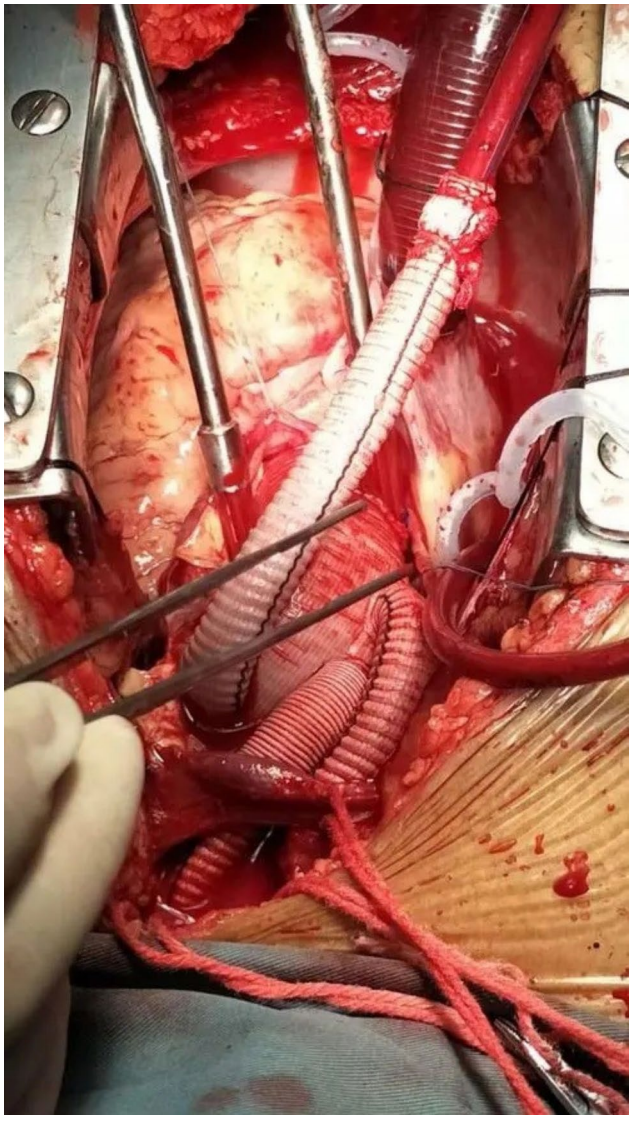

Fig. 2 Sun's operation (the total aortic arch replacement + "elephant trunk" stent implantationt)

Statistical analysis

The SPSS 23.0 was adopted for data analysis. The measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), and the independent samples t-test was adopted for comparison between groups. The countable data were expressed as rates, and the χ^2 test was used for comparison between groups. $P<0.05$ was considered statistically significant.

Results

Comparison of the surgical success rate between the two groups

Fifty cases (100%) had successful operations in the observation group, and fifty-four cases (100%) had successful operations in the control group. There were no cases with an unplanned secondary surgery.

Comparison of the related intraoperative and postoperative indicators between the two groups

The CPB duration, clamp time, operation duration, ventilator application duration, drainage volume within 24 h, duration of stay in the intensive care unit, and the postoperative length of hospital stay were all significantly lower in the observation group than in the control group ($P<0.001$ for all), while the difference in the volume of blood transfusion was not statistically significant between the two groups ($P=0.052$) (as shown in Table 2).

Comparison of the related follow-up indicators between the two groups

The proportion of cases with complete thrombosis of the false aneurysm cavity was significantly higher in the observation group than in the control group at 3 and 6 months after surgery ($P<0.05$). The difference still existed at 12 months after the operation, but the differences were not statistically significant ($P>0.05$ for all) (as demonstrated in Table 3).

Summary

In patients with acute Stanford type A AD involving the arch, the hybrid debranching technique was safe and effective. It was recommended for patients with advanced age and a high risk of intolerance to DHCA.

Discussion

Currently, Sun's operation is still widely applied for acute Stanford type A AD involving the aortic arch in clinical practice and is the procedure of choice for cardiovascular surgeons. However, an increasing number of cardiovascular surgery centers are choosing the hybrid debranching technique for patients with advanced age, combined

Table 2 Comparison of the related intraoperative and postoperative indicators between the two groups

	Observation group	Control group	t	*P*
Cardiopulmonary bypass duration (min)	110.36 ± 5.39	161.82 ± 14.48	-23.56	< 0.001
Aortic cross clamp (min)	57.62 ± 5.61	104.41 ± 2.97	-52.1	< 0.001
Operation duration(min)	363.21 ± 12.20	477.14 ± 14.71	-42.14	< 0.001
Lung ventilation duration (h)	57.15 ± 3.18	70.26 ± 3.00	-21.243	< 0.001
Drainage volume within 24 h(ml)	470.62 ± 11.13	784.05 ± 50.66	-42.75	< 0.001
Stay duration in the intensive care unit(d)	3.49 ± 0.29	3.83 ± 0.58	-3.717	< 0.001
Volume of blood transfusion(ml)	795.55 ± 65.62	824.83 ± 82.01	-1.971	0.052
Postoperative length of hospital stay(d)	9.02 ± 0.55	10.79 ± 0.78	-13.124	< 0.001

Table 3 Comparison of follow-up related indicators between the two groups

Complete thrombosis(%)	Three months after surgery	Six months after surgery	Twelve months after surgery
Observation group	40/50	42/48	38/43
	80%	87.50%	88%
Control group	27/51	23/47	29/47
	52.90%	48.90%	61.70%
P	<0.05	<0.01	<0.05

Note: The numerator was the number of cases with complete thrombosis of the false aneurysm cavity, and the denominator was the total number of patients who followed up

with multi-organ disease, and intolerance to DHCA. The hybrid debranching technique combines the advantages of traditional open thoracic surgery and percutaneous interventional surgery. This surgical style is free of DHCA while reducing surgical trauma and significantly shortening the overall operation duration, with better surgical effect and follow-up outcome than Sun's operation. Patients recover faster after surgery and have fewer complications [9–12]. According to the results in the present study, the surgical success rates were relatively good in both groups. Nevertheless, the operation duration, CPB duration, clamp time, ventilator application duration, drainage volume within 24 h, duration of stay in the intensive care unit, and the postoperative length of hospital stay was better in the observation group than in the control group, which was similar to the results of previous studies [13, 14]. The overall age of the patients in the observation group was significantly older than in the control group, and the overall LVEF was lower than in the control group, indicating that the patients in the observation group were relatively high-risk and less tolerant to trauma and DHCA. However, the surgical results in the observation group were significantly better than those in the control group, suggesting that the hybrid debranching technique was safe and effective.

Previous studies have shown that after surgical treatment of Stanford type A AD, patency of the false aneurysm cavity is an independent risk factor for dilatation of the descending aortic lesion, often predicting a poor long-term outcome and risk of secondary surgical intervention [15]. With the recent advances in medical science and technology, the treatment of Stanford type A AD has evolved from emergency life-saving in the early stage to focusing on the long-term results. Therefore, the degree of thrombosis of the false aneurysm cavity is crucial. Sun Lizhong's team improved Kato's elephant trunk stent and developed an independent intellectual property right of the elephant trunk stent artificial vessel, which greatly improved the rate of thrombosis of the false aneurysm cavity [16]. In addition to simplifying Sun's conventional operation, the hybrid debranching technique improves the thrombosis rate of the stent segment due to better adhesion of the interventional overmolded stent to the vessel compared with the artificial vessel of the elephant trunk stent [17]. The results of the present study showed that the thrombosis of the false aneurysm cavity was significantly better in the observation group than in the control group at 3 and 6 months after surgery, which indicates that the long-term clinical outcome might be better in the observation group.

Conclusion

In conclusion, the hybrid debranching technique was safe and effective in patients with Stanford type A AD combined with lesions in the aortic arch. However, it should be taken into account the fatigue-resistant durability and long learning curve of the overmolded stent, together with the fact that it is not a conventional surgical approach. But the hybrid debranching technique should still be preferentially recommended for those who are high-risk, have advanced age, and who cannot tolerate DHCA. Whether this procedure can be applied in patients with low- to medium-risk AD needs further confirmation.

Abbreviations

AD	Aortic dissection
CTA	Computed tomography angiography
DHCA	Deep hypothermic circulatory arrest
TEVAR	Thoracic endovascular aortic repair

LVEF Left ventricular ejection fraction
CPB Cardiopulmonary bypass

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Conception and design of the research: Jianjun Gu, Xiaochao Tian. Acquisition of data: Xiaochao Tian, Jiqiang Bu, Analysis and interpretation of the data: Jiqiang Bu, Ziying Chen. Statistical analysis: Jianjun Gu, Xiaochao Tian. Writing of the manuscript: Jianjun Gu Ziying Chen. Critical revision of the manuscript for intellectual content: Jiqiang Bu, Ziying Chen. All authors read and approved the final draft.

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Data availability
The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the declaration of Helsinki.This study was conducted with approval from the Ethics Committee of Second Hospital, Hebei Medical University.A written informed consent was obtained from all participants.

Consent for publication
Consent for publication was obtained from every individual whose data are included in this manuscript.

Competing interests
The authors declare no competing interests.

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