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Comparison of Standard Endovascular Repair and Chimney Graft for Juxtarenal Abdominal Aortic Aneurysm

Mingshan Wang[1], Huoying Cai[1], Zhen Liu[2], Lin Huang[1], Ruiming Liu[1], Siwen Wang[1], Yuansen Qin[1], Jin Cui[1], Guangqi Chang[1], Chen Yao[1], Shenming Wang[1], Jinsong Wang[3], Yu Zhou[1] and Zuojun Hu[1]

[1]Department of Vascular Surgery, National-Guangdong Joint Engineering Laboratory for Diagnosis and Treatment of Vascular Diseases, The First Affiliated Hospital, Sun Yat-Sen University, Guangzhou 510080, Guangdong, China

[2]Department of Vascular Surgery, Gansu Provincial Hospital, Lanzhou 730030, Gansu, China

[3]Department of Vascular and Plastic Surgery, Guangdong Provincial People's Hospital, 106 Zhongshan Second Road, Yuexiu District, Guangzhou City, 510055, China

Abstract

Objective: This study compared the efficacy of standard grafting (S-EVAR) and chimney grafting (Ch-EVAR) for treating juxtarenal abdominal aortic aneurysms (JAAA).

Methods: Data of patients with JAAA, who underwent S-EVAR and Ch-EVAR from January 2015 to December 2021, were collected. Follow-up was performed by CTA and intravascular ultrasonography of the aorta was performed before discharge, at 6 and 12 months postoperatively, and annually thereafter. Main outcome measures: AAA-related mortality, type Ia endoleak and reoperation.

Results: A total of 62 patients underwent S-EVAR and 23 underwent Ch-EVAR. The proportion of men who underwent S-EVAR (91.9%, 57/62) was higher than the proportion who underwent Ch-EVAR (69.6%, 16/23) ($p = 0.023$). The postoperative incidence rate of type Ia endoleak was lower in S-EVAR (9.7% vs. 13%, $p = 0.698$). Times for hospitalization, ICU monitoring, operation, and anesthesia, and perioperative bleeding were less in S-EVAR (12 vs. 17 days, 0 vs. 1 day, 122.5 vs. 220 min, 177.5 vs. 300 min, 50 vs. 100 mL, $p < 0.05$). In S-EVAR, a suprarenal aortic angle was associated with type Ia endoleak ($p = 0.016$). Median follow-up duration was 48 months, (range, 0-94 months) in the S-EVAR group and 42 months (range, 0-90 months) in the Ch-EVAR group. 1-year survival rate were (91.9% vs. 91.3%), 3-year survival rate (81.7% vs. 78.7%), 5-year survival rate (62.2% vs. 45.8%) were not statistically different. No significant differences were found in postoperative complications. The long-term patency rate of chimney stent was 100%.

Conclusions: The off-label use of S-EVAR for JAAA, with a straight and 8-10 mm aortic neck length, can be considered safe and effective. Ch-EVAR is more suitable for JAAA with excessive twisting of the neck (suprarenal aortic angle < 114°). In this study, long-term data of both technologies showed satisfactory results in preventing aneurysm rupture and the related mortality.

Keywords

Abdominal aortic aneurysm, Endoleak, Endovascular aneurysm repair, Postoperative complications, Treatment outcome

Introduction

Endovascular aneurysm repair (EVAR) has gradually replaced open surgical repair (OSR) for the treatment of abdominal aortic aneurysms (AAA) due to significantly lower mortality and complication rates compared to OSR [1,2]. However, EVAR is not indicated in certain AAA patients because of unsuitable anatomical characteristics. The ESVS guidelines define JAAA as an abdominal aneurysm with a short neck (< 10 mm) but not involving the renal arteries [3]. JAAA accounts for approximately 15% of all AAA [4]. According to the instructions for use (IFU) of the majority of manufacturers, the JAAA, due to its short neck < 10 mm, is not suitable for standard EVAR (S-EVAR). Therefore, various techniques, including fenestrated and branch stent technologies, have been used for endovascular treatment. However, the applicability of these techniques is limited by the anatomical characteristics of the neck, high costs, and lengthy manufacturing lead times [5]. Therefore; those techniques are unsuitable for emergency treatment of ruptured JAAA.

Greenberg, et al. [6] initially employed a combination of renal stents and an aortic stent graft for the management of JAAA. This technique does not need to be customized and can be combined with conventional stents according to a patient's specific requirement. Chimney EVAR (Ch-EVAR) has since become widely used in clinical practice. However, due to the "gutters" located between the aorta and the stent graft, the risk of a type Ia endoleak is relatively high, and the endoleak incidence rate continues to rise with increasing numbers of reconstructed visceral vessels. The reported perioperative endoleak incidence rate of Ch-EVAR is > 14% [7].

Some authors suggested using off-label standard stents to treat JAAA in patients who are unfit for OR [7]. Few papers have reported the early clinical results with small cohorts of S-EVAR for JAAA [8].

Until now, no retrospective series have compared S-EVAR and Ch-EVAR for JAAA. Therefore, this study aimed to compare the clinical outcomes of S-EVAR and Ch-EVAR for JAAA.

Methods

Patients

All consecutive patients with JAAA were treated with S-EVAR or Ch-EVAR between January 2015 and December 2021 in a tertiary vascular unit (Department of Vascular Surgery, the First Affiliated Hospital of Sun Yat-sen University, and Guangzhou, China). This research follows the principles outlined in the Declaration of Helsinki and informed consent was obtained from all participants. Ethical approval for this study was obtained from the Independent Ethics Committee for Clinical Research and Animal Trials of the First Affiliated Hospital of Sun Yat-sen University at the commencement of this study.

Inclusion criteria

JAAA including short-necked infrarenal (< 10 mm) and juxtarenal. The choice between S-EVAR and Ch-EVAR was determined by clinical and anatomic characteristics. Patients who required reconstruction of branch vessel were considered to be treated by Ch-EVAR.

Exclusion criteria

(1) Ruptured or near-ruptured JAAA requiring emergency surgery, (2) AAA caused by inflammation, infection, or other causes, and (3) Aortic pseudo aneurysm or dissection.

Preoperative assessment

All patients were assessed by performing computed tomography angiography (CTA) preoperatively.

Definitions

Chronic obstructive pulmonary disease was defined as FEV1/FVC < 70%. Hypertension, coronary heart disease and diabetes were identified in patients receiving medical treatment for these conditions. Renal function was graded according to serum creatinine values from I to V (I: < 133 mmol/L, II: 133-177 mmol/L, III: 177-443 mmol/L, IV: 443-707 mmol/L, V: > 707 mmol/L). Renal insufficiency refers to serum creatinine values > 133 mmol/L [9].

The α neck angle was defined as the angle between the suprarenal aortic and the infrarenal neck. The β neck angle was defined as the angle between infrarenal neck and the aneurysm. Severe calcification or thrombosis was defined as ≥ 50% of the neck circumference according to the study by Chaikof, et al. [10]. The conical neck was defined as being within 10 mm below the level of the renal artery, with the abdominal aorta diameter dilated ≥ 2 mm.

S-EVAR procedure

The patient was placed in the supine position under general anesthesia, a longitudinal incision was made at the pulsating femoral arteries on both sides of the groin, and the femoral arteries were punctured using the Seldinger method. Digital subtraction angiography was performed to determine anatomical characteristics, and the origin of major branches of the abdominal aorta. In combination with the preoperative imaging examination, this allowed the corresponding specification of the covered stent to be selected, and the main stent was delivered slowly to the proximal neck anchoring area through the femoral artery. After cannulation of the contra lateral iliac gate, the iliac limb was inserted through the opposite side of the guide wire and deployed. Angiography was performed again to identify a potential endoleak. If an Ia endoleak was found, balloon dilation optimized the sealing of the end graft. If there is a still significant Ia endoleak after balloon dilation, we will insert chimney stents to extend t proximal anchoring area and cuff was implanted proximal to the main stent to eliminate the Ia endoleak. The main stents used were the Endurant (Medtronic, Minneapolis, MN, USA), Excluder (Gore Medical, Flagstaff, AZ, USA), Sinus XL (Optimed Medical Instruments GmbH, Ettlingen, Germany), Huamai Tianzhuo (Huaimai Taike Medical Device Co., Ltd., Beijing, China), and Minos (Micro Port Endovascular MedTech Group Co., Ltd., Shanghai, China). The over sizing used for the main stent was between 20% and 30%, according to the neck diameter and angles. The most frequently used stent design in the S-EVAR group was a Endurant (Medtronic, USA) (39 of 62).

Ch-Evar procedure

This was performed as for the S-EVAR, but we used a left

***Corresponding author:** Zuojun Hu and Yu Zhou, Department of Vascular Surgery, National-Guangdong Joint Engineering Laboratory for Diagnosis and Treatment of Vascular Diseases, The First Affiliated Hospital, Sun Yat-Sen University, 58 Zhongshan 2nd road, Yuexiu District, Guangzhou 510080, Guangdong, China, Tel: +8613802536796; +8615626498866

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brachial artery approach and inserted chimney stents before delivering the main aortic stent. Chimney stents include: Viabhan (Gore, USA), Omnilink Elite (Abbott, USA), Absolute (Abbott, USA), Protege GPS (EV3, USA), Innova (Boston Scientific, USA), Pulsar-18 (BioTronic, German). The most frequently used chimney stent was a Viabhan (Gore, USA) (17 of 23). The chimney grafts usage data are presented in Table 1.

Follow-up protocol

CTA and intravascular ultrasonography of the aorta were performed before discharge, at 6 and 12 months postoperatively, and annually thereafter.

Statistical analysis

Statistical evaluation was performed using SPSS software version 23 (IBM Corp., Armonk, NY, USA). When appropriate, categorical variables were analyzed using the chi-squared test or Fisher's exact test; continuous variables were analyzed using the Student's t-test or Mann-Whitney U test. Time-to-event analysis was performed using Kaplan-Meier curves for overall survival. Logistic regression was used to analyze the relationship between anatomical characteristics of the neck and complications. The p-values were then determined; the significance level was $p < 0.05$.

The Yoden index was used to calculate the critical value of the proximal neck angulation. The Yoden index = sensitivity + specificity - 1, ranging from 0 to 1. The greater the Yoden index, the better the effect of the screening test; the critical diagnostic value of this method is the value of the test variable corresponding to its maximum value.

Table 1: The effect of different brand stents on type Ia endoleak in S-EVAR and Ch-EVAR.

Brand	S-EVAR (n = 62)	Ch-EVAR (n = 23)
Gore	2/10 (3.2)	2/12 (8.7)
Medtronic	4/39 (6.5)	1/10 (4.3)
Optimed	0/1 (0)	-
Huaimai Taike	0/11 (0)	0/1 (0)
Micro Port Endovascular	0/1 (0)	-
p-value	0.588	1.000

Numbers indicate n (%). EVAR: Endovascular Aneurysm Repair, S: Standard, Ch: Chimney.

Results

Patient characteristics

A total of 85 patients were enrolled: 63 patients (57 of whom were men) underwent S-EVAR and 23 (16 men) underwent Ch-EVAR. The demographic characteristics and underlying diseases of the patients are detailed in Table 2. The proportion of men who underwent S-EVAR (91.9%, 57/62) was greater compared with the proportion who underwent Ch-EVAR (69.6%, 16/23) ($p = 0.023$). In addition, significant differences were found between the S-EVAR group and Ch-EVAR group in smoking (59.7% vs. 4.3%) and alcohol consumption (16.1% vs. 56.5%) ($p < 0.01$). However, differences between the two groups in age and underlying diseases were not significant.

Table 2: Clinical data.

Variable	S-EVAR (n = 62)	Ch-EVAR (n = 23)	p-value
Age, years	72.1 ± 7.3	72.3 ± 7.5	0.949
Male, n (%)	57 (91.9)	16 (69.6)	0.023
Underlying disease, n (%)			
Hypertension	40 (64.5)	16 (69.6)	0.663
Coronary heart disease	15 (24.2)	6 (26.1)	0.857
Diabetes	6 (9.7)	2 (8.7)	1.000
Renal insufficiency			1.000
CKD1	0 (0.0)	0 (0.0)	-
CKD2	1 (1.6)	0 (0)	1.000
CKD3	2 (3.2)	1 (4.3)	1.000
CKD4	1 (1.6)	0 (0)	1.000
CKD5	1 (1.6)	0 (0)	1.000
Peripheral vascular disease	2 (3.2)	1 (4.3)	1.000
COPD	6 (9.7)	0 (0)	0.184
Cancer	4 (6.5)	4 (17.4)	0.264
Smoking	37 (59.7)	1 (4.3)	< 0.001
Drinking	10 (16.1)	13 (56.5)	< 0.001

Numbers indicate n (%) or mean ± standard deviation. EVAR: Endovascular Aneurysm Repair; S: Standard; Ch: Chimney; COPD: Chronic Obstructive Pulmonary Disease; CKD: Chronic Kidney Disease

Table 3: Abdominal aortic aneurysm anatomic data.

Variable	S-EVAR (n = 62)	Ch-EVAR (n = 23)	p-value
Aortic aneurysm length, mm	110.4 ± 30.9	124 ± 22.3	0.058
Aortic aneurysm diameter, mm	57.2 ± 15.9	65.4 ± 12.1	< 0.05
Aortic neck diameter, mm	26.05 ± 0.49	27.49 ± 0.78	0.124
Aortic neck length, mm	8.09 ± 0.12	5.9 ± 0.34	< 0.001
Aortic neck angle (α), °	162.9 ± 26	149.5 ± 29.6	0.045
Aortic neck angle (β), °	144.1 ± 31	119.5 ± 31.6	< 0.001
Conical neck, n (%)	14 (22.6)	3 (13)	0.502
Calcification/thrombus, n (%)	5 (8.1)	1 (4.3)	1.000
Common iliac artery involvement, n (%)			0.649
Unilateral	10 (16.1)	2 (8.7)	
Bilateral	21 (33.9)	8 (34.8)	
External iliac artery involvement, n (%)			0.617
Unilateral	1 (1.6)	1 (4.3)	
Bilateral	1 (1.6)	0 (0)	
Internal iliac artery involvement, n (%)			0.735
Unilateral	8 (12.9)	2 (8.7)	
Bilateral	6 (9.7)	1 (4.3)	

Numbers indicate n (%) or mean ± standard deviation. EVAR: Endovascular Aneurysm Repair, S: Standard, Ch: Chimney.

Table 4: Intraoperative and hospitalization-related data.

Variable	S-EVAR (n = 62)	Ch-EVAR (n = 23)	p-value
Anesthetic time (min)	177.5 (80,730)	300 (160,720)	< 0.001
Operative time (min)	122.5 (55,700)	220 (120,635)	< 0.001
Intraoperative bleeding (mL)	50 (5,1000)	100 (10,800)	< 0.001
Blood transfusion (mL)	0 (0,920)	0 (0,1320)	0.497
Hospitalization time (days)	12 (5,37)	17 (7,34)	0.016
ICU monitoring time (days)	0 (0,7)	1 (0,6)	0.013

Numbers indicate the median (min, max). EVAR: Endovascular Aneurysm Repair, S: Standard, Ch: Chimney.

JAAA anatomic data

In S-EVAR and Ch-EVAR groups, the neck length (8.09 ± 0.12 vs. 5.9 ± 0.3 mm), neck diameter ((26.05 ± 0.49 vs. 27.49 ± 0.78 mm), aneurysm diameter (57.2 ± 15.9 vs. 65.4 ± 12.1 mm), suprarenal angle (162.9 ± 26° vs. 149.5 ± 29.6°), infrarenal angle (144.1 ± 31° vs. 119.5 ± 31.6°). The anatomical data for JAAA are shown in Table 3.

Intraoperative stent usage

The stents used in this study were the Endurant (Medtronic, Minneapolis, MN, USA), Excluder (Gore Medical, Flagstaff, AZ, USA), Sinus XL (Optimed Medical Instruments GmbH, Ettlingen, Germany), Huamai Tianzhuo (Huaimai Taike Medical Device Co., Ltd., Beijing, China), and Minos (Micro Port Endovascular MedTech Group Co., Ltd., Shanghai, China). The analysis indicated no significant differences in the incidence of type Ia endoleak in different main body end graft brands ($p > 0.05$). The effects of different brands of stents on type Ia endoleak in S-EVAR and Ch-EVAR are listed in Table 1.

Intraoperative and hospitalization-related data

Intraoperative and hospitalization-related data are presented in Table 4. The S-EVAR group was superior to the Ch-EVAR in terms of hospitalization time, ICU monitoring time, operation time, anesthesia time, and perioperative bleeding ($p < 0.05$).

Perioperative events

The perioperative events are listed in Table 5. In S-EVAR there were three (4.8%) type Ia endoleak. One underwent conversion to OR for AAA rupture at 7 days and died (1/62, 1.6% proximal neck -related mortality). Two were follow-up observations due to minor type Ia endoleak. Among them, one sealed by endovascular repair at 12 months and another one continued observing. Another one (1.6%) patient was performed reintervention (Iliac leg extension) due to type Ib endoleak at 3 days.

In Ch-EVAR there were three (13%) type Ia endoleak. All of them were follow-up observations in view of minor type Ia

Table 5: Perioperative events.

Variable	S-EVAR (n = 62)	Ch-EVAR (n = 23)	p-value
Perioperative death, n (%)	1 (1.6)	0 (0)	1.000
Perioperative reoperation, n (%)	2 (3.2)	3 (13)	0.113
Perioperative operative complications, n (%)			
Heart	0 (0)	2 (8.7)	0.071
Brain	1 (1.6)	0 (0)	1.000
Lung	0 (0)	0 (0)	-
Kidney			
CKD1	0 (0)	0 (0)	-
CKD2	0 (0)	0 (0)	-
CKD3	1 (1.6)	0 (0)	1.000
CKD4	0 (0)	0 (0)	-
CKD5	0 (0)	0 (0)	-
Liver	0 (0)	0 (0)	-
Intestine	0 (0)	0 (0)	-
MODS	0 (0)	0 (0)	-
Bleeding	2 (3.2)	1 (4.3)	1.000
Endoleak			0.019
Ia	3(4.8)	3 (13)	0.295
Ib	1 (1.6)	0 (0)	1.000
II	2 (3.2)	2 (8.7)	0.295
III	1 (1.6)	2 (8.7)	0.177
IV	0 (0)	0 (0)	-
Stent migration/ fracture	0 (0)	0 (0)	-
Stent graft infections	0 (0)	0 (0)	-
Limb graft occlusion	1 (1.6)	1 (4.3)	0.470
Other	3 (4.8)	1 (4.3)	1.000

Numbers indicate n (%). EVAR: Endovascular Aneurysm Repair; S: Standard; Ch: Chimney; COPD: Chronic Obstructive Pulmonary Disease; CKD: Chronic Kidney Disease; MODS: Multiple Organ Dysfunction Syndrome

endoleak. Among them, one sealed by endovascular repair at 6 months. Another three (13%) patients were performed reoperation, including a pseudo aneurysm of the left brachial artery at 10 days, a right renal hemorrhage at 7 days and a right femoral artery thrombosis at 1 day. The chimney grafts usage and reconstruction of branching arteries are presented in Table 6.

Follow-Up mortality and complications

Follow-up mortality and complications are summarized in Table 7. Median follow-up duration was 48 months, (range, 0-94 months) in the S-EVAR group and 42 months (range, 0-90 months) in the Ch-EVAR group.

In S-EVAR there were three (4.8%) type Ia endoleak. Two were sealed by endovascular repair at 18 and 24 months. One rejects reoperation at 36 months. And there were two aneurysm-related deaths in the S-EVAR group; one death was due to a postoperative stent extrusion that led to JAAA rupture at 11 month, and one patient died of sepsis due to stent infection 1 month after surgery. There were 5 of 62 (11.3%) reinterventions during follow-up including: 2 type Ia endoleak, 2 type II endoleak, and 1 type Ib endoleak.

No new type Ia endoleak and aneurysm-related deaths occurred in the Ch-EVAR group. There were 2 of 23 (%) reinterventions during follow-up including: 1 type Ia endoleak, 1 type II endoleak. The patency rate of chimney stent was 100%.

Analysis of factors related to type Ia endoleak

The incidence of type Ia endoleak following S-EVAR was

Table 6: Date of chimney grafts usage and reconstruction of branching arteries.

	No. (%)
Reconstructed renal arteries	
left renal artery	12(52.2)
right renal artery	7(30.4)
bilateral renal artery	4(17.4)
Reconstructed SMA	1(4.3)
Chimney grafts	
Viabhan (Gore, USA),	17(73.9)
Omnilink Elite (Abbott, USA)	1(4.3)
Absolute (Abbott, USA)	1(4.3)
Protege GPS (EV3,USA)	1(4.3)
Pulsar-18 (BioTronic, German)	3(13)
Innova (Boston Scientific, USA)	1(4.3)

SMA: Superior Mesenteric Artery.

negatively associated with the α neck angle. Patients with type Ia endoleak had a smaller α neck angle. The Yoden index calculated a critical value of 114° for the α neck angle in the S-EVAR. When the α neck angle was < 114°, the incidence of type Ia endoleak following S-EVAR was significantly higher than that in patients with angles > 114°: 50% vs. 6.9%, (p = 0.005) (Table 8).

In contrast, the incidence of type Ia endoleak in the Ch-EVAR was not related to the proximal neck (Table 9).

Survival analysis

The estimated overall survival rates were similar in both groups (Figure 1). S-EVAR 1-year survival rate were 91.9%, 3-year survival rate 81.7%, 5-year survival rate 62.2%, respectively. The Ch-EVAR 1-year survival rate 91.3%, 3-year survival rate 78.7%, 5-year survival rate 45.8%, all lower than those of S-EVAR. But the difference was not statistically significant (P = 0.288).

Table 7: Follow-up mortality and morbidity.

Variable	S-EVAR (n = 62)	Ch-EVAR (n = 23)	p-value
Follow-up period death, n (%)	17 (27.4)	9 (39.1)	0.298
Follow-up period reoperation, n (%)	5 (9.7)	2 (8.7)	1.000
Follow-up period operative complications, n (%)			
Heart	1 (1.6)	0 (0)	1.000
Brain	1 (1.6)	1 (4.3)	0.470
Lung	0 (0)	0 (0)	-
Kidney			1.000
CKD1	0 (0)	0 (0)	-
CKD2	1 (1.6)	0 (0)	1.000
CKD3	2 (3.2)	0 (0)	1.000
CKD4	2 (3.2)	1 (4.3)	1.000
CKD5	2 (3.2)	1 (4.3)	1.000
Liver	0 (0)	0 (0)	-
Intestine	0 (0)	0 (0)	-
Endoleak			0.192
Ia	3 (4.8)	0(0)	0.083
Ib	1 (1.6)	2 (8.7)	0.177
II	2 (3.2)	3 (13)	0.120
III	0 (0)	0 (0)	-
IV	0 (0)	1 (4.3)	0.271
Stent migration/fracture	0 (0)	0 (0)	-
Stent graft infections	1 (1.6)	0 (0)	1.000
Limb graft occlusion	1 (1.6)	0 (0)	1.000
Other	1 (1.6)	0 (0)	1.000

Numbers indicate n (%). EVAR: Endovascular Aneurysm Repair; S: Standard; Ch: Chimney; CKD: Chronic Kidney Disease

Table 8: Analysis of factors related to Ia endoleak in S-EVAR.

	Univariate				Multivariate		
Variable	**OR**	**95%CI**	**P**		**OR**	**95%CI**	**P**
Aortic neck diameter	2.43	1.04-5.26	0.039		-	-	-
Aortic neck length	1.71	0.58-5.05	0.328		-	-	-
Aortic neck angle (α)	0.97	0.94-0.99	0.016		0.97	0.94-0.99	0.016
Aortic neck angle (β)	0.96	0.93-1	0.042		-	-	-
Conical neck	1.83	0.3-11.24	0.512		-	-	-
Calcification/thrombus	2.60	0.24-27.98	0.431		-	-	-

CI: Confidence Interval; OR: Odds Ratio

Table 9: Analysis of factors related to Ia endoleak in Ch-EVAR.

	Univariate				Multivariate		
Variable	**OR**	**95%CI**	**P**		**OR**	**95%CI**	**P**
Aortic neck diameter	0.75	0.52-1.07	0.116		-	-	-
Aortic neck length	1.22	0.63-2.34	0.561		-	-	-
Aortic neck angle (α)	1.02	0.97-1.08	0.391		-	-	-
Aortic neck angle (β)	1.02	0.98-1.06	0.324		-	-	-
Conical neck	-	-	1		-	-	-
Calcification/thrombus	-	-	1		-	-	-

CI: Confidence Interval; OR: Odds Ratio

Discussion

In this study, we compared the perioperative and follow-up results of S-EVAR and Ch-EVAR and found no statistical differences in type Ia endoleak, AAA-related mortality and reoperation.

Performing Ch-EVAR for the treatment of JAAA was first reported by Greenberg, et al. [6] in 2003 and has achieved good results by effectively maintaining the blood supply to the branch artery. Studies have shown that the long-term patency rate of renal artery chimney stents exceeds 97% [11]. In contrast to fenestrated and branch stent technologies, Ch-EVAR does not require customization based on the vascular anatomical characteristics of each patient. They can be combined with conventional stents according to specific patient requirements and are suitable for emergency surgery or AAA patients with perioperative emergencies. They are relatively easy to use and widely used in clinical practice. However, the gap between the chimney stent, main stent, and aortic wall results in a relatively high risk of type Ia endoleak.

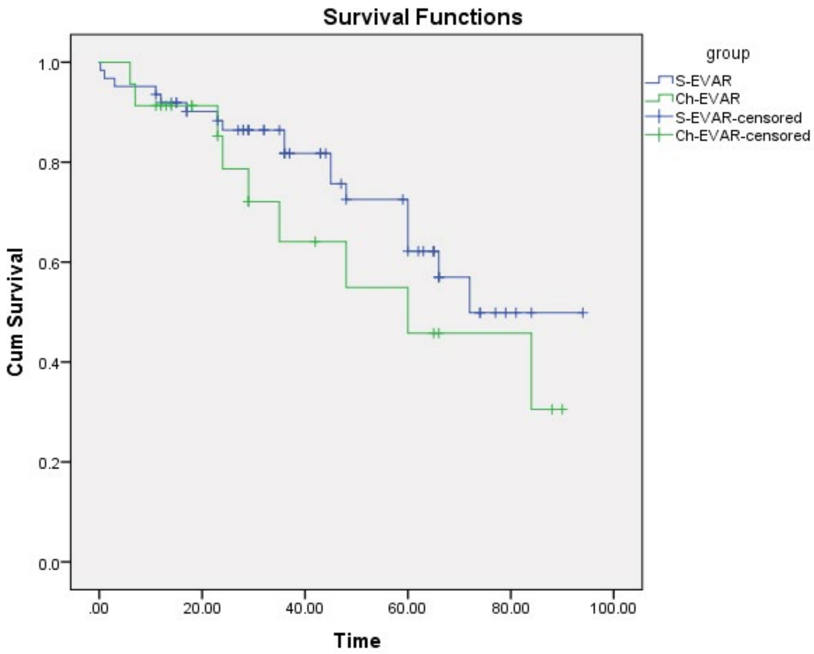
The Protagoras study [12] included 128 patients with 187 implanted chimney stents (160 RA, 15 ARA, 10 SMA, and 2 CA), with a 30-day mortality rate of 0.8%, an average follow-up of 24.6 months, and a type Ia endoleak rate of 1.6%. The primary and secondary intervention rates were 95.7% and 93.1%, respectively. Therefore, postoperative complications, such as type Ia endoleak and renal insufficiency, remain an issue following Ch-EVAR. In addition, Ch-EVAR has certain requirements for the operator's intracavity technology and costs 2-3 times more than S-EVAR.

With continuous improvements in endovascular repair instruments and increasing endovascular experience, the surgical indications for S-EVAR have gradually increased. Greenberg, et al. [7,13] indicated that challenging aortic anatomy and short proximal neck are not contraindications to EVAR in patients. Recently, Gallitto, et al. [14]. reported that EVAR may be safely performed in JAAA (outside the IFU) by use of suprarenal fixation stents.

Matsagkas, et al. [15] compared the clinical effects of the Endurant stent in AAAs with short (< 10 mm) and long aneurysm necks. Except for a small aneurysm neck angle in the short aneurysm neck group, no type I endoleak was observed in either group during the follow-up period. Furthermore, no significant differences were found between the two groups for secondary intervention or aneurysm-related mortality. This finding indicates that even if the patient's aneurysm neck length is less than 10 mm, as long as the aneurysm neck is not too twisted, an Endurant stent can achieve good clinical results.

The advantage of one technique over another is unclear because of the scarcity of reports comparing these two techniques. The most relevant reports are on the short- and long-term effects of S-EVAR and Ch-EVAR, respectively; comparative studies between the two surgical methods are lacking.

Therefore, current evidence is insufficient for determining which is the most appropriate method for the treatment of JAAA. Some experts may choose Ch-EVAR because of its theoretical superiority; others may prefer S-EVAR to avoid potential technical difficulties and type Ia endoleaks. At our institution, most patients who undergo S-EVAR have longer



Months	12	36	60
N at risk in S-EVAR	56	35	18
N at risk in Ch-EVAR	21	12	5

Figure 1: Survival analysis: The estimated overall survival rates were similar in both groups (Figure 1). S-EVAR 1-year survival rate were 91.9%, 3-year survival rate 81.7%, 5-year survival rate 62.2%, respectively. The Ch-EVAR 1-year survival rate 91.3%, 3-year survival rate 78.7%, 5-year survival rate 45.8%.

neck lengths, smaller neck diameters and bigger suprarenal or infrarenal aortic angles. This study aimed to provide data to aid in deciding between S-EVAR and Ch-EVAR for the treatment of JAAA.

In this study, all early- and long-term analyses showed no significant difference in the rate of AAA-related mortality, type Ia endoleak and reoperation between the two groups despite (1) Smaller suprarenal and infrarenal aortic angles in Ch-EVAR, (2) Longer neck length in the S-EVAR group.

In our study, S-EVAR had advantages over Ch-EVAR in terms of hospitalization time, ICU monitoring time, operative time, anesthesia time, and perioperative bleeding. Therefore, S-EVAR is a safe and effective treatment method for patients with JAAA who are generally poor and have difficulty tolerating a long operation time.

Renal insufficiency is another important factor; the incidence is 1-23% [16]. Several reasons for postoperative renal insufficiency after EVAR have been suggested: (1) Renal injury caused by the large amounts of contrast used during surgery, and (2) Renal ischemia caused by suprarenal fixation or renal artery stent occlusion. In the current study, the incidence of postoperative renal injury in both groups of patients was low (S-EVAR: 12.9%; Ch-EVAR: 8.7%; p>0.05). Ch-EVAR may be a better option to prevent renal insufficiency.

Compared with S-EVAR, Ch-EVAR is more suitable for JAAA involving a short neck length (< 5 mm) and excessive twisting of the neck (suprarenal aortic angle < 114°). In this study, 23 patients underwent Ch-EVAR to reconstruct 28 branching arteries (20 renal arteries and 1 superior mesenteric artery). Postoperative the type Ia endoleak was 13% which were satisfactory and consistent with the results reported internationally [17-19]. Meanwhile the long-term follow-up results of our center showed that the patency rate of chimney stent was 100%, which may be related to our adherence to long-term postoperative antiplatelets therapy.

This study was a retrospective study, and there was some bias in case selection. The heterogeneity of patient basic condition, diagnosis and lesion range interfered with the results to some extent. The patient of the Ch-EVAR is relatively small, and the evaluation of the outcome is not comprehensive, and the long-term follow-up results need to be further confirmed.

Conclusion

The off-label use of S-EVAR for JAAA, with a straight and 8-10 mm aortic neck length can be considered safe and effective. Ch-EVAR is more suitable for JAAA with excessive twisting of the neck (suprarenal aortic angle <114°). In this study, long-term data of both technologies showed satisfactory results in preventing aneurysm rupture and the related mortality.

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Author Contributions

Yu Zhou and Zuojun Hu had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: Mingshan Wang, Zhen Liu. Acquisition, analysis, or interpretation of data: Mingshan Wang, Zhen Liu, Huoying Cai, Lin Huang, Ruiming Liu, Siwen Wang, Yuansen Qin, Jin Cui. Drafting of the manuscript: Mingshan Wang, Zhen Liu. Critical revision of the manuscript for important intellectual content: Yu Zhou, Zuojun Hu. Statistical analysis: Mingshan Wang, Zhen Liu, Huoying Cai, Yu Zhou. Administrative, technical, or material support: Jinsong Wang, Guangqi Chang, Chen Yao, Shenming Wang, Yu Zhou, Zuojun Hu. Supervision: Yu Zhou, Zuojun Hu. All authors read and approved the final manuscript. Mingshan Wang, Huoying Cai and Zhen Liu contributed equally to this article and share co-first authorship.

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