Surgical Technique

Aneurysmal size reduction in the Kommerell diverticulum by stent graft-based therapy

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Abstract: Kommerell diverticulum (KD) with an aberrant subclavian artery is a rare congenital anomaly that often resembles a saccular aneurysm. Open surgery is the traditional treatment; however, recent reports have suggested success with endovascular or hybrid approaches. This study aimed to show the results of stent graft-based treatment and demonstrate the aneurysmal reduction rate in KD. Five patients with KD underwent stent graft-based therapy at the Osaka Metropolitan University Hospital between May 2009 and February 2024. Patient data and KD measurements were retrospectively analyzed using computed tomography scans. Two indices were measured to assess the size of the KD: (I) the distance from the tip of the KD to the opposite aortic wall (DAW), which is often used to assess KD size; (II) the height of the KD from the original virtual normal aortic wall, as in the evaluation of saccular aneurysms. The mean observation period after surgery was 62.4±36.9 months. Postoperative remodeling of the KD was assessed in these five cases. One patient underwent 1-debranch thoracic endovascular aortic repair, and four patients underwent the frozen elephant trunk (FET) technique via median sternotomy. On average, DAW was reduced to 76.1%±9.5% and the height of KD, the height of the protrusion from the normal aortic wall, was reduced to 31.0%±23.8%. None of the five cases required rehospitalization or reintervention. None of the patients died, and the KD was greatly reduced in size. Treatment using stent grafts greatly reduced the size of the KD. Decompression of KD is likely to lead to remodeling of the aortic wall, which constitutes KD.

Keywords: Frozen elephant trunk (FET); Kommerell diverticulum (KD); height of Kommerell diverticulum; stent graft

Submitted Oct 11, 2024. Accepted for publication Jan 10, 2025. Published online Feb 25, 2025.
doi: 10.21037/jtd-24-1709
View this article at: https://dx.doi.org/10.21037/jtd-24-1709

Introduction

Background

Kommerell diverticulum (KD) with an aberrant subclavian artery (ASCA) is a rare congenital vascular anomaly that is often dilated like an aneurysm (1,2). KD is estimated to occur in 0.04–2.0% of the population. Approximately 20–60% of individuals with ASCA have associated KD. The most common configuration associated with KD is an aberrant right subclavian artery (ARSA) arising from the left-sided aortic arch (53–63%), followed by an aberrant left subclavian artery (ALSA) arising from the right-sided aortic arch (37–47%) (3-5). Many patients with KD remain asymptomatic and are diagnosed incidentally. However, some patients may present with symptoms such as dysphagia lusoria caused by anatomical compression of the esophagus

by an enlarged KD (3). Patients with KD are at risk of aortic rupture (4–19%) or dissection (11–53%) (3,6,7).

Rationale

Historically, open surgery has been the most common treatment; however, recent reports have often included case reports of endovascular or various hybrid treatments (8-12). In recent years, large-sample reports, including review articles on the outcomes of KD treatment, have been published (5,13-16). The conclusions of these reports are nearly identical: open, endovascular, and hybrid approaches for patients with KD have higher success rates and lower mortality risks. Therefore, given the high probability of symptom relief and safety regardless of the treatment strategy, the decision regarding which intervention to use should be based on patient factors, such as age, symptoms, anatomy, and comorbidities (5,13,14). However, these conclusions focused specifically on mortality, complication rates, and avoidance of re-intervention, and there is no description of how the KD size changes in the distant phase in cases with stent grafts, including hybrid procedures.

Objective

This study aimed to present the results of stent graft-based treatment and demonstrate the reduction rate of KD. We present this article in accordance with the SUPER reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1709/rc).

Highlight box

Surgical highlights

- Kommerell diverticulum (KD) tends to shrink greatly, and in some cases disappear, when decompressed by treatment with stent grafts.

What is conventional and what is novel/modified?

- There are many reports on the treatment for KD; however, no studies have reported the changes in the size of KD after treatment with a stent graft.
- This study was able to more accurately assess the changes in the size of KD by measuring its height, in addition to the commonly used distance from aneurysm to the opposite aortic wall. The native aorta expanded due to the radial force of the stent graft.
- Evaluating the height of KD eliminated the influence of the expansion of the native aorta, which proved useful for size assessment.

What is the implication, and what should change now?

- There is a high likelihood that KD will greatly shrink or disappear following stent graft treatment.
- Therefore, it is necessary to select the most optimal and minimally invasive treatment, including stent graft therapy, tailored to individual patient.

Preoperative preparations and requirements

Setting

Between May 2009 and February 2024, five patients who underwent stent graft-based therapy for KD at the Osaka Metropolitan University Hospital were retrospectively reviewed. There are no surgical criteria for dilated KD that mandate intervention. Although the presence of symptoms is an accepted indication, size criteria for operation are undefined. KD is not frequent but can cause rupture or aortic dissection, so surgery is customarily recommended at our institution after careful assessment of the patient's condition if the distance from the tip of the KD to the opposite aortic wall (DAW) reaches approximately 50 mm, even if the patient is asymptomatic. This is in accordance with the surgical criteria for aortic aneurysms and is not based on any evidence. These five patients were operated on because the DAW was over 50 mm at diagnosis or approaching 50 mm with a tendency towards enlargement. *Table 1* summarizes the preoperative characteristics of the patients with stent grafts. The mean age of patients was 68.2±10.5 years. Two patients had a left-sided aortic arch with an ARSA and three patients had a right-sided aortic arch with an ALSA.

Measurement of KD using computed tomography (CT)

Each CT image was reanalyzed and KDs were measured according to the method described by Idrees *et al.* (6). These measurements are shown in *Figure 1*, including DAW. Additionally, the height of the KD was measured, which is the height of the protrusion from the normal aortic wall, as measured in saccular aneurysms. A virtual aortic perimeter was created by extending the normal aortic wall opposite the KD, referring to the adjacent slice of the CT scan so that it followed seamlessly (*Figure 1*). Contrast-enhanced CT scans were performed preoperatively in all surgical candidates to determine aneurysm size and surgical risk. At our institution, one of the criteria for surgical indication for KD is a DAW ≥50 mm and a rapid enlargement trend.

Ethics

This study was conducted in accordance with the

Table 1 Preoperative characteristics

Patient number	Age (years)	Side of arch	ASCA	Symptom	DAW (mm)	KD expansion trend	Preoperative complication
1	50	Right	Left	None	50.1	+	HT, DM, schizophrenia
2	68	Right	Left	None	48.5	–	HT, DM, post CABG
3	66	Right	Left	None	68.4	+	HT
4	79	Left	Right	None	58.1	+	HT, DL
5	78	Left	Right	None	49.9	–	HT, DM, DL, prostate cancer

KD expansion tendency was indicated as +, while absence was indicated as –. ASCA, aberrant subclavian artery; CABG, coronary artery bypass grafting; DAW, distance to the opposite aortic wall; DL, dyslipidemia; DM, diabetes mellitus; HT, hypertension; KD, Kommerell diverticulum.

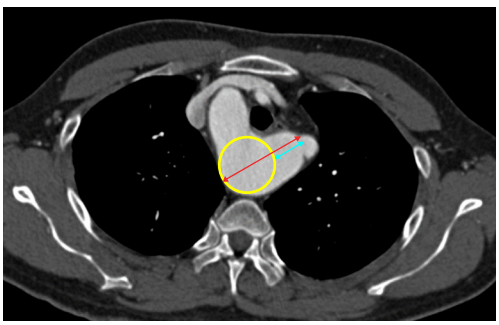

Figure 1 The measurement sites of the KD are shown in the computed tomographic image. The DAW is indicated by the red double-headed arrow. The height of KD is indicated by the blue double-headed arrow. The yellow circle indicates the estimated native aortic diameter. DAW, distance to the opposite aortic wall; KD, Kommerell diverticulum.

Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Osaka Metropolitan University Graduate School of Medicine, Osaka, Japan (No. 2024-023), and informed consent was taken from all the patients.

Step-by-step description

At our institution, patients with symptoms, such as dysphagia due to pressure from an enlarged KD, are treated with lateral thoracotomy to directly resect the KD. In the absence of symptoms, treatment is initially planned with thoracic endovascular aortic repair (TEVAR), if anatomically possible. If not possible, the patient is treated using frozen elephant trunk (FET) technique with a median sternotomy. Of the five patients, one underwent 1-debranch TEVAR and four underwent FET.

In all cases, the landing zone should be at least 2 cm to avoid endoleaks, and stent grafts should be placed in the straightening descending aorta to avoid distal aortic injuries and dissections. In addition, we tried to reduce the risk of paraplegia. In addition, to reduce the risk of paraplegia, we try to place the implantation above the level of the aortic valve.

TEVAR with cervical debranching

Under general anesthesia, right common carotid artery (CCA) to right subclavian artery (SCA) bypasses were reconstructed using 6 mm PROPATEN® vascular graft (W.L. Gore & Associates, Newark, DE, USA). A 22-Fr introducer sheath was inserted through the common femoral artery. TAG® aortic stent-graft (W.L. Gore & Associates) was inserted at the orifice of the right CCA. Orifices of the right SCA were embolized using metallic coils. The preoperative and postoperative 3D-CT images are presented in *Figure 2*.

FET with ASCA reconstruction

Cardiopulmonary bypass was performed after median sternotomy. Core cooling was performed until rectal temperature dropped to 27 ℃. After circulatory arrest, selective cerebral perfusion via direct ostial cannulation was initiated, with the exception of the ASCA. Under open distal circulatory arrest, the aortic arch was transected between the right CCA and the right SCA (Zone II), followed by J graft Frozenix® (Japan LifeLine, Tokyo, Japan) insertion to the aorta. A branched Dacron graft was anastomosed to the trimmed aorta. After resuming circulation, the neck vessels were reconstructed. The 4-branch graft was then anastomosed to the proximal ascending aorta. The ASCA

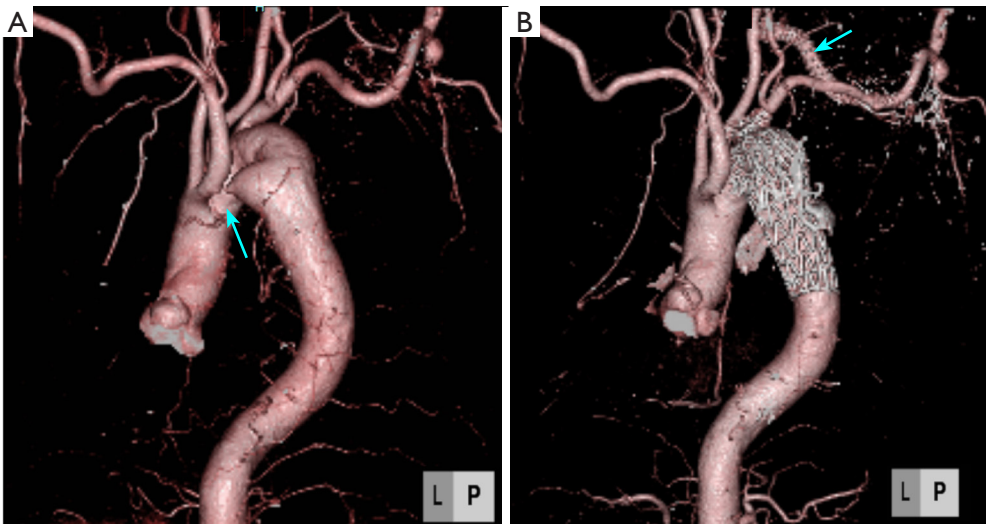

Figure 2 Patient 3 who underwent thoracic endovascular aortic repair is shown. The blue arrow indicates that the left subclavian artery was connected to the KD, but obstructed preoperatively (A). The right common carotid artery to the right subclavian artery bypass was performed to make sufficient landing for stent graft. The blue arrow indicates the bypass graft (B). KD, Kommerell diverticulum.

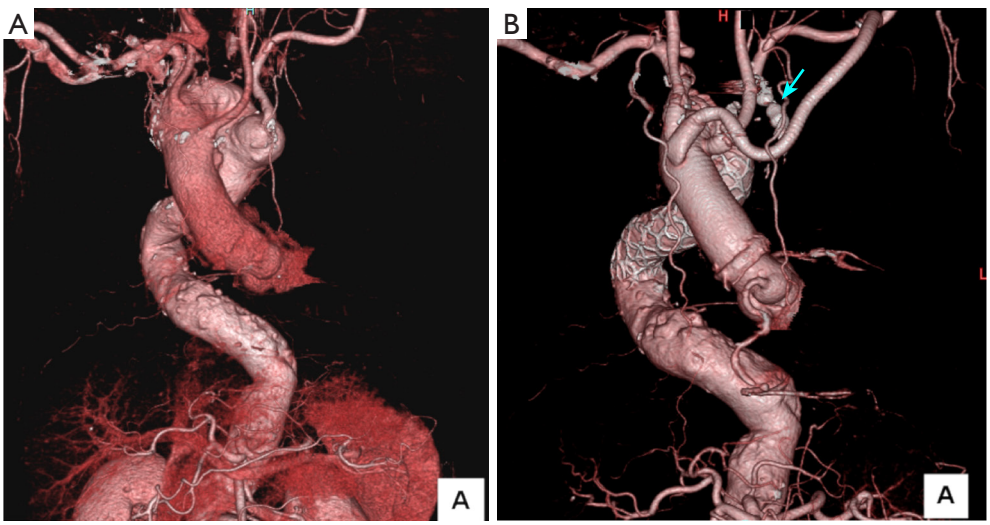

Figure 3 Patient 3 who underwent frozen elephant trunk with reconstruction of the left subclavian artery is shown. Preoperative and postoperative images of the right aortic arch with KD. The preoperative image shows the aberrant left subclavian artery arising from the KD (A). Frozen elephant trunk with reconstruction of the left subclavian artery is shown. The blue arrow indicates that the ASCA is embolized by metallic coil and plug (B). KD, Kommerell diverticulum; ASCA, aberrant subclavian artery.

was exposed at the subclavian incision and the 8 mm Dacron graft was anastomosed to the ASCA, passed through the thoracic cavity, and anastomosed to the replaced 4-branched artificial graft. Finally, the ASCA was transcatheterally coil embolized or ligated under direct visualization. The coil embolization is placed at the beginning of the ASCA; at the tip of the KD. The preoperative and postoperative 3D-CT images are presented in *Figure 3*.

Table 2 Procedural details and perioperative outcomes

Patient number	Procedure	Approach	Surgery time (min)	Postoperative complication	Postoperative hospital stay (days)	Follow-up time (months)
1	TAR with FET	Sternotomy	544	Aspiration pneumonia	45	110
2	TEVAR and left CCA to ALSA bypass	Common FA	221	None	12	86
3	TAR with FET	Sternotomy	475	None	12	75
4	TAR with FET	Sternotomy	378	None	15	33
5	TAR with FET	Sternotomy	331	None	12	8
Mean ± SD			390±112		19.2±12.9	62.4±36.9

DAW, distance to the opposite aortic wall; TAR, total arch replacement; FET, frozen elephant trunk; TEVAR, thoracic endovascular aortic repair; CCA, common carotid artery; ALSA, aberrant left subclavian artery; FA, femoral artery; SD, standard deviation.

Table 3 Changes in the Kommerell diverticulum size and reduction rate in cases with stent grafts

Patient number	Preoperative DAW (mm)	Postoperative DAW (mm)	DAW reduction rate (%)	Preoperative height of the KD (mm)	Postoperative height of the KD (mm)	Height reduction rate (%)
1	50.1	31.3	62.4	20.0	9.4	47.3
2	48.5	43.0	88.7	15.4	4.1	26.9
3	68.4	48.1	70.4	25.9	1.0	3.9
4	58.1	45.3	78.0	10.6	1.0	9.4
5	49.9	42.2	84.5	17.5	11.9	67.7
Mean ± SD	55.0±7.4	42.0±5.7	76.1±9.5	17.9±5.0	5.5±4.4	31.0±23.8

DAW, distance to the opposite aortic wall; KD, Kommerell diverticulum; TAR, total arch replacement; FET, frozen elephant trunk; TEVAR, thoracic endovascular aortic repair; CCA, common carotid artery; SCA, subclavian artery; SD, standard deviation.

Postoperative considerations and tasks

The procedural details and perioperative outcomes are presented in *Table 2*. One patient underwent 1-debranch TEVAR, and four patients underwent FET with a median sternotomy. One patient who underwent FET developed postoperative aspiration pneumonia, resulting in a prolonged hospital stay. There were no aortic-related complications of stent graft, such as endoleaks, distal aortic injuries or dissections.

The KD sizes are listed in *Table 3*. Preoperative DAW was 55.0±7.4 mm on average. In all five cases, KD was greatly reduced. On average, the DAW was reduced to 76.1%±9.5% and the height of KD was reduced to 31.0%±23.8% during the follow-up period. The respective changes in DAW and height of KD over time are shown in *Figure 4*. It can be visually seen that both show great changes up to the first 3 years after surgery.

Tips and pearls

Notably, in three out of five cases, the height of the KD almost disappeared. In the remaining two patients, the height of the KD was reduced to less than half. Axial CT images of Patients 2 and 3 with similar observation periods were analyzed. In Patient 2 who underwent TEVAR, the DAW decreased from 48.5 to 43.0 mm and the height of the KD decreased from 15.4 to 4.1 mm, indicating that the KD almost disappeared. In contrast, the original aortic diameter increased from 33.1 to 38.9 mm (*Figure 5*). In Patient 3, who underwent FET, the KD disappeared completely, as the KD was completely covered by the stent graft. The DAW decreased from 68.3 to 48.1 mm and the height of the KD decreased from 25.9 to 1.0 mm. In contrast, the original aortic diameter increased from 42.4 to 47.1 mm (*Figure 6*). Thus, in both cases, the original diameter of the KD covered by the stent graft was expanded and the KD

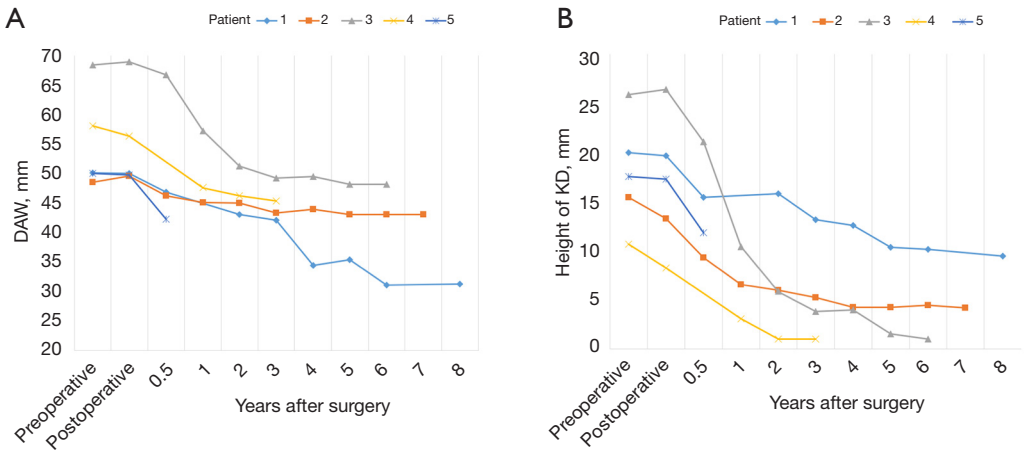

Figure 4 The changes in DAW (A) and height of KD (B) are shown in chronological order. Both show rapid reduction up to the first three years after surgery. Both show no re-expansion. DAW, the distance from the tip of the KD to the opposite aortic wall; KD, Kommerell diverticulum.

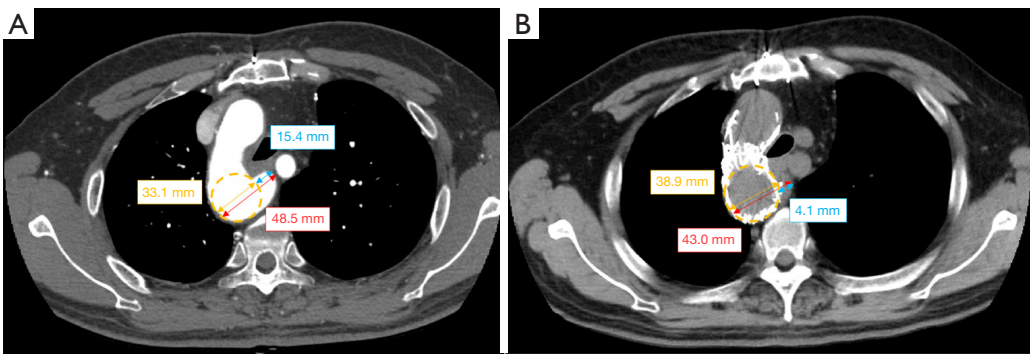

Figure 5 Preoperative (A) and postoperative (B) axial images of Patient 2. Both the DAW and the height of KD reduced after stent grafting, but the native aortic diameter enlarged from 33.1 to 38.9 mm. Red double-headed arrow representing DAW; blue double-headed arrow representing the height of the KD; orange circle and double-headed arrow representing native aortic diameter. DAW, distance to the opposite aortic wall; KD, Kommerell diverticulum.

aneurysm was reduced.

Discussion

Surgical highlights

There were no cases of mortality or the need for additional treatment across all procedures, and the treatment outcomes for KD were excellent. These results are consistent with those reported in other large-scale studies (3,5,13). A notable finding of this study is that in all cases where a stent graft was used for KD, a significant reduction in KD size was observed, with some cases showing complete resolution of KD.

Strengths and limitations

No studies have been reported on the size of KD and changes in native aorta after stent graft implantation. The limitations of this study include its single-center retrospective design and small population size. KD is a rare disease; therefore, sub-analyses at various centers are required. In this study, we defined the height of the KD as the difference between the DAW and native aortic diameter. However, the native aortic diameter in that cross-section was evaluated by supplementing the normal aortic diameter depicted in the most natural form, assuming there was no KD; therefore, it was not measured directly. Therefore, owing to its estimative nature, the accuracy of assessing the

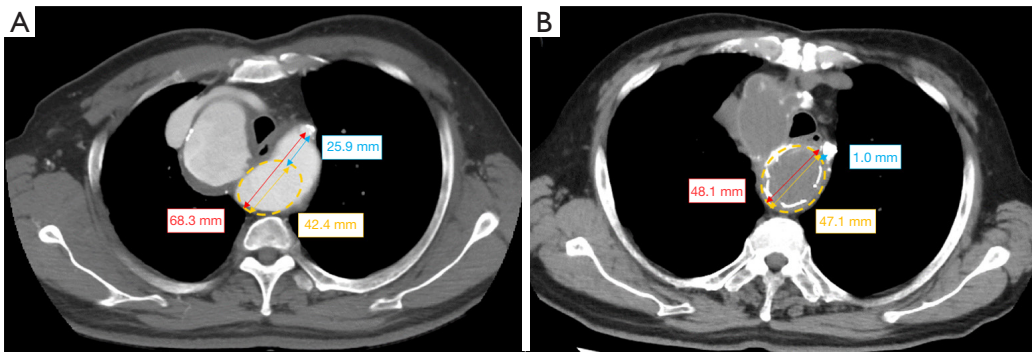

Figure 6 Preoperative (A) and postoperative (B) axial images of Patient 4. The DAW reduced and KD disappeared after stent grafting, but the native aortic diameter enlarged from 42.4 to 47.1 mm. Red double-headed arrow representing DAW; blue double-headed arrow representing the height of the KD; orange circle and double-headed arrow representing native aortic diameter. DAW, the distance from the tip of the KD to the opposite aortic wall; KD, Kommerell diverticulum.

height of the KD was inevitably compromised. However, we believe that this method does not result in significant deviations.

Another point is the need to take into account the different nature of the devices used. The two types of devices used in this study were Frozenix® and TAG®. Frozenix® is a woven polyester fabric product. TAG® is an expanded polytetrafluoroethylene product, also without type 4 endoleak. Although the two devices in this study are different in nature, both are products that can be considered to have no type 4 endoleak, and we believe that their influence on the therapeutic effect is small.

Comparison with other researches

Previous studies have reported that when TEVAR or FET is used to treat aortic aneurysms and dissections, the native aorta is affected by the radial force of the stent graft and enlarges (17,18). Our study showed that aortic remodeling occurs in the normal descending aorta when stent grafts are inserted during the treatment of KD (*Figures 5*,*6*). Although DAW is often used to objectively assess the diameter of KD aneurysms, it includes the native aorta within the measurement range, and is based on the assumption that there is no change in the size of the native aorta.

However, aortic remodeling after stent grafting should be considered, suggesting that DAW may not be an accurate method of assessment following changes in KD size. Therefore, we considered that the assessment of the height of the KD is appropriate to exclude the influence of aortic remodeling due to the stent graft, and this allowed for a clearer assessment of the extent of KD reduction.

Implications and actions recommended

In our facility, we prefer to incorporate the FET technique because these hybrid techniques are effectively performed with low morbidity and mortality rates and high rates of symptom relief (19). Furthermore, the evolution of the endovascular approach does not affect late outcomes of mortality and morbidity (20). Therefore, it is necessary to select the most optimal and minimally invasive treatment, including stent graft therapy, tailored to each patient. TEVAR is undoubtedly the least invasive procedure. However, TEVAR is associated with endoleaks. The advantage of FET is that it eliminates type Ia endoleaks. In our view, FET is a more reliable treatment than TEVAR for patients with surgical tolerance and is less invasive than descending aortic replacement. In addition, enlarged KDs are often strongly adherent to the esophagus; FET is considered a safer technique because, unlike lateral open thoracotomy KD resection, it does not require peri-esophageal surgery and carries virtually no risk of esophageal injury. Other techniques include total debranching TEVAR as an alternative to FET, but complications are not uncommon and remote results are not good, so we generally avoid this technique. Although it is certainly a minimally invasive procedure, safety and reliability are the most important factors (21). The FET allows patients who would otherwise require a descending thoracotomy through a lateral open thoracotomy to be treated with a median sternotomy. This greatly reduces

stress on the surgeon and increases the safety of the procedure.

In patients who already have dysphagia lusoria due to KD, there is a tendency to undergo surgery to remove the diverticulum as directly as possible because there is no evidence of the effect of stent graft treatment on reducing the size of the KD. The results of this study suggest that treatment with stent grafts may be applicable in cases of physical esophageal strictures caused by KD enlargement. However, case selection should be performed carefully because KD does not shrink immediately. Indeed, we have heard comments that stent graft treatment for KD did not cure dysphagia. Our hypothesis regarding this is that this is due to the fact that the esophagus is pulled because of the strong adhesion between the esophagus and KD, although the KD has shrunk. In this case, the esophageal compression has been released and the physical dysphagia may have improved, although there is still some discomfort when swallowing.

Conclusions

Long-term results of KD with stent graft-related treatment at our institution are reported. In addition to the conventional evaluation method, the height of KD was defined and measured to clearly identify the aneurysmal volume reduction effect of the preoperative and postoperative treatment. After stent graft-related treatments, the KD was obviously reduced in size. This suggests that the decompression of the KD is likely to lead to remodeling of the aortic wall, which constitutes KD.

Acknowledgments

None.

Footnote

Reporting Checklist: The authors have completed the SUPER reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1709/rc

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1709/prf

Funding: None.

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1709/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work and ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Osaka Metropolitan University Graduate School of Medicine, Osaka, Japan (No. 2024-023), and informed consent was taken from all the patients.

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Cite this article as: Inno G, Takahashi Y, Morisaki A, Nishiya K, Kawase T, Nishimoto Y, Noda K, Nagao M, Nangoya R, Shibata T. Aneurysmal size reduction in the Kommerell diverticulum by stent graft-based therapy. J Thorac Dis 2025;17(2):1064-1072. doi: 10.21037/jtd-24-1709