JACC: CASE REPORTS VOL. 29, 2024

CASE REPORT

CLINICAL CASE

Thoracic Endovascular Aortic Repair Without Subclavian Revascularization of a Ruptured Kommerell Diverticulum

Sho Takagi, MD, PhD, Yoshihiro Goto, MD, Junji Yanagisawa, MD, Yui Ogihara, MD, Yasuhide Okawa, MD

ABSTRACT

A ruptured Kommerell diverticulum is extremely rare. This is the first report of thoracic endovascular aortic repair without subclavian revascularization of a ruptured Kommerell diverticulum with a right-sided aortic arch. However, decisions regarding subclavian revascularization should be individualized based on the patient's anatomy and clinical presentation. (J Am Coll Cardiol Case Rep 2024;29:102349) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 46-year-old male patient was transferred to a hospital due to sudden chest and back pain. Upon arrival, his heart rate, blood pressure, and blood oxygen saturation in room air were 124 beats/min with sinus rhythm, 58/unmeasurable mm Hg, and 80%, respectively. The patient appeared pale, with prominent cold sweat on the extremities. The shock index was >2, indicating severe hemorrhagic shock. Acute aortic syndrome was diagnosed based on plain computed tomography (CT) findings, and the patient was transferred to our hospital for treatment.

LEARNING OBJECTIVES

- To immediately treat a ruptured KD with a right-sided aortic arch.
- To understand the limitations of TEVAR without subclavian revascularization.

PAST MEDICAL HISTORY

The patient was 173 cm tall, weighed 73.9 kg (body mass index 24.7 kg/m^2), and had no medical history.

DIFFERENTIAL DIAGNOSIS

The patient was admitted to our operating room and underwent several evaluations to determine the appropriate treatment. Sudden chest and back pain with shock can indicate tension pneumothorax, pulmonary embolism, or acute aortic syndrome such as aortic dissection with rupture.

INVESTIGATIONS

Contrast-enhanced CT imaging showed an aneurysmatic left subclavian artery, abnormally shaped aortic arch, and extravasation, including an aortic hematoma; therefore, a ruptured Kommerell diverticulum (KD) with a right-sided aortic arch was diagnosed (**Figure 1**). Contrast-enhanced CT imaging confirmed the right-sided aortic arch and the

From the Department of Cardiovascular Surgery, Toyohashi Heart Center, Toyohashi, Japan.
The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received January 16, 2024; revised manuscript received March 4, 2024, accepted March 26, 2024.

ISSN 2666-0849 https://doi.org/10.1016/j.jaccas.2024.102349

ABBREVIATIONS AND ACRONYMS

CT = computed tomography

CTAG = conformable GORE TAG thoracic endoprosthesis

KD = Kommerell diverticulum

MRA = magnetic resonance angiography

TEVAR = thoracic endovascular aortic repair

following cervical branching sequence: left common carotid, right common carotid, right subclavian, and left subclavian arteries. The left subclavian artery originated from the descending aorta.

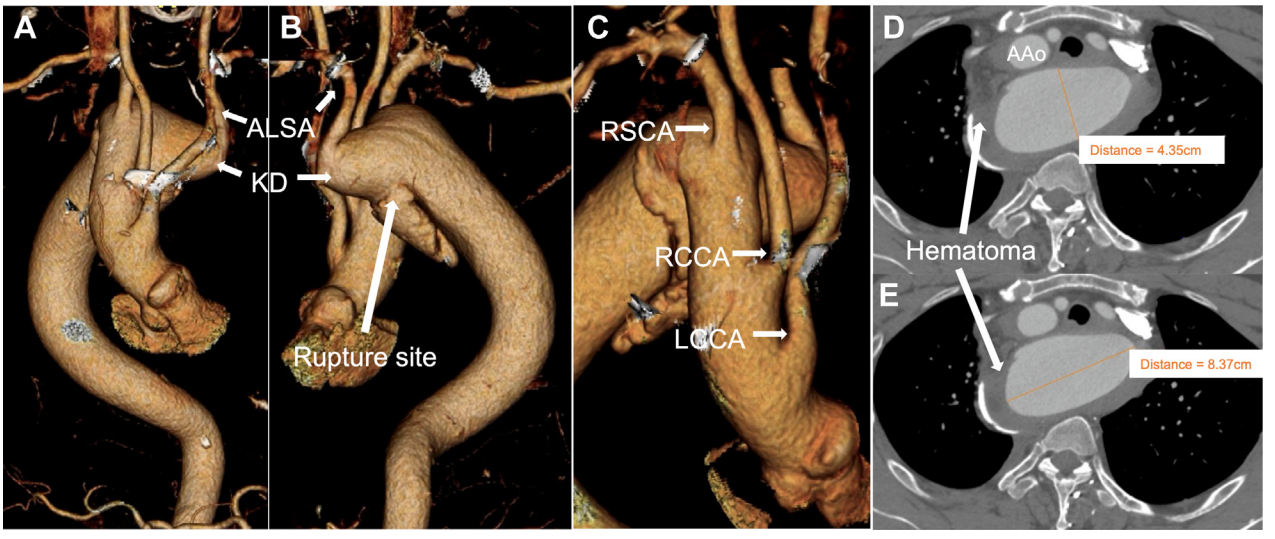
The diameters of the aneurysmal subclavian artery and KD were 43.5 and 83.7 mm, respectively (Figures 1D and 1E). The distance from the right subclavian artery to the KD was close, but the distance from the right common carotid artery to the KD was 39 mm. Preoperative hemoglobin and hematocrit levels were 8.0 g/dL and 25.1%.

MANAGEMENT

Immediate salvage surgery was planned, followed by thoracic endovascular aortic repair (TEVAR) and bilateral subclavian artery revascularization. We chose TEVAR instead of open repair for this young man without a medical history because, first, the proximal landing zone was sufficiently long for TEVAR if we set the proximal landing zone immediately under the right common carotid artery. Second, our patient experienced severe shock; it was therefore necessary to immediately control the hemorrhage from the ruptured KD. Third, there was a high risk of damage to the esophagus and trachea due to a hematoma or bleeding that could obstruct the visual field.

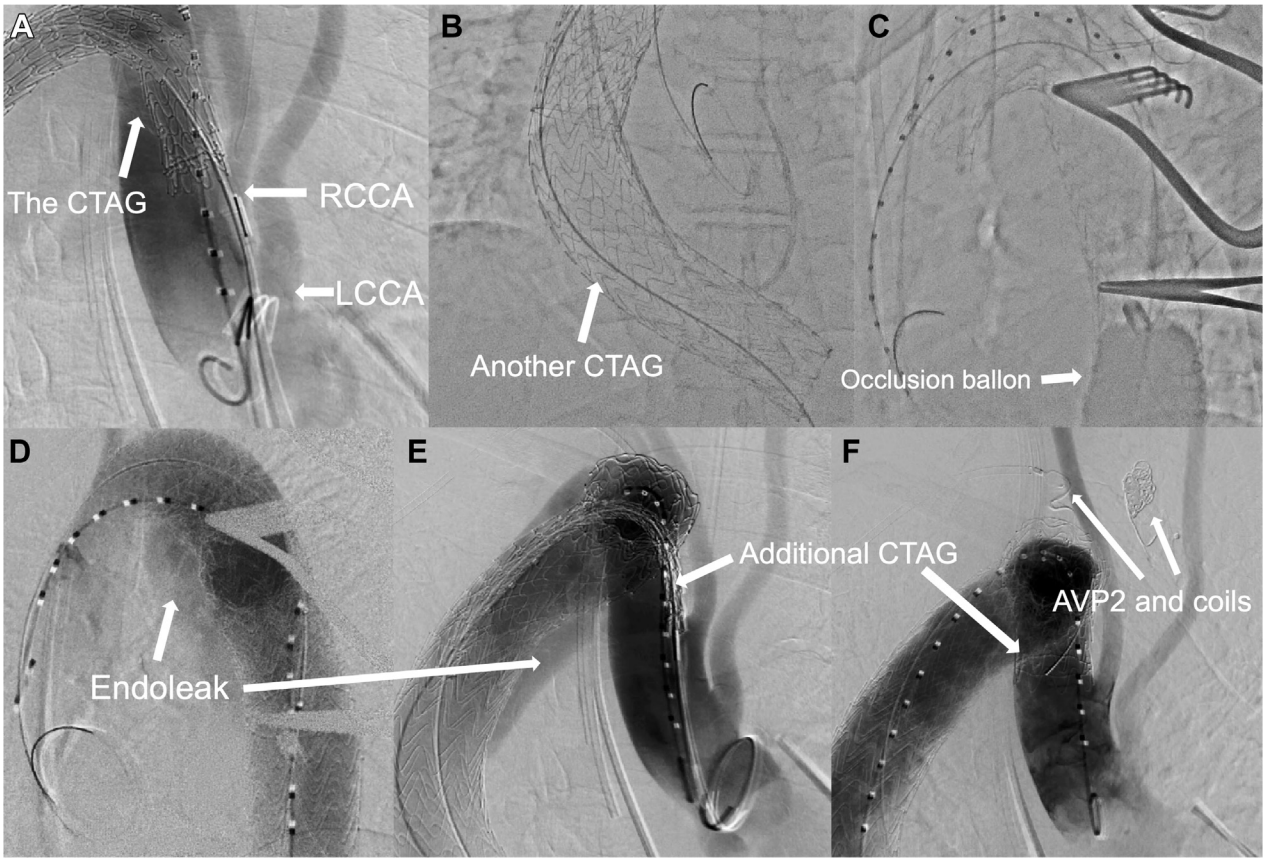
TEVAR was performed with the patient under general anesthesia using the right common femoral artery approach. A Conformable GORE TAG Thoracic Endoprosthesis (CTAG; W.L. Gore & Associates) with dimensions of 28 × 28 × 200 mm was deployed below the right common carotid artery (Figure 2A). The aortic diameter below the right common carotid artery was 23.5 mm, and the rate of oversizing was approximately 120%. Due to the large diameter (27 mm) of the distal aorta, an additional CTAG with dimensions of 31 × 31 × 150 mm was deployed at the Th10 level (Figure 2B). The rate of oversizing with the distal CTAG was approximately 115%. However, the proximal stent graft migrated into the KD during the stent-graft junction touch-up using an occlusion balloon (Figures 2C and 2D). Therefore, another CTAG (28 × 28 × 150 mm) was positioned in the proximal region (Figures 2E and 2F). The origin of both subclavian arteries was occluded with an Amplatzer Vascular Plug II (Abbott Vascular) and pushable fiber platinum coils using the percutaneous approach from the bilateral transbrachial arteries (Figure 2F). The final angiography showed no endoleaks or extravasation, indicating preservation of the blood flow to both upper limbs via the vertebral basilar circulation. After the TEVAR procedure, due to prolonged severe

FIGURE 1 Contrast-Enhanced Computed Tomography Imaging Before Surgery



(A-C) Ruptured Kommerell diverticulum (KD) with a right-sided aortic arch. (D and E) The diameters of the aneurysmatic subclavian artery and KD were 43.5 mm and 83.7 mm, respectively. A hematoma was present around the trachea and esophagus. AAo = ascending aorta; ALSA = aberrant subclavian artery; LCCA = left common carotid artery; RCCA = right common carotid artery; RSCA = right subclavian artery.

FIGURE 2 **Angiography During Surgery**



(A) The Conformable GORE TAG Thoracic Endoprosthesis (CTAG) is deployed below the right brachiocephalic artery. (B) Another CTAG is deployed at the distal end. (C) Touch-up of the stent-graft junction using an occlusion balloon. (D and E) The proximal stent graft migrates into the Kommerell diverticulum and toward the distal side. (E and F) An additional CTAG is therefore placed in the proximal region. AVP2 = Amplatzer Vascular Plug II; other abbreviations as in **Figure 1**.

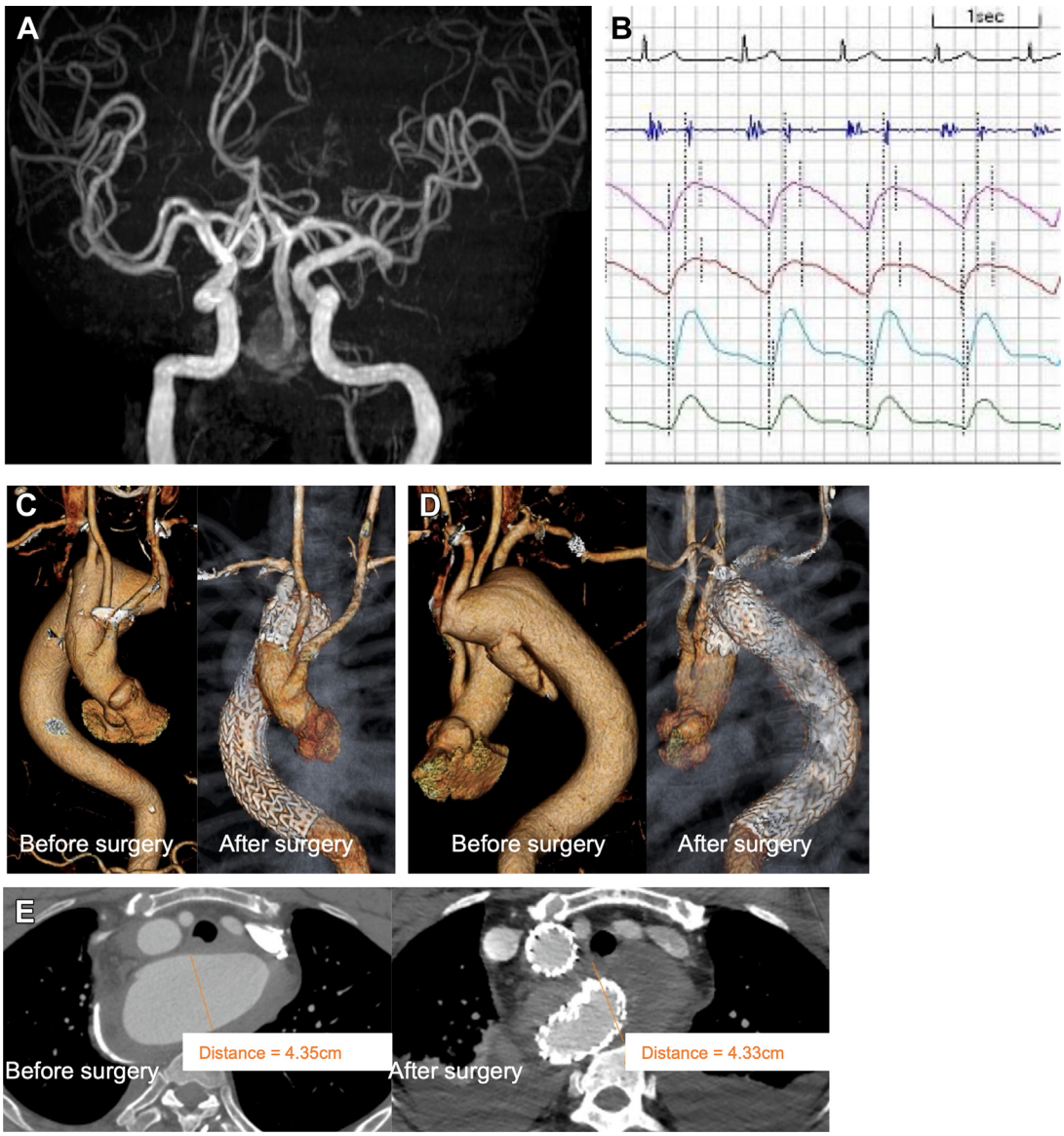
hemorrhagic shock, revascularization of the bilateral subclavian arteries was not performed.

DISCUSSION

KD is a rare developmental abnormality of the aorta associated with an aberrant subclavian artery in 20% to 60% of cases.[1] Surgical correction is recommended for symptomatic patients due to increased growth rates and rupture risks. KD with a right aortic arch, a rare anomaly, is associated with significant risks of distal embolization, dissection, and rupture; risks of rupture and dissection are reportedly up to 53%.[2] Intervention is typically suggested for KD with a base >30 mm and distance >50 mm from the apex to the opposite wall of the aorta.[2,3] Even when patients present with symptoms such as dysphagia, intervention is required.[4] Our patient met this criterion; therefore, there was a high risk of rupture. Open surgical repair and endovascular repair including hybrid repair approaches seem equally effective, regardless of arch laterality.[4] KD can be repaired in asymptomatic patients, resulting in excellent outcomes, and young healthy patients may be considered better candidates for open approaches instead of endovascular or hybrid modalities because of the lower likelihood of reintervention and lower early mortality rate.[5]

Factors such as patient health, aortic pathology, and medical resources determine whether open surgical repair or TEVAR should be used to treat a ruptured KD.[1] Decisions regarding procedures for KD should be made based on the patient's specific case by a skilled team of vascular surgeons and interventional cardiologists. KD's presence, characterized by a sharply curved aortic arch, predisposes patients to

FIGURE 3 MRA, ABPI Assessment, and Contrast-Enhanced CT Imaging After Surgery

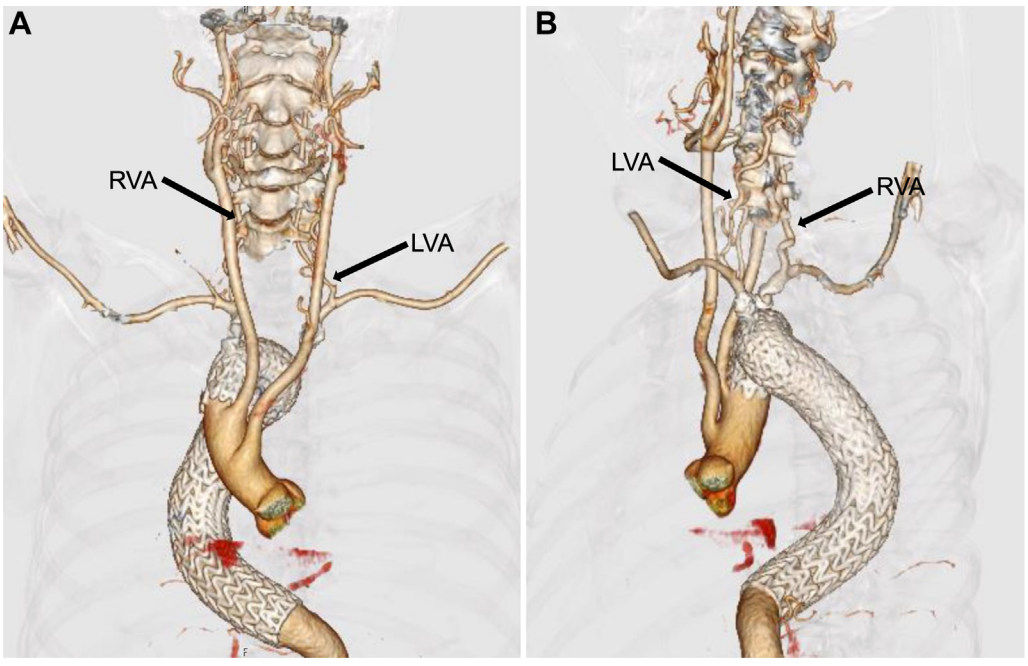


(A) Magnetic resonance angiography (MRA) reveals poor visualization of the bilateral vertebral arteries. (B) The ankle-brachial pressure index (ABPI) values were 1.25 on the right and 1.26 on the left (upper limb blood pressure: 89/53 mm Hg [right] and 86/50 mm Hg [left]; lower limb blood pressure: 111/67 mm Hg [right] and 112/65 mm Hg [left]). (C-E) Contrast-enhanced computed tomography (CT) imaging shows no endoleaks or extravasation (compared with **Figures 1A, 1B, and 1D**).

complications such as kinking, graft collapse, or aortic wall injury due to stent fractures.[6,7]

Recently, hybrid and endovascular approaches using different supra-aortic vessel revascularization techniques in combination with TEVAR have been described.[8,9] We planned revascularization of the bilateral subclavian arteries; however, only simple TEVAR was performed because the final angiography showed that blood flow to both upper limbs was maintained via the vertebral basilar circulation; furthermore, due to prolonged severe hemorrhagic shock, revascularization of the bilateral subclavian arteries was dangerous. After TEVAR, we confirmed blood flow to both subclavian arteries via the bilateral vertebral arteries. Postsurgery, we confirmed that the patient was awake and had no cranial nerve

FIGURE 4 Contrast-Enhanced Computed Tomography Imaging 2 Years After Surgery



(A and B) Contrast-enhanced computed tomography imaging shows no endoleaks or stent graft migration. The bilateral vertebral artery feeds the bilateral subclavian artery. LVA = left vertebral artery; RVA = right vertebral artery.

dysfunction symptoms. Postoperative magnetic resonance imaging revealed no abnormalities. Our patient was young and had mild intracranial arteriosclerosis; therefore, it is possible that intracranial vascular communication was abundant. Young adults have fewer arteriosclerotic changes and are less likely than older adults to develop ischemic symptoms of the basilar artery system.[10] To our knowledge, no cases of successful TEVAR without subclavian revascularization of a ruptured KD with a right-sided aortic arch have been reported.

An endovascular approach may be considered for emergent cases such as ours or those with high surgical risks. For this case, three CTAGs were used due to CTAG migration, resulting in its placement along the strong angulation of KD, thus potentially increasing the stent graft fixation strength and leading to positive outcomes. Endovascular therapy is effective for treating a ruptured KD. However, open repair may be required when evolving conditions require reintervention or when endovascular methods are unsuitable because of the local anatomy. Individualized therapy planning by specialized teams is vital to achieving satisfactory patient outcomes.[11]

FOLLOW-UP

Immediately postsurgery, the patient awoke without evident symptoms of cranial nerve loss. The patient experienced a cold sensation in both upper limbs but no paralysis. Magnetic resonance angiography (MRA) revealed poor visualization in the bilateral vertebral arteries; however, diffusion-weighted imaging showed no brain infarction (**Figure 3A**). The ankle-brachial pressure index values were 1.25 (right) and 1.26 (left). Upper limb blood pressure measurements were 89/53 mm Hg (right) and 86/50 mm Hg (left). Lower limb blood pressure measurements were 111/67 mm Hg (right) and 112/65 mm Hg (left) (**Figure 3B**). Postoperative contrast-enhanced CT imaging revealed no endoleaks or extravasation (**Figures 3C to 3E**). The patient was discharged 14 days after surgery and has shown favorable progress with no clinical manifestations over 2 years. Changes in the ankle-brachial pressure index and MRA results and stent-graft migration with endoleaks were not observed (**Figure 4**). In addition, feeding of the bilateral subclavian arteries by the bilateral vertebral arteries was observed.

CONCLUSIONS

The current case provides insights into the treatment of a ruptured KD. TEVAR can be a viable treatment option for a ruptured KD with a right-sided aortic arch; however, decisions regarding subclavian revascularization should be individualized based on the patient's anatomy and clinical presentation. A specialized health care team is crucial for assessing and planning patient care.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

ADDRESS FOR CORRESPONDENCE: Dr Sho Takagi, Department of Cardiovascular Surgery, Toyohashi Heart Center, 21-1 Gobudori, Oyama-cho, Toyohashi 441-8530, Japan. E-mail: sho.takagi25@gmail.com.

REFERENCES

1. Velandia-Sánchez A, Gómez-Galán S, Gallo-Bernal S, et al. Emergent hybrid surgical approaches for non-dissecting ruptured Kommerell's aneurysm: a case report series. *J Cardiothorac Surg*. 2023;18:93.

2. Cinà CS, Althani H, Pasenau J, Abouzahr L. Kommerell's diverticulum and right-sided aortic arch: a cohort study and review of the literature. *J Vasc Surg*. 2004;39:131-139.

3. Erben Y, Brownstein AJ, Velasquez CA, et al. Natural history and management of Kommerell's diverticulum in a single tertiary referral center. *J Vasc Surg*. 2020;71:2004-2011.

4. Moffatt C, Bath J, Rogers RT, et al. International multi-institutional experience with presentation and management of aortic arch laterality in aberrant subclavian artery and Kommerell's diverticulum. *Ann Vasc Surg*. 2023;95:23-31.

5. Bath J, D'Oria M, Rogers RT, et al. Contemporary outcomes after treatment of aberrant subclavian artery and Kommerell's diverticulum. *J Vasc Surg*. 2023;77:1339-1348.e6.

6. Vendramin I, Lechiancole A, Frigatti P, et al. Aortic arch aneurysm and Kommerell's diverticulum: repair with a single-stage hybrid approach. *J Card Surg*. 2019;34:641-644.

7. Morishita A, Tomioka H, Katahira S, Hoshino T, Hanzawa K. Surgical treatment for Kommerell's diverticulum associated with a right-sided aortic arch and an aberrant left subclavian artery: endovascular or hybrid. *Ann Vasc Dis*. 2019;12:228-232.3.

8. Gray SE, Scali ST, Feezor RJ, et al. Safety and efficacy of a hybrid approach for repair of complicated aberrant subclavian arteries. *J Vasc Surg*. 2020;72:1873-1882.

9. Fukuhara S, Ahmed Y, Shiomi S, et al. Aberrant subclavian arteries and associated Kommerell diverticulum: endovascular vs open repair. *Ann Thorac Surg*. 2022;114:2163-2171.

10. Yamamoto K, Hiraiwa T. Conservative treatment of traumatic occlusion of subclavian artery: a case report. *Jpn J Vasc Surg*. 2007;16:791-794.

11. Dueppers P, Floros N, Schelzig H, Wagenhäuser M, Duran M. Contemporary surgical management of aberrant right subclavian arteries (Arteria Lusoria). *Ann Vasc Surg*. 2021;72:356-364.

KEY WORDS aortic rupture, Kommerell diverticulum, thoracic endovascular aortic repair