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Clinical Case Report

Two autopsy cases of rupture of the aorta by fistula formation after thoracic endovascular aortic repair and open stent-grafting on aortic arch aneurysm

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ABSTRACT

The mortality rate of aortic aneurysm/dissection is low in Japan. Two surgical procedures, the thoracic endovascular aortic repair (TEVAR) and the open stent-grafting have contributed much in survival of such aneurysmal patients. We encountered with two autopsy cases of death by aortic rupture with fistula formation after these procedures. Case 1 is an 85-year-old male who had the history of TEVAR for thoracic aorta aneurysm one and a half year before his death. His endovascular stent-graft was composed of a steel endoskeleton consisting of six Z-shape elements while at autopsy, one of the elements locating at the distal part was found inserted deep into the wall of descending aorta, causing aorto-esophageal fistula. Case 2 is an 88-year-old male who had the history of open stent-grafting for aortic aneurysm eight years ago. At autopsy, the stent-graft was found detached from aorta at its lesser curvature, causing gap formation between the aorta and the stent. Six Z-shaped stent elements, the parts of stent-graft, were found separated from descending aorta and located in the aneurism. Furthermore, three of the separated elements were found inserted deep in the aortic wall, causing aorto-pulmonary fistula.
Since aorto-esophageal fistula formation after surgery for aortic aneurysm is very rare in TEVAR and there are no reported cases of death by aorto-pulmonary fistula in the open stent-grafting, these cases are reported here.

1. Introduction

The mortality rate of aortic aneurysm/dissection is low in Japan (1.3% in 2015) [1]. Such low mortality is caused mainly by the improvements of surgical procedure. Previously, open thoracic surgeries have been introduced as the main therapeutic procedure for aortic aneurysm. However, these operations (e.g. left thoracotomy) had some difficulties in hemostasis. Also they sometimes cause vocal cord paralysis [2,3]. Therefore, much less invasive treatments have been awaited.

In 1994, the thoracic endovascular aortic repair (TEVAR) was introduced by Dake et.al [4]. This method is a kind of endovascular stent-grafting. The graft in this procedure was made of self-expanding stainless-steel stents covered with woven Dacron grafts. The TEVAR, even though certainly less invasive, has difficulties in surgery of the aortic arch aneurysm in requiring adequate landing zone around the cephalic vessels.

Then, the open stent-grafting technique was invented in 1996 [5] as another much less invasive method. This method is to substitute the ascending aorta with artificial blood vessel that has four branches for major arteries, by opening the ascending aorta and inserting the stent downwardly into the descending aorta. The stent is inserted in the distal end of the aorta and is fixed to vascular wall by self-expansion. This method has a merit in avoiding suture of aortic wall at its distal side that requires left thoracotomy. Shimamura et al. stressed that this procedure is less invasive and thus the surgical burden is alleviated [6].

Here we report two autopsy cases of death by aortic fistula formation after TEVAR and open stent-grafting. In these cases, fistulae are formed on the distal part of stent-graft. In both of those cases, the Z-shape stent elements are found to have caused the fistulae. We believe those rare cases are worth to be reported for the improvement of those treatments.

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Table 1
Clinical information and autopsy findings

	Case 1	Case 2
Age, sex	85 y.o. male	88 y.o. male
Clinical history	Chronic obstructive pulmonary disease Hypertension Hyperlipidemia Cholangitis	Hypotension Dementia
Method	TEVAR	Open stent-grafting
Timing	One and half year ago	Eight years ago
Fistula formation	Aorto-esophageal fistula	Aorto-pulmonary fistula
Other findings	Moderate chronic obstructive pulmonary disease Mild coronary stenosis Mild cardiomegaly The drain was inserted in gallbladder	Mild interstitial pneumonia Mild coronary stenosis

Thoracic endovascular aortic repair: TEVAR

2. Case report 1

2.1. Background

The case is an 85-year-old male who had chronic obstructive pulmonary disease, hypertension, hyperlipidemia and cholangitis. TEVAR and bypassing of the left common carotid artery with the left subclavian artery was carried out for the thoracic aorta aneurysm one and half year before his death (Table 1). Two hours before the death, he complained of chest pain with respiratory discomfort and vomited blood. He was in comatose state on arrival at the hospital. In the hospital, 100 ml of intraoral blood was absorbed, while he was confirmed dead on arrival. Autopsy based on administrative law was carried out 33 hours after the death.

2.2. Autopsy findings

His height was 162 cm. His weight was 51 kg. The aortic aneurysm of 4 cm in diameter, true aneurysm not coalesced, was found at the end of aortic arch (Fig. 1). The lower part of the esophagus, which was ulcerated, was strongly coalesced with the descending aorta (Fig. 2). When aorta was cut open, the endovascular stent-graft was found in the aortic arch and the descending aorta.

Fig. 1. Aortic aneurysm of the aortic arch (Case 1) →; aneurysm.

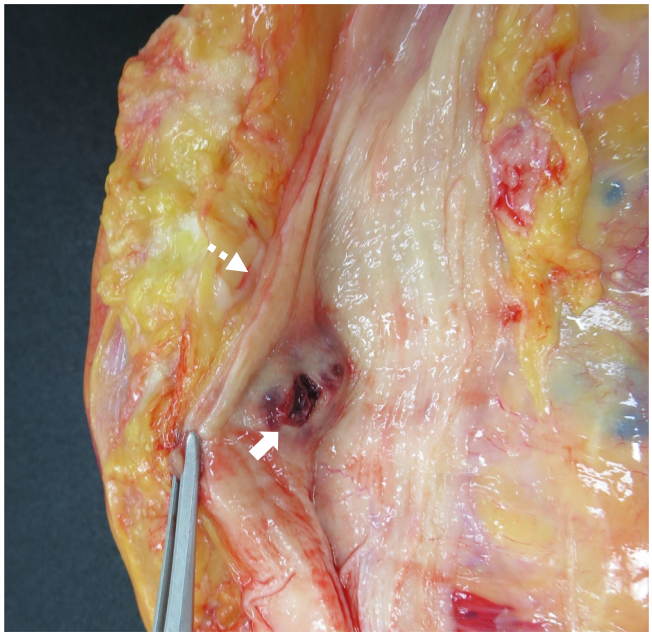

Fig. 2. Esophagus ulcer in the lower part of esophagus (Case 1) →; ulcer→; esophagus.

His endovascular stent-graft was composed of a steel endoskeleton consisting of six Z-shape stent elements, while one of the Z-shape elements at the distal part was inserted deep into the descending aortic wall (Fig. 3a). The place where element stuck in aorta was found to be fragile because of atherosclerosis (Fig. 3b) and its height accorded with esophagus ulcer (Fig. 3c). Massive hemorrhage was found in stomach and small intestine, and thus was evaluated as the cause of death. There was no obstruction of aortic orifice at where the artery that feed the esophagus starts, no element stuck by other five Z-shape elements and no bleeding in mediastinum nor thorax.

He suffered from moderate degree of chronic obstructive pulmonary disease, mild coronary stenosis, mild cardiomegaly and cholangitis. At autopsy, a drain was found inserted in gallbladder. There was no data suggestive of renal dysfunction (Table 1).

Histologically, hematoxylin–eosin (HE) stained sections revealed that aortic wall around fistula simply showed atherosclerotic change, and inflammatory change such as neutrophilic infiltration, deposition of fibrin, and thrombus formation was found in site of the aortic wall where element stuck exclusively (Fig. 4a,b). Also, no histological findings suggestive of allergic change nor bacterial infection/sepsis were noted.

3. Case report 2

3.1. Background

The case is an 88-year-old male who suffered from hypotension and dementia. He received open stent-grafting to the aortic aneurysm eight years ago (Table 1). Eight days before the death, the patient vomited blood and taken to the hospital. The physician in outpatient clinic could not find any abnormal findings on CT survey and thus he was discharged. On the next day, however, presence of the chest aortic aneurysm was noticed in his CT record by the chief physician. However, his symptoms subsided and thus he was submitted to follow-up.

Seven days later, he vomited blood and transported to the hospital by ambulance. He was in comatose state on arrival and was confirmed

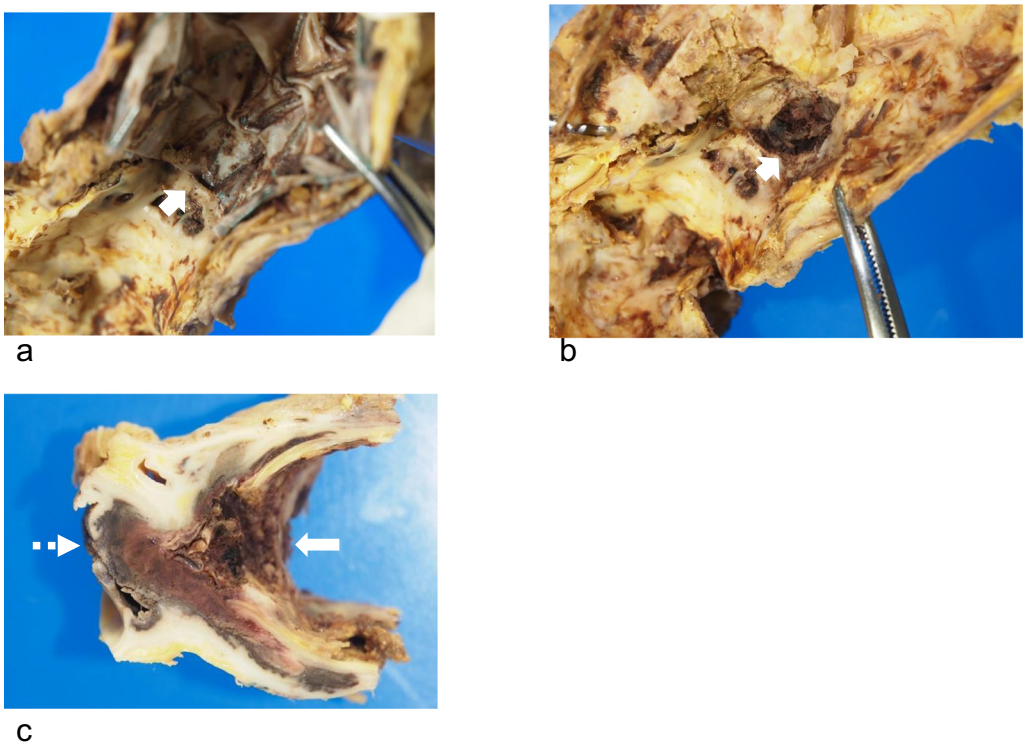

Fig. 3. The distal part of endovascular stent-graft (Case 1). (a) →; The Z-shape element was inserted into descending aortic. (b) →; The detachment of a part of Z-shape element from aorta. (c) Aortio-esophageal fistula →; aortic side,⇢ esophagus side.

dead. Autopsy based on administrative law was carried out 26 hours after the death.

3.2. Autopsy findings

His height was 161 cm. His weight was 58 kg. The weight of lungs and heart was not measured since those organs were perfused with fixative (20% formalin) before isolation. The aortic arch, bearing aortic aneurysm (true aneurysm) of 3.5 cm in diameter was found adhered to the left lung at its apex firmly. When aorta was cut open, ascending aorta was found replaced by 4-branched graft (Fig. 5a). The stent graft was found inserted through the opened aortic arch and reached to the proximal portion of the descending aorta (Fig. 5b). The suture scars were found in the upper part of the aortic valve and at the opened aortic arch respectively. Meanwhile, the stent which had been inserted in the distal end of the graft was found not fixed to the vascular wall (Fig. 6a). On the distal portion of stent that is not fixed by suture, the distal part of the stent structure composed of six Z-shaped elements were found detached and moved away from aortic wall into the aneurysmal cavity. Then three of them were inserted deep into the aneurysmal wall and formed aorto-pulmonary fistula with the left lung upper lobe (Fig. 6b,c). This detachment of elements caused shorting of graft, forming a gap between aorta and stent (Fig. 6d). There was no new aneurysmal formation nor the enlargement of original aneurysm around the part where Z-shape elements were to be attached. A large amount of blooding from fistula was pooled in the lungs while no bleeding was noted in the mediastinum nor thorax.

He also had mild interstitial pneumonia and mild coronary stenosis. There was no evidence of renal dysfunction (Table 1).

Histologically, HE stained sections revealed that the locus where element was inserted into aneurysmal wall showed rupture of the wall which was covered by fibrous granulation composed of fibroblasts, histiocytes and macrophages (Fig. 7a). Bleeding without inflammatory cell infiltrate was found in bronchioli and alveoli (Fig. 7a). A part of bronchiole (ciliated epithelium) was found in the rupture site (Fig. 7b).

4. Discussion

The aorto-esophageal fistula (AEF), found in Case 1, is reported to be caused by the erosion of aortic aneurysm into the esophagus [7]. AEF as the complication in operation of the aortic aneurysm is reported to occur very rarely [8,9]. According to Chiesa et al., the incidence of AEF among patients who were operated TEVAR remains 1.7% [9]. The development of AEF in TEVAR has been explained by 1) direct penetration of the rigid stent-graft through the aorta into the esophagus, 2) esophageal necrosis by ischemia due to stent-graft coverage of aortic orifice that feed the esophagus, 3) pressure necrosis of the esophageal wall due to the continuing forces of the self-expanding endoprosthesis and 4) infection of stent-graft prosthesis [10,11]. In our Case 1, hypothesis 2) and 4) were excluded by no coverage of aortic orifice that feed the esophagus and no histological findings suggestive of allergy or infection such as sepsis. Then, presence of fibrin deposition with thrombus formation in the aorta side suggested that the necrosis of aorta occurred initially. Moreover, there were no elements stuck by other five Z-shape elements. Therefore, hypothesis 3) was also excluded. Thus we speculate that AEF was caused by direct penetration of the Z-shape element. Accordingly, our Case 1 will be explained by the hypothesis 1).

Then, how could such phenomenon have occurred. We speculate that the detached element must have been exposed under higher pressure than the other elements, presumably due to uneven intimal structure that might have been caused by uneven thickness of aneurysmal wall and this continuing high pressure in a limited portion of the graft must have induced structural deform of the graft and fragility in a limited portion of the elements. The resulting looseness of the elements might have influenced in progression of atherosclerosis by its possible vibration on each pulse.

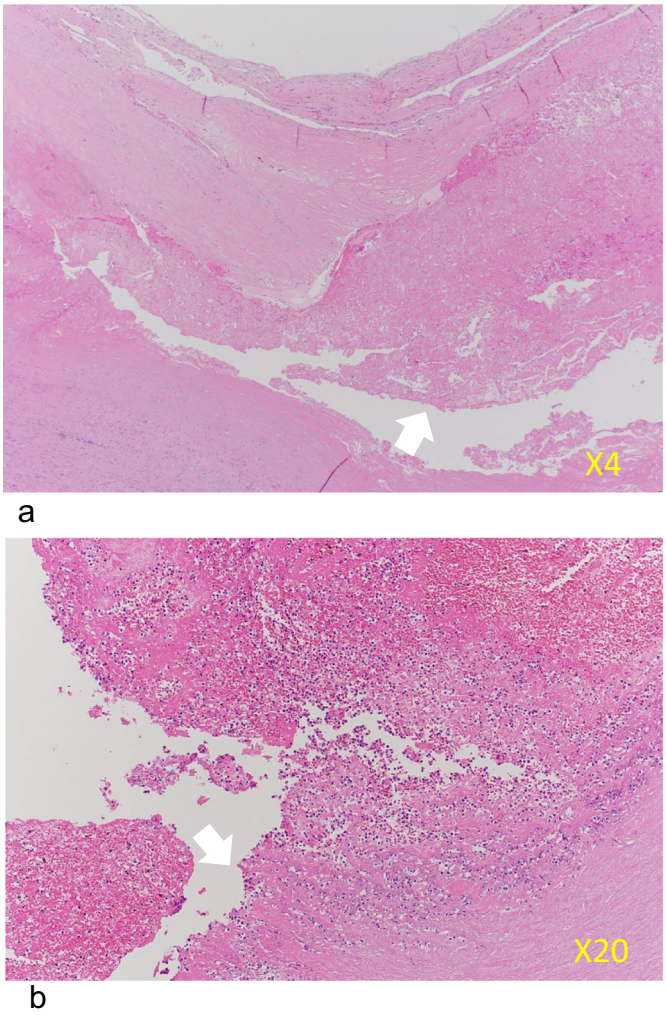

Fig. 4. Hematoxylin–eosin (HE) staining (Case 1). (a) The aortic wall around the fistula. →; atherosclerosis. (b) The locus where element inserted into aortic wall. →; aortic wall.

Now, the fatal complication of aorto-pulmonary fistula remains in less than 1% of TEVAR, and there are no case reports that turned out fatal in open stent graft [6,12,13]. The cause of death in aorto-pulmonary fistula, as was written above, was attributed to the detachment of a part of Z-shape elements from the aorta. Then, how came the detachment of the elements? We speculate that as the first step, a thrombus must have been formed in distal part of the graft between stent and aorta, since the distal portion of the graft was free and not fixed. Here, the elements in distal part of the graft must have been included in the thrombus, causing twitching and shortening of the graft and the fragileness of the elements. Those detached parts must have been under higher pressure since they were located at aneurysmal part of the aorta whose internal surface is not smooth. Then, those elements also had occurred in the same phenomenon as Case 1, causing the aorto-pulmonary fistula.

According to the previous report, it takes about 1 year in median time interval for the aorto-pulmonary fistula to develop after TEVAR [13]. If we could regard this elapsed time identical with open stent graft, the graft must have worked normally in early period after surgery and the deformity of stent occurred later. In the previous report which was written about TEVAR, one of the causes of detachment was the increase of aortic diameter which was induced by aneurysmal degeneration of previously healthy vasculature [14]. However, in Case 2, there was no new aneurysmal degeneration and nor enlargement of original aneurysm around the part where Z-shape elements was attached. Therefore, the enlargement of aortic wall, as was described in this report, might not have occurred in our cases. Therefore, it might be possible that the morphological change of aortic wall by the progress of atherosclerosis have induced uneven pressure in limited portion of elements causing fatal events. Thus we would like to stress in this report that stent can deform later along with morphological change of aneurysmal wall in cases of open stent grafting and that this possibility has to be reminded in the following up of patients on CT scanning.

5. Conclusion

We showed here two autopsy cases of death by fistula formation after stent-grafting. Both of them occurred after the surgery of aortic

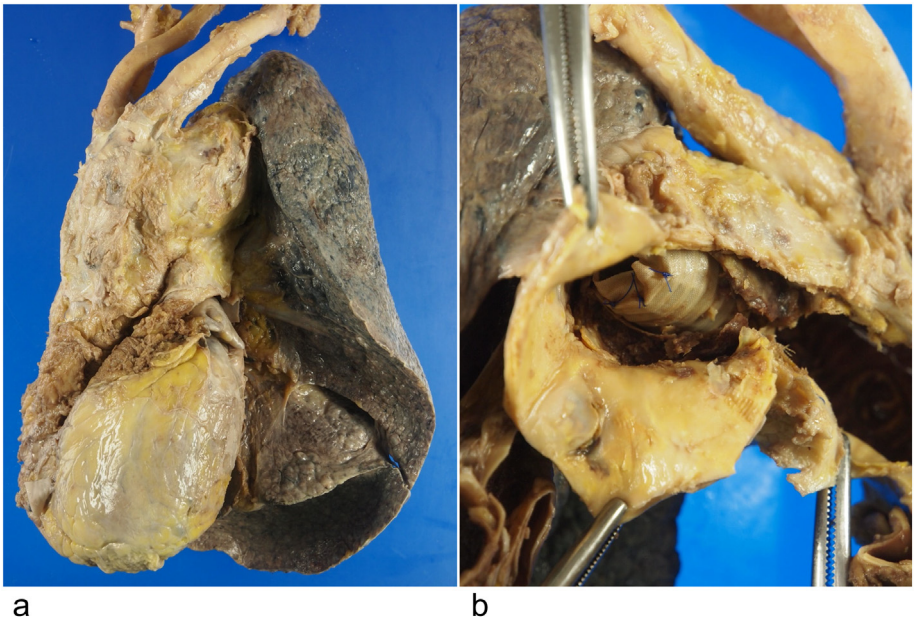

Fig. 5. State of open stent-grafting (Case 2). (a) Heart, aorta and the left lung. Ascending aorta was replaced by 4-branched graft. (b) Aortic arch was cut opened form dorsal surface.

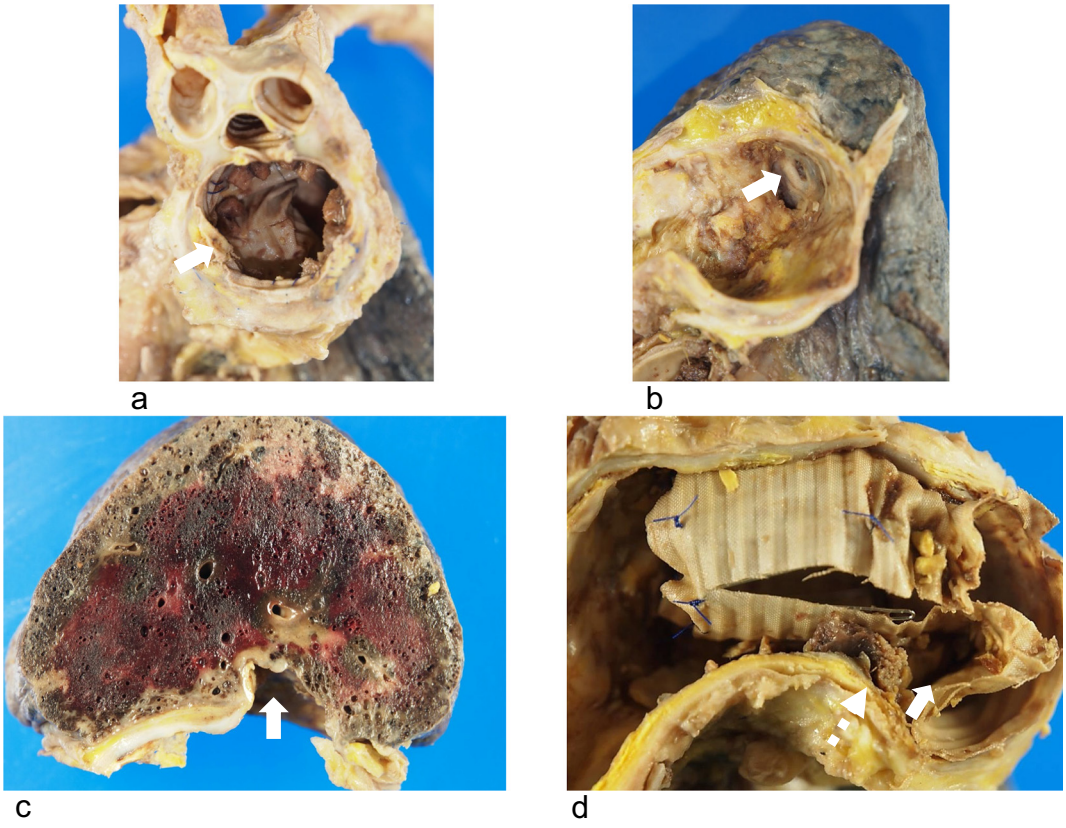

Fig. 6. Stent-graft and aortopulmonary fistula (Case 2). (a) Aortic arch viewed from ascending aorta side. →; the non-fixed part. (b) Aortic arch viewed from ascending aorta side. →; the fistula made by Z-shape stent. (c) Aortopulmonary fistula. →; Aaortic side. (d) Aortic arch viewed from dorsal surface. →; the gap between aorta and stent. →; thrombus.

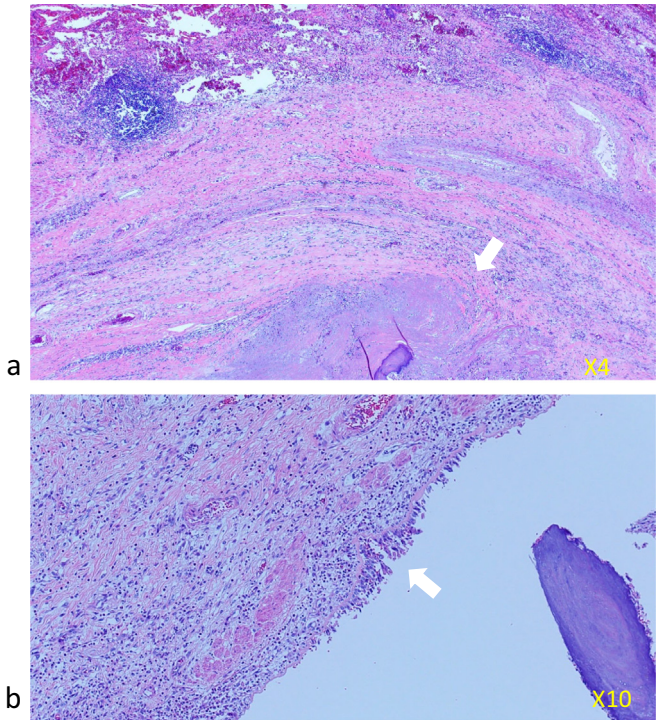

Fig. 7. Hematoxylin–eosin (HE) staining (Case 2). (a) The locus where element inserted into aneurysmal wall. →; aortic wall. (b) Ciliated epithelium was found with in rupture site. →; ciliated epithelium.

arch aneurysm. In both, the detachment of the graft elements was shown as the direct cause of fistula formation. We speculate increased fragility of the aortic wall has contributed much in detachment of the elements. Therefore, we suggest a careful observation concerning the location of Z-shape elements and the properties of vascular intima should be done in the preoperative or postoperative inspection hereafter, for the decrease the mortality of fistula after stent-grafting.

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Conflict of interest

No conflict of interest to declare.

Ethical approval

This report was approved by the University of Denver's Institutional Review Board (IRB), and is in compliance with all regulations regarding human subjects research.

References

[1] Ministry of Health, Labor and welfare. Demographic statiscs. http://www.mhlw.go.jp/toukei/saikin/hw/jinkou/kakutei16/dl/11_h7.pdf, Accessed date: 27 March 2018.
[2] Ohta N, Kuratani T, Hagihira S, Kazumi K, Kaneko M, Mori T. Vocal cord paralysis after aortic arch surgery: predictors and clinical outcome. J Vasc Surg 2006;43:721–8.

[3] Ishimoto S, Ito K, Toyama M, Kawase I, Kondo K, Oshima K, et al. Vocal cord paralysis after surgery for thoracic aortic aneurysm. Chest 2002;121:1991–4.
[4] Dake MD, Miller DC, Semba CP, Mitchell S, Walker PJ, Robert RP. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. N Engl J Med 1994;331:1729–34.
[5] Kato M, Ohnishi K, Kaneko M, Ueda T, Kishi D, Mizushima T, et al. New graft-implanting method for thoracic aortic aneurysm or dissection with a stented graft. Circulation 1996;94:II188–93.
[6] Shimamura K, Kuratani T, Matsumiya G, Kato M, Shirakawa Y, Takano H, et al. Long-term results of the open stent-grafting technique for extended aortic arch disease. J Thorac Cardiovasc Surg 2008;135:1261–9.
[7] Coselli JS, Crawford ES. Primary aortoesophageal fistula from aortic aneurysm: successful surgical treatment by use of omental pedicle graft. J Vasc Surg 1990;12:269–77.
[8] Svensson LG, Grawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operations. J Vasc Surg 1993;17:357–68.
[9] Chiesa R, Melissano G, Marone EM, Marrocco-Trischitta MM, Kahlberg A. Aorto-esophageal and aortobronchial fistulae following thoracic endovascular aortic repair: a national survey. Eur J Vasc Endovasc Surg 2010;39:273–9.
[10] Eggebrecht H, Mehta RH, Dechene A, Tsagakis K, Kühl H, Huptas S, et al. Aortoesophageal fistula after thoracic aortic stent-graft placement: a rate but catastrophic complication of a novel emerging technique. JACC Cardiovasc Interv 2009;2:570–6.
[11] Tao M, Shlomovitz E, Draham G, Roche-Nagle G. Secondary aorto-esophageal fistula after thoracic aortic aneurysm endovascular treated by covered esophageal stenting. World J Clin Cases 2016;4:233–7.
[12] Kato M, Kuratani T, Kaneko M, Kyo S, Ohnishi K. The results of total arch graft implantation with open stent-graft placement for type a aortic dissection. J Thorac Cardiovasc Surg 2002;124:531–40.
[13] Czerny M, Reser A, Eggebrecht H, Janata K, Sodeck G, Etz C, et al. Aorto-bronchial and aorto-pulmonary fistulation after thoracic endovascular aortic repair: an analysis from the European registry of endovascular aortic repair complications. Eur J Cardiothorac Surg 2015;48:252–7.
[14] Grande W, Stavropoulos SW. Treatment of complications following endovascular repair of abdominal aortic aneurysms semin. Intervent Radiol 2006;23:156–64.