Endovascular stent-graft placement for vascular failure of the thoracic aorta

Yoshihiko Kurimoto[1]
Kiyofumi Morishita[2]
Yasufumi Asai[1]

[1]Department of Traumatology and Critical Care Medicine, Sapporo Medical University, Sapporo, Japan; [2]Department of Thoracic and Cardiovascular Surgery, Sapporo Medical University, Sapporo, Japan

Abstract: It still remains undetermined whether endovascular stent-graft placement (ESGP) is the optimal initial treatment for elective cases of thoracic aortic disease because of unknown long-term results. However, it is also recognized that ESGP contributes to better outcome as an initial treatment for aortic emergency, such as rupture, aortic injury, and complicated acute type B aortic dissection. Despite the fact that most patients are elderly, early mortality rates of ESGP are reportedly around 10% in cases of ruptured degenerative thoracic aortic aneurysm. Postoperative morbidity is also superior in ESGP compared with conventional open repair. Postoperative paraplegia has rarely occurred with ESGP. In cases of blunt aortic injury (BAI), other complications may also be present because of other serious injuries. ESGP has changed the surgical strategy for BAI and partially resolved some of the clinical dilemmas. Early mortality rate is almost zero when a stent graft can be placed before re-rupture. While BAI is a very good indication for ESGP, young patients need careful management and attention because of the unknown long-term outcome. In cases of complicated acute type B aortic dissection, the two main determinants of death, shock from rupture and visceral ischemia, could be managed by ESGP with or without conventional endovascular interventions. Recent reports disclosed less than 10% early mortality with ESGP for complicated acute aortic dissection. Even if the possibility of endotension remains, ESPG seems to be beneficial for these critical patients as the preferable initial treatment. The importance of close follow-up should be stressed to avoid some devastating late complications following ESGP.

Keywords: stent graft, ruptured thoracic aortic aneurysm, aortic injury, aortic dissection, organ ischemia

Introduction

Recent advances in surgical management of thoracic aortic diseases has provided better outcomes and has led to an expansion of surgical indication for high-risk patients with comorbidities (Kouchoukos and Dougenis 1997; Svensson et al 1997). However, surgical management of these diseases cannot avoid thoracotomy, extracorporeal bypass, and aortic clamping, which, given the invasiveness of these treatment methods, mean that there are still limitations for critically ill patients. For this reason, the emersion of endovascular stent-graft placement (ESGP), a completely different approach, had a substantial and positive impact on management of aortic disease (Parodi et al 1991; Dake et al 1994). Many studies have investigated the effectiveness of ESGP for abdominal aortic aneurysm (AAA) prior to its application for thoracic aortic disease (Moore and Rutherford 1996; Buth and Laheij 2000; Harris et al 2000; Buth, Harris, et al 2002). Although the long-term outcome of ESGP for AAA was not as satisfactory as initially expected (Bequemin et al 1999; Buth, van Marrewijk, et al 2002; Alric et al 2003; Jacobs et al 2003; Sampram et al 2003), the number of ESGPs for AAA has not diminished as an initial treatment, even following the

Correspondence: Yoshihiko Kurimoto
Department of Traumatology and Critical Care Medicine, Sapporo Medical University, South 1 West 16, Chuoku, Sapporo 060-8543, Japan
Tel +81 11 611 2111
Fax +81 11 611 4963
Email kurimoto@sapmed.ac.jp

disappointing reports (Buth, Jajibi, et al 2002). We believe that the reason for this is that ESGP is less invasive.

As is the case with AAA, the early outcome of ESGP for thoracic aortic disease seems satisfactory compared with conventional open surgery. Recently, the middle-term outcome (a few years postoperative) of ESGP for thoracic aortic disease has been reported to be acceptable (Doss et al 2004; Milnitchouk et al 2004; Makaroun et al 2005). Although there are only a few reports assessing the long-term outcome with follow-ups of five years or more (Orend et al 2003; Demers et al 2004), considerable stent-graft related events have been confirmed. It is easy to understand that localized aortic diseases, such as penetrating aortic ulcer, anastomotic pseudoaneurysm, and aortic isthmus injury, can be treated well by ESGP, but further follow-up assessments are still necessary to determine the appropriate treatment for elective cases of thoracic aortic disease.

On the other hand, ESGP has also been performed for emergency cases of acute thoracic aortic disease, in view of the high mortality of open surgical treatment (Miller et al 1984; Cowley et al 1990; Crawford et al 1991; Johansson et al 1995; von Segesser et al 1996; Miller and Calhoon 1997; Nienaber et al 1999; Lemaire et al 2002). It is rational that ESGP is applied for debilitated patients with aortic emergency if ESGP is less invasive. Based on the reported satisfactory early outcome of ESGP for thoracic aortic disease (Mitchell et al 1999; Bortone et al 2004), ESGP seems to contribute to better outcome as an initial treatment for aortic emergency.

We review reports on the use of ESGP for thoracic aortic emergency, divided into three categories; ruptured thoracic aortic aneurysm, blunt aortic injury, and complicated aortic dissection.

Ruptured degenerative thoracic aortic aneurysm

Generally, the affected population is of an older age with a variety of comorbidities. Despite advancements in open surgical techniques, early mortality rate is still high (Crawford et al 1991; Mastroroberto and Chello 1999) and 50% in elderly patients (Huynh et al 2002). Several important points must be addressed to perform ESGP successfully, including identification of an access artery and accurate configuration of the ruptured aortic aneurysm. One popular reason for unsuccessful ESGP was reported to be access route troubles (Makaroun et al 2005). The latter investigators have reported that conduits to deliver the stent-graft system were required in approximately 15% of patients with thoracic aortic aneurysm. In order to choose ESGP for an emergency case, it is necessary that the left subclavian artery (LSA) does not originate from the ruptured aortic aneurysm (Figure 1). Although the usual indications for elective ESGP have reported that an aortic diameter of proximal and distal landing zone should be less than 40 mm, depending on available endoprosthesis, and a length for both landing zones of more than 20 mm (at least 10 mm) (Greenberg et al 2005; Makaroun et al 2005), emergency ESGP had to be often performed in even unfavorable

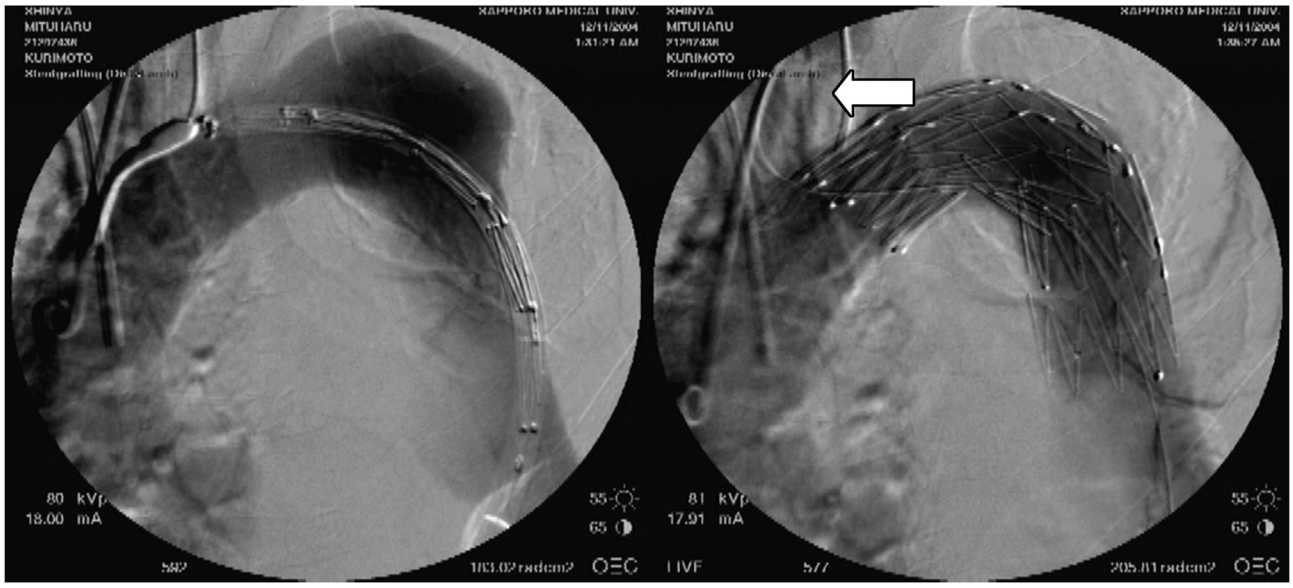

Figure 1 92-year-old man with distal aortic arch aneurysm ruptured into mediastinum. The left subclavian artery is covered by the stent graft, but full patency of the left carotid artery is achieved by the fenestrated stent graft (white arrow).

anatomical states. It is recognized that imaging modalities, such as computed tomography (CT) angiography and magnetic resonance (MR) angiography, are preferable to evaluate suitability of patients for ESGP if the patients' clinical condition allows further examinations. According to previously published reports, it seems to be a relatively safe technique to occlude the LSA intentionally by stent graft in order to make a proximal neck (Czermak et al 2002; Görich et al 2002; Destrieux-Garnier et al 2004; Dagenais et al 2005). On the other hand, carotid left subclavian bypass has commonly been performed before placing stent garft proximal to the LSA in the US (Makaroun et al 2005). Theoretically, cerebellar or brain stem ischemia is possible following occlusion of the LSA (van Herzeele et al 2003) and we experienced that LSA occlusion test revealed the patient in whom the LSA was crucial for brain circulation (Kurimoto et al 2005), but this infrequent adverse event might be an acceptable risk in such emergency situations.

Currently, there are only a few reports which consist of more than 10 cases of ruptured degenerative thoracic aortic aneurysm (Doss et al 2004; Scheinert et al 2004), and early mortality rates are reportedly around 10%, although there are some reports with a small number of cases in which early mortality rate is almost 0% (Semba et al 1997; van Herzeele et al 2003; Bortone et al 2004; Ianneli et al 2004; Milnitchouk et al 2004; Morishita et al 2004). Despite the fact that there are no reports presenting the results of ruptured degenerative thoracic aortic aneurysm in exclusion from other acute aortic diseases, there is a possibility that ESGP provides a better early mortality rate than conventional open surgery. In addition, postoperative morbidity is also superior in ESGP, as exemplified by shorter periods of mechanical ventilator support and lower rates of postoperative renal failure. In particular, postoperative paraplegia, a devastating complication which sometimes occurs following descending thoracic aorta operation, has rarely happened with ESGP, even in emergency operations. Most studies have reported a 0% postoperative paraplegia rate (Semba et al 1997; van Herzeele et al 2003; Bortone et al 2004; Destrieux-Garnier et al 2004; Ianneli et al 2004; Morishita et al 2004; Scheinert 2004) and a few disclose a 4% rate of paraparesis (Dake et al 1994; Dagenais et al 2005). It is likely that post-stent-grafting paraplegia is very rare even in emergency cases of thoracic aortic diseases, as well as in elective cases. In addition, most cases with post-stent-grafting spinal ischemic complication seem to be able to recover to some degree following some rehabilitation.

In contrast to the satisfactory early outcome (Mitchell et al 1999; Bortone et al 2004; Grabenwoger et al 2004), there seems to be problems in the follow-up periods after ESGP (Buth and Laheij 2000). In the first few years after ESGP, there are rarely serious stent-graft related events. However, re-rupture secondary to endoleak or stent-graft migration has been reported in the middle-term periods, especially 5 or more years after ESGP (Buth and Laheij 2000), in cases who were not closely checked by CT examination after ESGP and for whom appropriate treatments, such as re-ESGP, were not performed.

Nevertheless, for elderly patients with significant comorbidity, ESGP is still a preferable initial treatment of choice for ruptured degenerative thoracic aortic aneurysm if the configuration of aneurysm allows it. In near future, the use of branched grafts might further expand the indication for stent-grafting for ruptured distal arch aneurysm (Schneider et al 2003).

Blunt aortic injury

Since an anecdotal report by Parmley et al (1958), immediate open surgical treatment has been recommended to avoid re-rupture of pseudoaneurysm at the aortic isthmus. However, most patients with blunt aortic injury (BAI) are complicated with other serious injuries, such as head injury, which do not always allow immediate open repair of the injured aorta. Despite recent advancements in surgical techniques, extracorporeal bypass and aortic clamping are still potentially harmful for these patients. In this context, the timing of open repair of injured aorta has been controversially discussed for a decade because conventional open repair is possibly too invasive for multi-trauma patients (Walker and Pate 1990; Holmes et al 2002; Rousseau et al 2005).

However, the emergence of ESGP has changed surgical strategy for BAI and partially resolved some clinical dilemmas regarding thoracotomy, unilateral lung ventilation, aortic clamping, and heparinization for extracorporeal bypass. In the period when there were only the two choices of open repair or conservative treatment, initial conservative treatment and delayed open repair may well have been a reasonable strategy (Holmes et al 2002; Rousseau et al 2005), considering the high mortality associated with immediate open repair (Walker and Pate 1990). Nowadays, we know that ESGP is less invasive and very effective for BAI (Marty-Ane et al 2003; Dunham et al 2004; Neuhauser et al 2004; Wellons et al 2004; Rousseau et al 2005).

Considering the fact that 10% of BAIs have the possibility to re-rupture in the acute phase despite medical treatment (Fabian et al 1997; Holmes et al 2002), ESGP should be performed as early as possible if the patients can be transferred to an operating room or angiography suite.

Although there is no report that describes which type of BAI is indicated for initial conservative treatment, traumatic type B aortic dissection and pseudoaneurysm without mediastinal hematoma are probably candidates (Frykberg et al 1991). Since ascending aorta injury is fatal, commonly combining with cardiac injury or cardiac tamponade (Parmley et al 1958; Fishbone et al 1973), the incidence of BAIs affecting the aortic isthmus is high at more than 80% in patients who can be clinically treated for BAI (Duhaylongsod et al 1992; Fabian et al 1997). With the exception of young patients with acutely angled distal arch, ESGP seems to be very well suited to BAI because of the localized affect of the lesion, small diameter of aorta for landing neck and easy access to the injured aorta (Figure 2).

Early mortality rate of ESGP for BAI is almost zero in many reports (Marty-Ane et al 2003; Dunham et al 2004; Neuhauser et al 2004; Wellons et al 2004; Rousseau et al 2005). The cause of early death after ESGP was reportedly due to other concomitant critical injuries (Dunham et al 2004). The postoperative paraplegia rate following open repair for BAI is approximately 5% even when using distal aortic perfusion, which has been a concern because the patients are relatively young compared with those with degenerative aortic aneurysm (Fabian et al 1997; Rousseau et al 2005). Certainly, the introduction of ESGP has made this devastating complication very rare (Marty-Ane et al 2003; Dunham et al 2004; Neuhauser et al 2004; Wellons et al 2004; Rousseau et al 2005) but a small number of cases have needed re-ESGP due to secondary endoleak (Neuhauser et al 2004). Critical events, such as rupture, are very rare in the middle term after ESGP. However, considering the small diameter of the aorta in young patients, migration of the deployed stent graft of small size is highly possible in some decades after ESGP (Duhaylongsod et al 1992). For the time being, indication of ESGP for young patients should be limited to those complicated with severe brain injury.

Complicated aortic dissection

Except for Stanford type A retrograde aortic dissection (Doenst et al 2000), Stanford type B aortic dissection is a possible candidate for ESGP. Generally, type B aortic dissection has been managed by conservative treatment in acute phase if no dissection-related complications were present (Umana et al 2002; Suzuki et al 2003; Kusagawa et al 2005). The in-hospital mortality rate of acute type B was an average of 13% and was highest for patients who required surgery, at 32% (Suzuki et al 2003). Seventy percent of patients died from rupture with visceral ischemia being the next most frequent cause at 19% (Suzuki et al 2003). Emergency surgery has been performed for ruptured descending thoracic aorta and organ ischemia secondary to

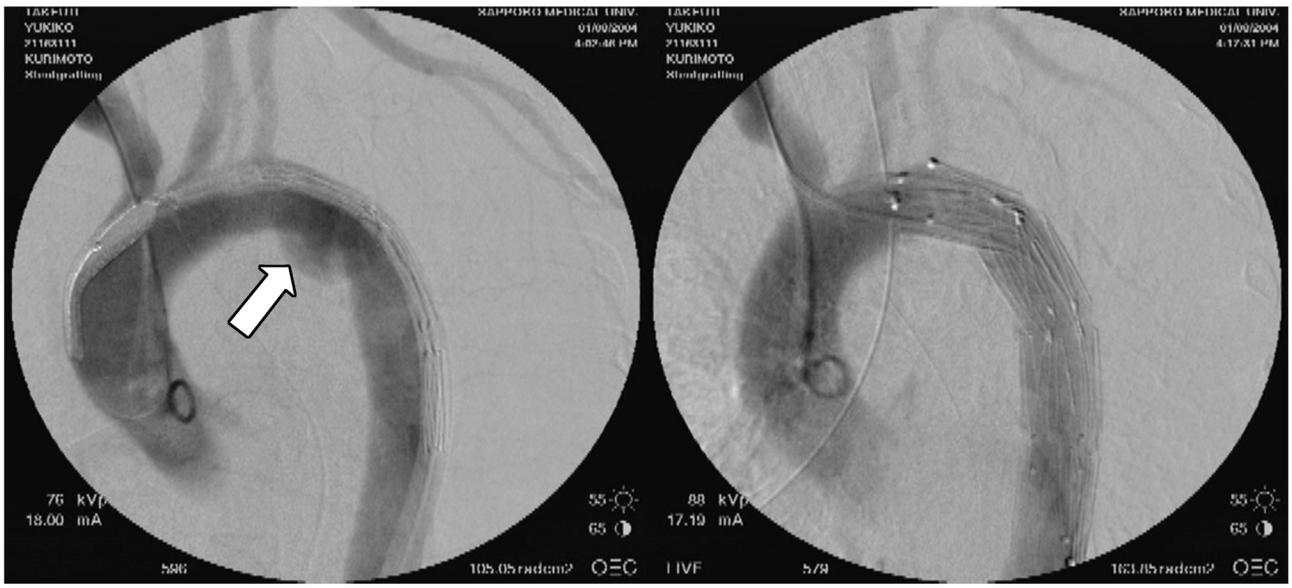

Figure 2 74-year-old woman with blunt aortic injury associated with intracranial hemorrhage and pelvic fracture. Emergency stent-grafting was performed 2 hours after arrival. Typical aortic isthmus injury (white arrow) is well excluded by the stent graft.

aortic branch malperfusion. Mortality rates for type B dissection with hypotension due to rupture or with organ ischemia were as high as 61.6% and 45.5%, respectively (Suzuki et al 2003).

Aortic side branch occlusion associated with spontaneous acute aortic dissection was common, with an incident rate of 40% (Cambria et al 1988; Lauterbach et al 2001). Surgical procedure to restore the flow into an ischemic organ depends on whether the mechanism of aortic branch occlusion is dynamic or static (Lauterbach et al 2001; Beregi et al 2003; Vedantham et al 2003). Open surgical fenestration has been performed in cases of dynamic mechanism in which a true lumen of aorta is critically compressed by an expanded false lumen (Cambria et al 1988; Deeb et al 1997; Oderich and Panneton 2002). Lauterbach et al (2001) reported a recent improvement of in-hospital mortality rate to 23% in the group with end-organ ischemia (Cambria et al 1988). It was reported that after aortic rupture or tamponade is ruled out, mesenteric and renal revascularization precedes a proximal aortic operation, most often by open aortic fenestration (Lauterbach et al 2001). Deeb et al (1997) also recommended management of end-organ malperfusion prior to proximal aortic replacement even in cases of acute type A dissection (Oderich and Panneton 2002). Contrarily, Fann et al (1990) reported a 92% resolution of upper and lower limb ischemia following proximal aortic repair and insisted that proximal aortic operation should be performed first for cases of acute aortic dissection complicated with peripheral vascular malperfusion, including mesenteric ischemia (Elefteriades et al 1990). Although endovascular treatments, such as balloon fenestration and stent placement, for end-organ ischemia caused by acute aortic dissection have been reported for selected patients (Fann et al 1990; Lauterbach et al 2001; Beregi et al 2003), the emergence of ESGP has changed surgical strategy for cases with complicated acute aortic dissection including rupture at the descending thoracic aorta (Slonim et al 1999; Bortone et al 2002; Herold et al 2002; Hutschala et al 2002; Duebener et al 2004).

The two main determinants of death due to acute type B dissection, shock from rupture (Figure 3) and visceral ischemia (Figure 4) (Umana et al 2002; Suzuki et al 2003), could be managed less invasively by ESGP with or without conventional endovascular interventions (Fann et al 1990; Slonim et al 1999; Doenst et al 2000; Lauterbach et al 2001; Herold et al 2002; Hutschala et al 2002; Beregi et al 2003; Duebener et al 2004). Considering reports of insufficient fenestrated re-entry size to rescue malperfusion in the acute phase and rupture in the late phase following percutaneous fenestration, primary entry closure using stent grafts seems to be preferable in cases with malperfusion by the dynamic mechanism (Cambria et al 1988; Bortone et al 2002). Initially, an early mortality rate of 16% was reported in patients with complicated acute type B dissection treated by ESGP (Williams et al 1990). Recent reports disclosed less than 10% early mortality with ESGP for complicated acute aortic dissection (Doenst et al 2000; Herold et al 2002; Hutschala et al 2002; Duebener et al 2004). Early outcomes

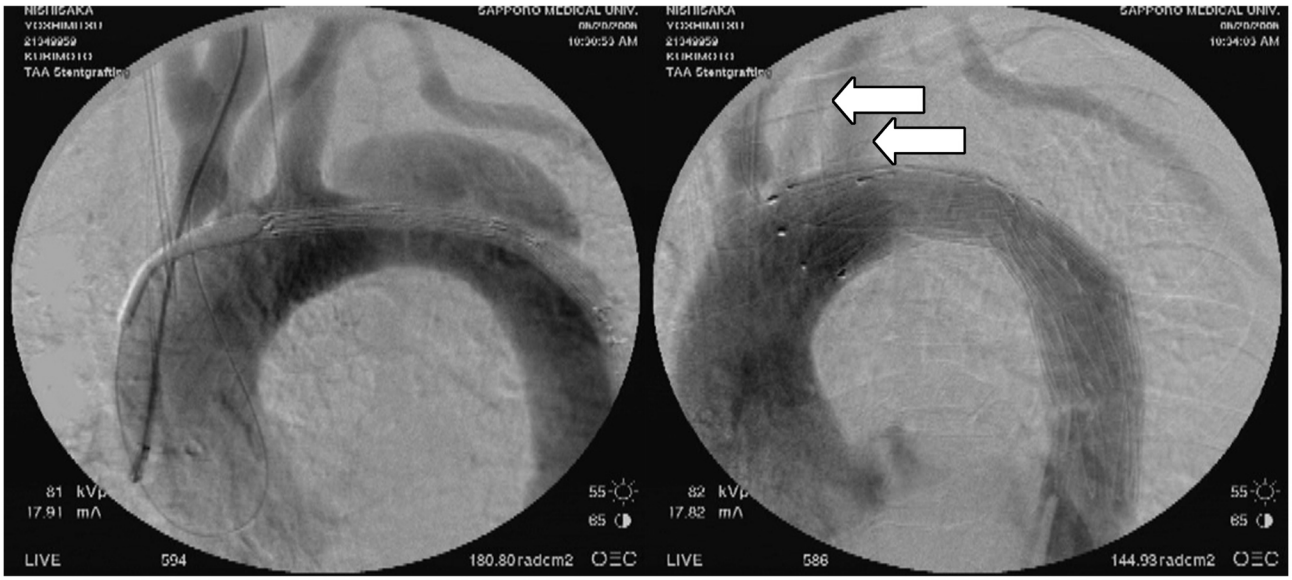

Figure 3 57-year-old man with acute type IIIa aortic dissection ruptured into the left pleural cavity. In addition to complete entry closure, full patency of the left carotid artery and the left subclavian artery is achieved by the fenestrated stent graft (white arrow).

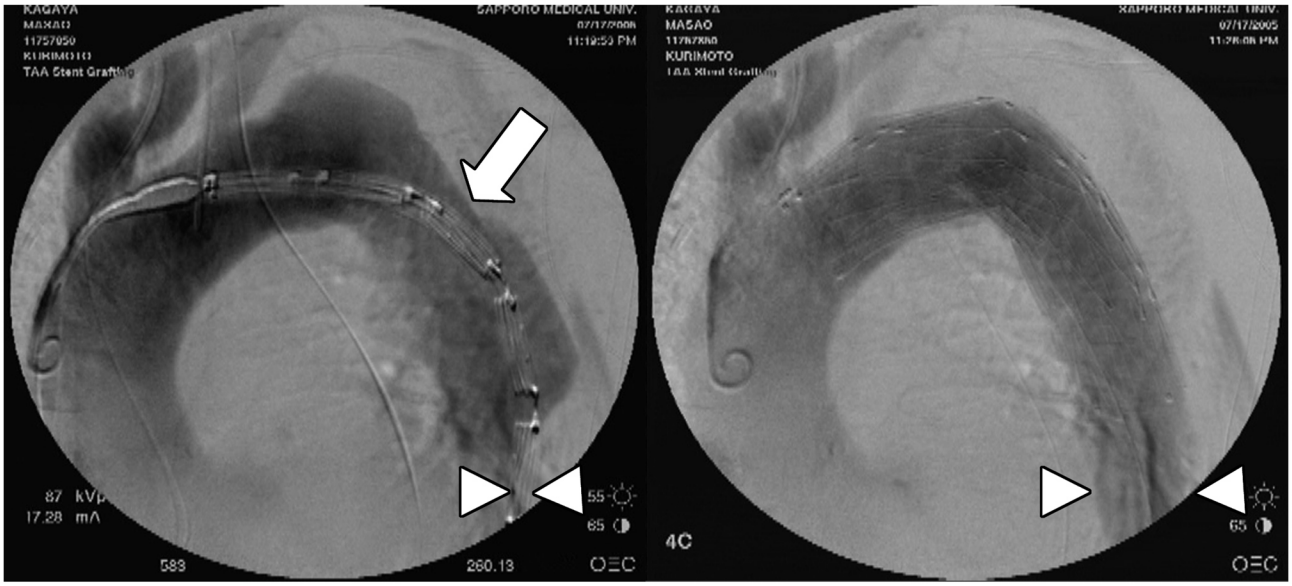

Figure 4 81-year-old man with acute type IIIa aortic dissection complicated with visceral and leg ischemia. The entry site (white arrow) was revealed by intravascular ultrasound (IVUS) before deployment of the stent graft. Critically compressed true lumen of the distal descending thoracic aorta is sufficiently expanded by the entry closure using the stent graft (white arrowheads).

of ESGP were satisfactory. However, ESGP cannot close all entries or re-entries through the aorta, which means there is a possibility that endotension of a false lumen continues and causes critical late complications, such as re-rupture and aorto-esophageal fistula (Dake et al 1999; Duebener et al 2004). Even if the possibility of endotension remains, the value of ESPG is not reduced because patients undergo a second intervention, including open surgery, with acceptable results due to their stabilized condition. There are still some unclear problems in ESGP for aortic dissection including intramural hematoma which is obviously one possible lethal disease. Thus, there is a need to stress the importance of close follow-up to avoid devastating late complications.

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