

Number and mortality of aortic surgery in Japan

Akihiko Usui, Rena Usui and Shunsuke Nakata

Cardiovascular Surgery, Fujita Health University Okazaki Medical Center, Okazaki, Japan

ABSTRACT

According to the Japanese Association for Thoracic Surgery annual surgery survey, the number of aortic surgery has been increasing constantly in the last two decades, with the rates approximately doubling in each decade (5,167, 11,956, and 22,708 cases in 1999, 2009, and 2019, respectively). In 2019, aortic surgery was performed for 11,036 (49%) nondissecting unruptured aneurysm, 730 (3%) ruptured aneurysm, 6,351 (28%) acute type A aortic dissection, 1,412 (6%) chronic type A aortic dissection, 2,385 (11%) acute type B aortic dissection, and 703 (3%) chronic type B aortic dissection cases. The outcomes have been improving annually. From 1999 to 2019, the hospital mortality rates decreased significantly in each case: nondissecting unruptured aneurysm, 9.8% to 4.2%; ruptured aneurysm, 38.5% to 19.7%; acute type A aortic dissection, 18.7% to 10.4%; chronic type A aortic dissection, 7.2% to 4.5%; acute type B aortic dissection, 25.2% to 9.8%; and chronic type B aortic dissection, 7.5% to 3.4%. Furthermore, stent graft, a new technology developed in 1990, was performed in 35%, 53%, 1%, 21%, 62%, and 75% of cases mentioned above, respectively, in 2019. The widespread use of stent graft greatly contributed to the increased number of aortic surgeries and improvement of surgical outcomes.

Keywords: aortic surgery, aneurysm, aortic dissection, stent graft, thoracic endovascular aortic repair

Abbreviations:

JATS: Japanese Association for Thoracic Surgery

TEVAR: thoracic endovascular aortic repair

JCVSD: Japanese Cardiovascular Surgery Database

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INTRODUCTION

Since 1986, the Japanese Association for Thoracic Surgery (JATS) has been conducting an annual surgery survey, revealing changes in the number of surgeries and surgical outcomes over three decades in Japan.^{1,2} Currently, approximately 70,000 cardiovascular surgeries are performed in Japan. In particular, more than 20,000 aortic surgeries are performed for thoracic and thoracoabdominal aortic diseases, accounting for approximately 30% of all cardiovascular surgeries. This ratio is higher than those in Europe and the United States and is considered a characteristic of Japan.

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Corresponding Author: Akihiko Usui, MD, PhD

Cardiovascular Surgery, Fujita Health University Okazaki Medical Center, 1 Gotanda, Harisaki-cho, Okazaki 444-0827, Japan

TEL: +81-564-64-8133, E-mail: ausui@med.nagoya-u.ac.jp

Several new surgical techniques have been developed for cardiovascular surgery. Especially in aortic surgery, stent graft technology was developed by Parodi³ in Argentina in 1990. Thoracic endovascular aortic repair (TEVAR) using stent grafts is less invasive and has been performed worldwide. Handmade stent grafts were used from the late 1990s to the early 2000s. In Japan, a commercially available stent graft for thoracic aortic aneurysm and that for aortic dissection were approved in 2008 and 2015, respectively. Thereafter, TEVAR has become more widespread. An open stent graft used for open surgery was reported by Kato et al⁴ in 1996. Initially, homemade open stent grafts were used; however, a commercially available open stent graft was approved in Japan in 2014. Additionally, procedures using open stent grafts have become popular and applied extensively as frozen elephant trunk procedures. In this study, using the JATS annual surgery survey data from 1997 to 2019, we aimed to determine the changes in the number of aortic surgeries for thoracic and thoracoabdominal diseases and the surgical outcomes. In particular, we estimated the effects of commercially available stent grafts and open stent grafts on surgical indications and surgical outcomes and evaluated the progress in aortic surgery in Japan.

THE JATS ANNUAL SURGERY SURVEYS

The number of surgeries and the rate of hospital mortality were obtained from the JATS annual surgery surveys. Data were tabulated for each of the following diseases: acute type A aortic dissection, acute type B aortic dissection, chronic type A aortic dissection, chronic type B aortic dissection, nondissecting unruptured aneurysms, and nondissecting ruptured aneurysms. We also calculated data for each of the following surgical procedures: open surgery for the ascending aorta, aortic root, ascending aorta to aortic arch, aortic arch to descending aorta, descending aorta, or thoracoabdominal aorta; TEVAR; and surgery using open stent grafts.

In the JATS surgery surveys, data were initially collected using self-reported questionnaire sheets in each participating institution. Since 2015, an automatic package has been available for download from the Japanese Cardiovascular Surgery Database (JCVSD).

In this study, hospital mortality was defined as death within any time interval following surgery among patients yet to be discharged. Transfer to a nursing home or a rehabilitation unit was considered hospital discharge unless the patient subsequently died of complications from surgery.

Regarding the timing of aortic dissection, presentation within 14 days of symptom onset defined the acute phase, whereas presentation beyond 2 months after symptom onset defined the chronic phase. In the JCVSD definition, the interval between 2 weeks and 2 months from the symptom onset was defined as the subacute phase. The JATS annual surgery surveys defined acute aortic dissection as presentation within 14 days of symptom onset and chronic aortic dissection as presentation beyond 14 days after symptom onset, including the subacute and chronic phases defined in the JCVSD.^{1,2}

The Stanford classification was used for aortic dissection. Aortic dissection involving the ascending aorta defined type A, whereas aortic dissection without ascending aorta involvement defined type B. A nondissecting aneurysm referred to any aortic disease other than aortic dissection, including true aneurysm, pseudoaneurysm, and others.

AORTIC SURGERY IN JAPAN

Over the last two decades, the number of aortic surgeries has been increasing constantly according to the JATS annual surgery surveys, with the rates approximately doubling in each

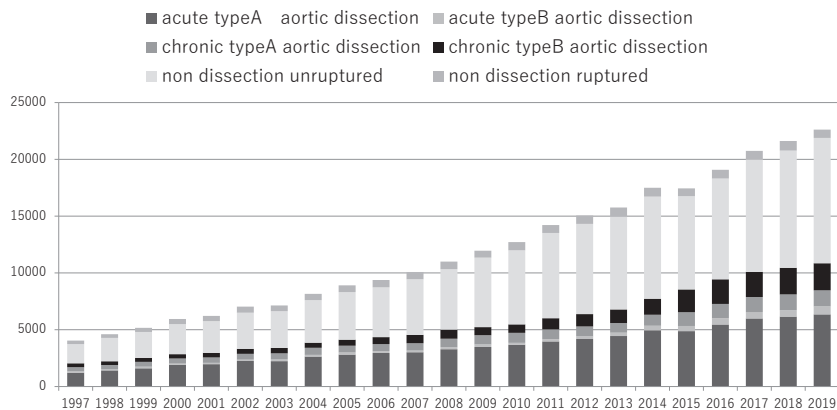


Fig. 1 Number of aortic surgeries for each disease

decade (5,167, 11,956, and 22,708 cases in 1999, 2009, and 2019, respectively; Figure 1). The JATS annual surgery survey changed the method from a questionnaire to data conversion from the JCVSD in 2015. Therefore, a slight decline was observed in 2015. In the latest survey, 22,708 surgeries were performed for thoracic and thoracoabdominal aortic diseases. Aortic dissection accounted for approximately half of the cases (10,847 cases, 48%), while nondissecting aneurysm accounted for 11,861 (52%). In all procedures for aortic dissection, acute type A aortic dissection had the highest number of cases (6,351, 28%), whereas acute type B aortic dissection had the lowest (703, 3%). Among the cases of chronic aortic dissection, 1,412 patients (6%) underwent surgeries for type A aortic dissection, and 2,385 (11%) underwent surgeries for type B aortic dissection. In surgeries for nondissecting aneurysms, most of the cases were unruptured aneurysms (11,036 cases, 49%); such cases accounted for approximately half of the aortic surgeries that were performed during the study period. Meanwhile, emergency surgery for ruptured aneurysms was performed in only 730 cases (3%; Figure 1).

HOSPITAL MORTALITY IN AORTIC SURGERY

The outcomes of aortic surgery have been improving annually (Figure 2). Surgical procedures for nondissecting unruptured aneurysms, chronic type A aortic dissection, and chronic type B aortic dissection were mainly performed electively, and their hospital mortality rates were similar. In 1999, the hospital mortality rates were 9.8% for nondissecting unruptured aneurysms, 7.2% for chronic type A aortic dissection, and 7.5% for chronic type B aortic dissection; their rates improved steadily to 4.6%, 5.3%, and 7.2% in 2009 and further improved to 4.2%, 4.5%, and 3.4% in 2019, respectively. Likewise, the outcomes of surgery for nondissecting ruptured aneurysms, acute type A aortic dissection, and acute type B aortic dissection, which require emergency operation, have improved over time. In 1999, the hospital mortality rates were 38.5% for nondissecting ruptured aneurysms, 18.7% for acute type A aortic dissection, and 25.2% for acute type B aortic dissection. Then, they improved to 26.9%, 12.7%, and 22.0% in 2009 and further improved to 19.7%, 10.4%, and 9.8% in 2019, respectively. Notably, surgeries for acute type A aortic dissection showed a hospital mortality rate of approximately 10%.

Aortic surgery in Japan

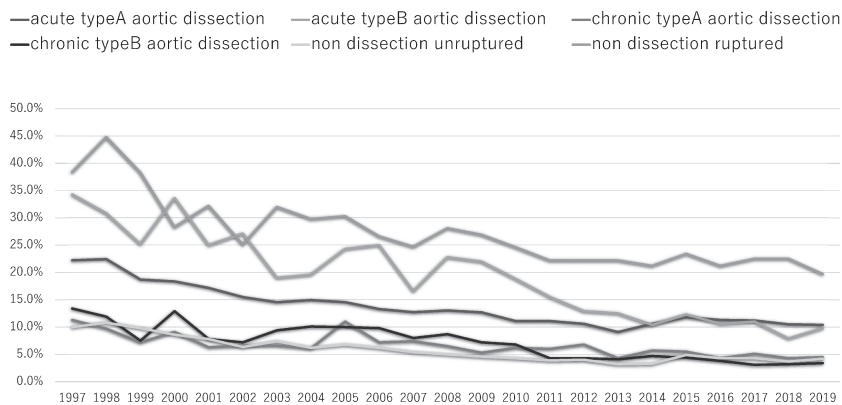


Fig. 2 Hospital mortality rates according to disease in patients undergoing aortic surgery

SURGERY FOR NONDISSECTING UNRUPTURED ANEURYSMS

After a commercially available stent graft was approved for use in 2008, the number of TEVAR procedures using stent grafts increased rapidly. They continued to increase, even in 2019, with a small decline in 2015 resulting from the change in the surgery survey method (Figure 3). The number of surgeries using open stent grafts also significantly increased after the approval of a commercially available open stent graft in 2014 and continued to increase through 2019. In open surgery, the numbers of surgeries for ascending aortic replacement and the aortic arch have increased over time. However, those for the descending aorta and thoracoabdominal aorta, which require left thoracotomy, have plateaued. After a commercial open stent graft became available, surgeries for both the aortic arch and descending aorta significantly decreased.

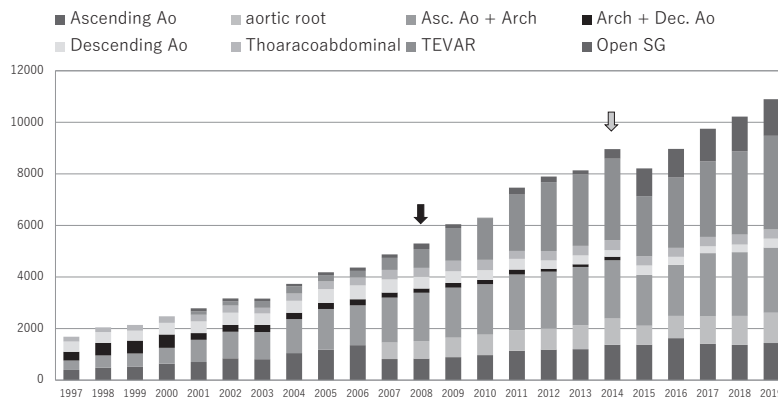


Fig. 3 Procedures performed for nondissecting unruptured aneurysms

The black and gray arrows indicate the approval of commercially available stent grafts and open stent grafts, respectively.

Ao: aorta

Asc. Ao: ascending aorta

Dec. Ao: descending aorta

TEVAR: thoracic endovascular aortic repair

Open SG: open stent graft

SURGERY FOR NONDISSECTING RUPTURED ANEURYSMS

The transition in the surgical procedure for ruptured aneurysms was characteristic. Since the approval of a commercially available stent graft in 2008, the number of TEVAR procedures using stent grafts has increased dramatically (Figure 4). Similarly, surgeries using open stent grafts have increased since the approval of commercially available open stent grafts in 2014. Conversely, open surgical procedures gradually decreased, except for surgeries intended for the ascending aorta, which are difficult to treat with a stent graft.

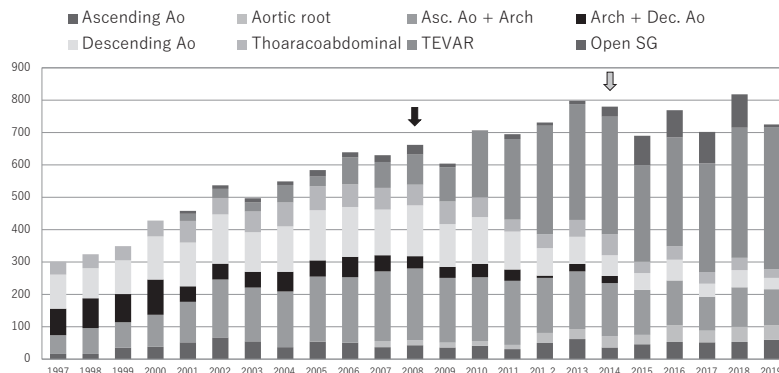


Fig. 4 Procedures performed for nondissecting, ruptured aneurysms

The black and gray arrows indicate the approval of commercially available stent grafts and open stent grafts, respectively.

Ao: aorta

Asc. Ao: ascending aorta

Dec. Ao: descending aorta

TEVAR: thoracic endovascular aortic repair

Open SG: open stent graft

SURGERY FOR ACUTE TYPE A AORTIC DISSECTION

Acute type A aortic dissection is difficult to treat with a stent graft, with a low number of TEVAR procedures performed. However, the number of surgeries for this condition has steadily increased over time (Figure 5). The approval of a commercially available open stent graft in 2014 had a significant impact on the choice of surgical procedure. Surgeries using an open stent graft have increased since 2014, with up to 1,400 cases. In contrast, the number of ascending aortic surgeries has decreased slightly since 2014, reaching a plateau of approximately 2,400 cases in 2017. The number of aortic arch surgeries without an open stent graft has also recently remained at approximately 2,000, while that of aortic root surgeries plateaued at approximately 400 cases (6%).

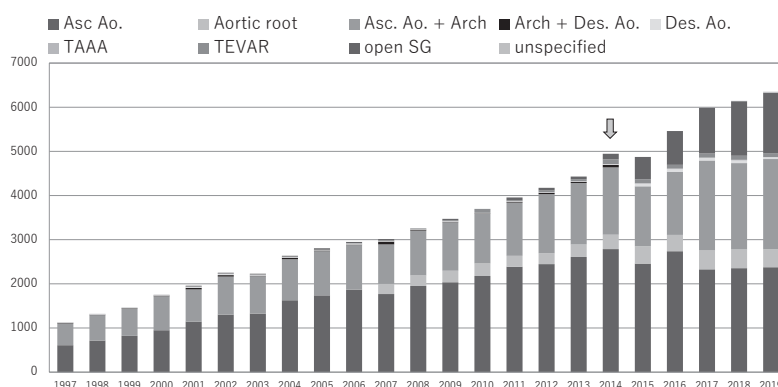


Fig. 5 Procedures performed for acute type A aortic dissection

Asc. Ao: ascending aorta

Dec. Ao: descending aorta

TAAA: thoracoabdominal aorta

TEVAR: thoracic endovascular aortic repair

Open SG: open stent graft

SURGERY FOR ACUTE TYPE B AORTIC DISSECTION

Usually, acute type B aortic dissection is treated conservatively, with surgery required only for complicated cases (eg, cases involving rupture, rapid expansion, or malperfusion). The commercially available stent graft that was approved in 2008 was not indicated for aortic dissection, but in 2015, a stent graft for aortic dissection was approved. Few patients with acute type B aortic dissection underwent open surgery, showing a slight decrease, with the number of cases remained below 100 annually. Conversely, the number of TEVAR procedures using stent grafts has increased since 2008 and further increased from 2015 (Figure 6). Most cases of acute type B aortic dissection were treated by TEVAR, which was the main reason for the increase in the number of surgeries. The approval of a commercially available open stent graft in 2014 also showed a significant impact; this open stent graft was used in approximately 100 cases in the recent year.

SURGERY FOR CHRONIC TYPE A AORTIC DISSECTION

Only few patients with chronic type A aortic dissection were eligible for stent graft treatment. However, since 2008, the number of stent graft users has increased. It further increased after a commercially available stent graft was approved for aortic dissection in 2015. The approval of a commercially available open stent graft in 2014 also led to an increasing trend in aortic arch replacement using open stent grafts (Figure 7). The increase in the number of surgeries for the ascending aorta, aortic arch, and aortic root may be explained by the fact that many patients are ineligible for TEVAR. Meanwhile, the number of surgeries for the descending aorta and thoracoabdominal aorta has gradually increased.

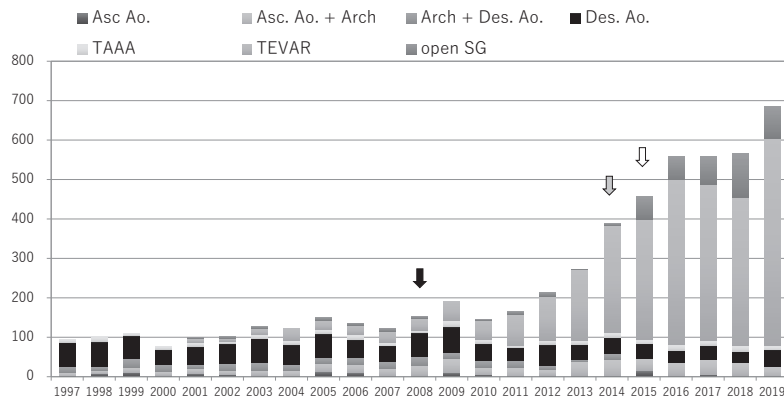


Fig. 6 Procedures performed for acute type B aortic dissection

Black, gray, and white arrows show the approval of commercially available stent grafts, open stent grafts, and stent grafts for aortic dissection, respectively.

Asc. Ao: ascending aorta

Dec. Ao: descending aorta

TAAA: thoracoabdominal aorta

TEVAR: thoracic endovascular aortic repair

Open SG: open stent graft

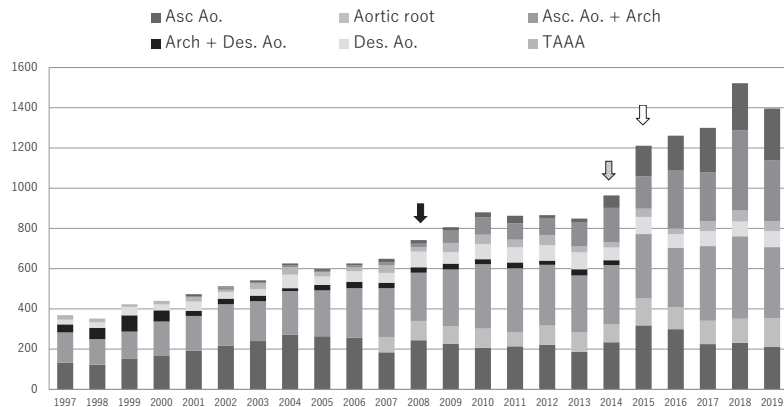


Fig. 7 Procedures performed for chronic type A aortic dissection

Black, gray, and white arrows show the approval of commercially available stent grafts, open stent grafts, and stent grafts for aortic dissection, respectively.

Asc. Ao: ascending aorta

Dec. Ao: descending aorta

TAAA: thoracoabdominal aorta

TEVAR: thoracic endovascular aortic repair

Open SG: open stent graft

SURGERY FOR CHRONIC TYPE B AORTIC DISSECTION

Since the approval of a commercially available stent graft in 2008, the number of TEVAR performed for chronic type B aortic dissociation has increased dramatically (Figure 8). It further increased after a commercially available stent graft was approved for aortic dissection in 2015,

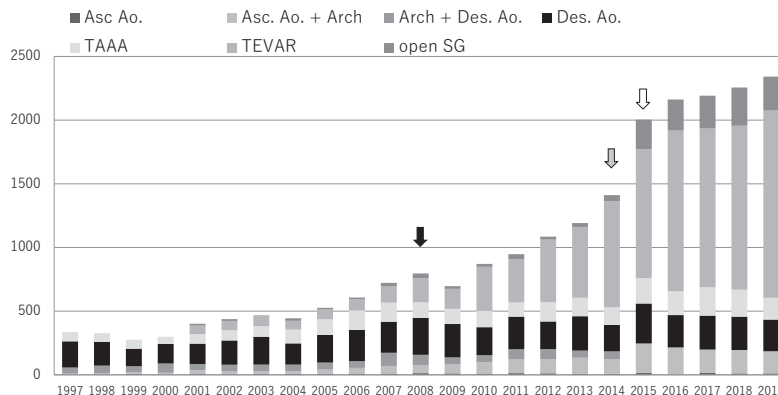


Fig. 8 Procedures performed for chronic type B aortic dissection

Black, gray, and white arrows show the approval of commercially available stent grafts, open stent grafts, and stent grafts for aortic dissection, respectively.

Asc. Ao: ascending aorta

Dec. Ao: descending aorta

TAAA: thoracoabdominal aorta

TEVAR: thoracic endovascular aortic repair

Open SG: open stent graft

with 1,470 cases in 2019, accounting for 63% of all surgeries. Meanwhile, the number of open surgeries has plateaued; however, it was significantly influenced by the approval of a commercially available open stent graft in 2014. Consequently, 267 surgeries using an open stent graft were performed, accounting for 30% of open surgeries.

DISCUSSION

The number of aortic surgeries has continuously increased, with the rate doubling over 10 years in the last two decades. The spread of TEVAR was strongly associated with an increase in the number of aortic surgeries performed. The rate of TEVAR varies depending on the surgical range and aortic disease, considering that this procedure is a good indication for diseases of the descending aorta. TEVAR procedures were performed in 35%, 53%, 75%, 62%, 1%, and 21% of nondissecting unruptured aneurysms, nondissecting ruptured aneurysms, acute type B aortic dissections, chronic type B aortic dissections, acute type A aortic dissections, and chronic type A aortic dissections, respectively.

TEVAR popularity was greatly influenced by the approval of a commercially available stent graft in 2008 and a commercially available stent graft for aortic dissection in 2015. Given that TEVAR is less invasive than open surgery, its indications expand to the older adult population and high-risk patients with some morbidity. The number of TEVAR procedures performed for nondissecting unruptured aneurysms increased in 2019 and has not yet reached a plateau. The number of TEVAR cases for acute and chronic type B aortic dissection increased dramatically because of the recommendation of preemptive TEVAR for this pathophysiology. This increase was even higher^{5,6} in 2019. Additionally, with the advancement of stent graft technology, the indications for TEVAR expand to include the aortic arch and thoracoabdominal ranges.

However, the number of open surgeries has steadily increased. For nondissecting unruptured aneurysms, it was 1,727, 4,397, and 7,405 in 1999, 2009, and 2019, respectively. As described

subsequently, the surgical outcomes of open surgeries have been steadily improving. These improved surgical outcomes have led to the expansion of indications for open surgery, thereby increasing the number of surgeries.

In principle, TEVAR for acute type A aortic dissection is impossible, and open surgery is the only treatment option. The number of surgeries for acute type A aortic dissection has increased steadily, with the rate doubling every decade (1,604, 3,487, and 6,347 cases in 1999, 2009, and 2019, respectively). In Japan, computed tomography is widely performed, providing higher diagnostic performance for aortic dissection. In addition, the ambulance transport system is well developed, the number of older adults continues to increase, and surgical indications for this population are expanding.⁷ These are the main reasons for the increase in surgeries for acute type A aortic dissection, and the number of surgeries continued to increase even in 2019.

In open surgery, the use of a hybrid approach combined with stent grafting has been increasing. Since commercially available open stent grafts were approved in 2014, aortic arch surgery using open stent grafts has been increasingly performed. Surgery using open stent grafts, which are usually called frozen elephant trunk, accounted for 13%, 18%, and 11% of nondissecting unruptured aneurysms, chronic type A aortic dissections, and chronic type B aortic dissections, respectively, in 2019. The actual number of two-stage hybrid surgeries with TEVAR after aortic arch surgery could not be estimated from the JATS annual surgery survey. Since 2015, the number of surgeries for nondissecting unruptured aneurysms involving the aortic arch and descending aorta has significantly decreased. The cases that would be targeted for such surgery may have shifted to hybrid surgery.⁸

Since the approval of a commercially available open stent graft in 2014, certain changes emerged in the selection of surgical procedures. This approval had a remarkable impact on surgery for acute type A aortic dissection. The number of surgeries using open stent grafts increased to 1,387 (22%) in 2019.⁹ Before 2014, ascending aortic surgery accounted for two-thirds of all surgeries. However, in 2019, it decreased to 37% (2,376 cases); meanwhile, aortic arch replacement increased to 2,045 cases (32%). By adding open stent grafts to aortic arch replacement, aortic arch surgery accounted for 54% of the procedures. In chronic type B aortic dissection, the number of surgeries using open stent grafts has also increased, reaching 257 cases (22%) in 2019.

The steady improvement in surgical outcomes is a notable feature of Japanese aortic surgery. The spread of TEVAR has contributed to improving these outcomes; however, of note, the surgical outcomes of open surgery have also improved. In 2019, the hospital mortality rates of surgery for nondissecting unruptured aneurysms were 3.1% for ascending aortic surgery and 3.4% for aortic arch surgery (Table 1). These rates are equivalent to that of isolated aortic valve replacement (2.9%), a common cardiac surgery. Aortic surgery for the ascending aorta and aortic arch range can be performed with the same safety level as cardiac surgery. The surgical outcomes of thoracoabdominal aortic surgery requiring left thoracotomy have also improved, but the hospital mortality rate was still 9.6% in 2019; thus, further improvement is required.² The hospital mortality rate of TEVAR was 2.7% in 2019 in nondissecting unruptured aneurysms. Although comparing the surgical outcomes between open surgery and TEVAR is difficult, the hospital mortality rate of open surgery for the descending aorta (the same surgical range as TEVAR) was 5.8%. Furthermore, aortic arch surgery had a hospital mortality rate of 3.4%, which is equivalent to that of TEVAR. The indications for TEVAR are expanding to the aortic arch range; however, surgical procedures should be selected according to patients' age and condition.

TEVAR has contributed greatly to improving surgical outcomes in type B acute aortic dissection. Although it has also improved the surgical outcomes in ruptured aneurysms, further improvement is required. TEVAR was performed in 53% of ruptured aneurysm cases, and the hospital mortality rate for all cases improved to 19.7% in 2019, considering that hospital mortality

Table 1 Hospital mortality in 2019

	Nondissection		Dissection			
			Acute		Chronic	
	Unruptured	Ruptured	Type A	Type B	Type A	Type B
Ascending aorta	3.1%	23.3%	9.9%		5.7%	16.7%
Aortic root	4.3%	11.1%	15.5%		12.0%	
Aortic arch	3.4%	15.5%	8.6%	8.7%	2.5%	3.0%
Aortic root+Asc. Ao +Aortic arch	4.2%	12.5%	15.0%		7.8%	37.5%
Descending aorta	5.8%	42.9%	7.0%	11.9%	5.0%	6.8%
Thoracoabdominal Ao	9.6%	29.6%		18.2%	10.2%	9.4%
TEVAR	2.7%	16.5%	23.2%	7.8%	1.7%	1.9%
Open stent graft	5.8%	15.4%	10.7%	23.1%	4.2%	2.6%
All cases	4.2%	19.7%	10.4%	9.8%	4.5%	3.4%

Asc.: ascending

Ao: aorta

TEVAR: thoracic endovascular aortic repair

rate of TEVAR for ruptured aneurysms was 16.5%. The effect of TEVAR was more remarkable in patients with acute type B aortic dissection, with a hospital mortality rate of 7.8% (75% of cases). In 2019, the overall hospital mortality rate improved to 9.8% for all patients with acute type B aortic dissections (Table 1).

The excellent surgical outcomes of acute type A aortic dissection in Japan are internationally recognized.¹⁰ However, these surgical outcomes are based only on open surgery because TEVAR cannot be indicated for this pathophysiology. The hospital mortality rate of acute type A aortic dissection was 9.9% for ascending aortic surgery, 8.6% for aortic arch surgery, and 10.7% for surgery using an open stent graft in 2019. For aortic root reconstruction, it was 15.5%, which was slightly higher than the others. Japan's excellent surgical outcomes for acute type A aortic dissection can be attributed to multiple factors, such as the improvements of the emergency transportation system, surgical skills in each facility, hemostasis methods, and blood transfusion therapy.¹¹ In 2019, 405 aortic root reconstructions were performed, accounting for only 6% of all cases. The surgical strategy to avoid aortic root reconstruction may be one of the factors for improving surgical outcomes.

In this study, we used data from 2019, just before the COVID-19 pandemic broke out. The number of cardiovascular surgeries reportedly decreased by approximately 10% because of COVID-19 infection.¹²

CONCLUSION

According to the JATS annual surgery survey data, the number of aortic surgeries has constantly been increasing, and the surgical outcomes have steadily improved over the last two decades. New technologies, including stent grafts, have a certain influence on the field of aortic surgery.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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