General Thoracic and Cardiovascular Surgery (2019) 67:751–757
https://doi.org/10.1007/s11748-019-01163-x

CURRENT TOPICS REVIEW ARTICLE

Current status of cardiovascular surgery in Japan, 2015 and 2016: analysis of data from Japan Cardiovascular Surgery Database. 4—Thoracic aortic surgery

Hideyuki Shimizu[1,4] · Norimichi Hirahara[2] · Noboru Motomura[3] · Hiroaki Miyata[2] · Shinichi Takamoto[2]

Received: 14 March 2019 / Accepted: 11 June 2019 / Published online: 16 July 2019

Abstract

Background Thoracic and thoracoabdominal aortic diseases are treated using operative procedures like open aortic repair (OAR), thoracic endovascular aortic repair (TEVAR), or hybrid aortic repair (HAR), or a combination of OAR and TEVAR. The surgical approach to aortic repair has evolved over the decades. The purpose of this study was to examine the current trends in treatment.

Methods We extracted nationwide data of aortic repair procedures performed in 2015 and 2016 from the Japan Cardiovascular Surgery Database (JCVSD). In addition to estimating the number of cases, we also reviewed the respective operative mortalities and associated major morbidities (e.g., stroke, spinal cord insufficiency, and renal failure) according to disease pathology (e.g., acute dissection, chronic dissection, ruptured aneurysm, and unruptured aneurysm), site of operative repair (i.e., aortic root, ascending aorta, aortic root to arch, aortic arch, descending aorta, and thoracoabdominal aorta), and the preferred surgical approach (i.e., OAR, HAR, or TEVAR).

Results The total number of cases studied was 35,427, with an overall operative mortality rate of 7.3%. Among the 3 procedures, 64% of patients were treated with OAR. Compared to the data from our previous report (also derived from the JCVSD in 2013 and 2014), the total number of cases and number of OAR, HAR, and TEVAR procedures have increased by 17.0%, 2.4%, 126.1%, and 34.9%, respectively. While the overall stroke rates following aortic arch surgical repair with HAR, OAR, and TEVAR were 10.1%, 8.4%, and 7.3%, respectively, OAR was found to have the lowest stroke rate when limited to cases presenting with a non-dissected/unruptured aorta. The incidence rates of paraplegia following descending/thoracoabdominal aortic surgical repair using HAR, OAR, and TEVAR were 6.3%/10.4%, 4.3%/8.9%, and 3.4%/4.6%, respectively. TEVAR was found to be associated with the lowest incidence of postoperative renal failure.

Conclusions The number of operations for thoracic and thoracoabdominal aortic diseases has increased, though the rate of operations using an OAR approach has decreased. While TEVAR showed the lowest mortality and morbidity rates, OAR demonstrated the lowest postoperative stroke rate for non-dissecting aortic arch aneurysms.

Keywords Japan Cardiovascular Surgery Database (JCVSD) · Aortic aneurysm · Aortic dissection · Stroke · Paraplegia · Renal failure

This is a secondary publication of the paper published in the *Japanese Journal of Cardiovascular Surgery* (Vol. 48, No. 1, pp 18–24).

✉ Hideyuki Shimizu
shimizu.md@gmail.com

[1] Department of Cardiovascular Surgery, School of Medicine, Keio University, Tokyo, Japan

[2] Department of Health Policy and Management, School of Medicine, Keio University, Tokyo, Japan

[3] Department of Cardiovascular Surgery, Toho University Sakura Medical Center, Chiba, Japan

[4] The Japan Society for Cardiovascular Surgery, 2-26-9 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

Introduction

The surgical approach for aortic repair has evolved over the decades. Thoracic and thoracoabdominal aortic diseases are treated using operative procedures like open aortic repair (OAR), thoracic endovascular aortic repair (TEVAR), or even hybrid aortic repair (HAR), a combination of OAR and TEVAR. However, a clear indication of treatment selection has not yet been established. In our previous studies [1, 2], we extracted the nationwide data of aortic repair procedures performed between 2013 and 2014 from the Japan Cardiovascular Surgery Database (JCVSD) and reported many important findings: 73.2% of patients were treated with OAR, whereas in cases of descending aorta, only 30% of patients were treated with OAR; the rate of operation using an OAR approach remained stable regardless of the JapanSCORE for the arch and descending aorta, whereas it decreased with an increasing JapanSCORE in the thoracoabdominal aorta; the operative mortality of OAR correlated well with the JapanSCORE, whereas, for TEVAR and HAR procedures, the operative mortality was lower than the JapanSCORE range, although it did correlate with the JapanSCORE. In a previous study, we focused on the operative mortality and did not review postoperative complications in detail. Thus, in the present study, our aim was to examine the current trends in treatment including assessment of postoperative morbidity.

Methods

Data relative to surgical diseases of the thoracic/thoracoabdominal aorta from 2015 to 2016 were extracted from the JCVSD. The number of cases and the respective operative mortalities were reviewed according to aortic pathology (acute aortic dissection, chronic aortic dissection, ruptured aneurysm, and unruptured aneurysm), site of aortic repair (aortic root, ascending aorta, aortic root to aortic arch, aortic arch, descending aorta, or thoracoabdominal aorta), and surgical approach (open surgery, endovascular aortic repair, and hybrid procedure). Operative mortality was defined as in-hospital mortality and/or 30-day mortality. In addition, we studied the incidence of major postoperative complications (stroke, paraplegia, and renal failure) after each procedure in the aortic arch, descending aorta, and thoracoabdominal aorta, where all three approaches are commonly available.

Results

Number of cases

The total number of cases was 35,427. The number of cases and the rate of each surgical approach were 22,683 (64.0%) OAR, 4442 (12.5%) HAR, and 8302 (23.4%) TEVAR, respectively (Table 1). Comparing the data from 2015 and 2016 with data extracted from the JCVSD in 2013 and 2014 [1, 2], the entire population and the number of OAR, HAR, and TEVAR procedures increased by 17.0% (30,271–35,427), 2.4% (22,151–22,683), 126.1% (1965–4442), and 34.9% (6155–8302), respectively (Fig. 1). The rate of operations using an OAR approach decreased to 64.0% from 73.2% in the previous study ($p < 0.01$).

With respect to the number of operations by aortic pathology, it increased by 23.3% (9089–11,295) in acute dissection, by 25.7% (4938–6207) in chronic dissection, by 10.9% (1262–1399) in ruptured aneurysm, and by 10.3% (14,982–16,526) in unruptured aneurysm. The number of OAR increased only for acute dissections, although the number of HAR and TEVAR procedures increased for all aortic pathologies (Fig. 2). The rate of surgical procedures using the OAR approach in acute dissection, chronic dissection, ruptured aneurysm, and unruptured aneurysm was 80.7%, 49.5%, 46.2%, and 59.6%, respectively.

Operative mortality

The operative mortality for the entire population, acute dissection, chronic dissection, ruptured aneurysm, and unruptured aneurysm was 7.3%, 11.3%, 4.5%, 22.3%, and 4.5%, respectively (Table 1). Operative mortality following OAR, HAR, and TEVAR was 8.1%, 7.7%, and 5.2%, respectively. There was no statistically significant difference among the surgical approaches used and the operative mortality following acute dissection and ruptured aneurysm: acute dissection, 11.5%, 10.0%, and 10.5% in OAR, HAR, and TEVAR, respectively; ruptured aneurysm, 23.2%, 19.4%, and 22.2% in OAR, HAR, and TEVAR, respectively. However, there was a significant difference in operative mortality following chronic dissection and unruptured aneurysm: chronic dissection, 6.0%, 4.1%, and 2.5% in OAR, HAR, and TEVAR (in descending order), respectively ($p < 0.01$); unruptured aneurysm: 6.6%, 4.5%, and 3.4% ($p < 0.01\%$) in HAR, OAR, and TEVAR (in descending order), respectively.

Major morbidity by site of operative repair and surgical approach

Table 2 shows the incidence of stroke, paraplegia, and renal failure observed after aortic repair in the aortic arch, descending aorta, and thoracoabdominal aorta following surgical intervention. The incidence of stroke after procedures using OAR, HAR, and TEVAR was 8.4%, 10.1%, and 7.3% ($p < 0.05$), respectively, across all arch pathologies; and 6.3%, 10.1%, and 9.1% ($p < 0.05$), respectively, for unruptured arch aneurysm. The stroke rate after OAR, HAR, and TEVAR procedures for descending aortic pathology was

Table 1 Number of cases and operative mortality by aortic pathology, site of treatment, and procedure

	Acute aortic dissection			Chronic aortic dissection			Non-dissection, ruptured			Non-dissection, Un-ruptured			Total		
	Cases	Operative mortality		Cases	Operative mortality		Cases	Operative mortality		Cases	Operative mortality		Cases	Operative mortality	
		n	Percentage		*n*	Percentage		*n*	Percentage		*n*	Percentage		*n*	Percentage
Root															
Open	560	118	21.1	197	22	11.2	95	19	20.0	1922	76	4.0	2774	235	8.5
Hybrid	57	10	17.5	16	0	0.0	4	0	0.0	34	2	5.9	111	12	10.8
TEVAR	5	1	20.0	3	0	0.0	2	0	0.0	9	0	0.0	19	1	5.3
Ascending															
Open	5606	585	10.4	699	37	5.3	116	21	18.1	3158	95	3.0	9579	738	7.7
Hybrid	102	11	10.8	26	0	0.0	4	1	25.0	105	6	5.7	237	18	7.6
TEVAR	8	2	25.0	16	0	0.0	8	2	25.0	69	6	8.7	101	10	9.9
Root–arch															
Open	225	31	13.8	81	2	2.5	10	5	50.0	210	9	4.3	526	47	8.9
Hybrid	72	13	18.1	11	0	0.0	3	0	0.0	37	2	5.4	123	15	12.2
TEVAR	3	0	0.0	0	0	NA	0	0	NA	2	1	50.0	5	1	20.0
Arch															
Open	2372	265	11.2	844	40	4.7	214	43	20.1	2938	151	5.1	6368	499	7.8
Hybrid	677	57	8.4	324	18	5.6	62	13	21.0	958	67	7.0	2021	155	7.7
TEVAR	87	8	9.2	215	9	4.2	62	20	32.3	689	35	5.1	1053	72	6.8
Descending															
Open	327	49	15.0	873	60	6.9	146	44	30.1	998	61	6.1	2344	214	9.1
Hybrid	450	45	10.0	384	13	3.4	89	16	18.0	950	60	6.3	1873	134	7.2
TEVAR	636	63	9.9	1880	50	2.7	450	93	20.7	3411	95	2.8	6377	301	4.7
Thoracoabdominal															
Open	30	4	13.3	379	23	6.1	66	18	27.3	617	48	7.8	1092	93	8.5
Hybrid	8	1	12.5	19	1	5.3	4	2	50.0	46	4	8.7	77	8	10.4
TEVAR	70	11	15.7	240	6	2.5	64	15	23.4	373	17	4.6	747	49	6.6
Subtotal															
Open	9120	1052	11.5	3073	184	6.0	647	150	23.2	9843	440	4.5	22,683	1826	8.1
Hybrid	1366	137	10.0	780	32	4.1	166	32	19.3	2130	141	6.6	4442	342	7.7
TEVAR	809	85	10.5	2354	65	2.8	586	130	22.2	4553	154	3.4	8302	434	5.2
Total	11,295	1274	11.3	6207	281	4.5	1399	312	22.3	16,526	735	4.4	35,427	2602	7.3

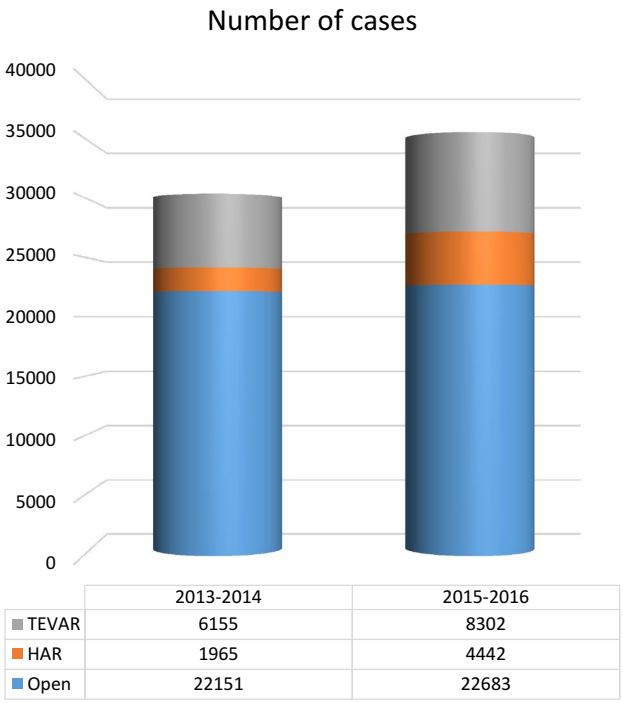

Fig. 1 Number of thoracic/thoracoabdominal aortic cases in the Japan Cardiovascular Surgery Database (JCVSD) in 2013–2014 and 2015–2016

6.1%, 8.9%, and 3.0% ($p < 0.01$), and for thoracoabdominal aortic pathology, the stroke rate was 3.4%, 3.9%, and 2.5% (p value not significant), respectively.

The stroke rate after ascending aortic repair with and without arch repair for acute dissection was 11.9% with, and 10.8% without concomitant arch repair, a difference was not statistically significant (Table 3).

The incidence of paraplegia after OAR, HAR, and TEVAR was 2.4%, 6.2%, and 3.4% ($p < 0.01$), respectively, for all aortic arch pathologies and 2.0%, 5.4%, and 3.3% ($p < 0.01$), respectively, in unruptured arch aneurysms. The incidence of paraplegia after OAR, HAR, and TEVAR for a descending aortic pathology was 4.3%, 6.3%, and 3.4% ($p < 0.01$), respectively, and paraplegia following all thoracoabdominal aortic pathologies occurred in 8.9%, 10.4%, and 4.6% ($p < 0.01$), respectively, and for chronic dissection, paraplegia occurred in OAR 8.7%, HAR 15.8%, TEVAR 1.7% ($p < 0.01$); and for unruptured aneurysm, paraplegia occurred in 8.3%,8.7%, and 4.8% of OAR, HAR, and TEVAR procedures (p value not significant), respectively.

The incidence of renal failure after OAR, HAR, and TEVAR was 7.9%, 8.9%, and 3.2% ($p < 0.01$) for aortic arch pathology; 7.4%, 8.2%, and 2.9% ($p < 0.01$) for descending aortic pathology; and 12.6%, 7.8%, and 4.1% ($p < 0.01$) for thoracoabdominal aortic pathology, respectively.

Discussion

This is the study to review the current status of treatment of thoracic/thoracoabdominal aortic diseases, focusing on major postoperative morbidities as well as mortality by site of repair and surgical approach utilising data from the JCVSD, which is a nationwide database in Japan containing clinical data from almost all Japanese institutions performing cardiovascular surgery.

In comparison with our previous study, it was clarified that the plateau of number of OAR procedures and the rapid increase in HAR and TEVAR procedures resulted in an overall 10.0% increase of the number of cases of aortic repair. It was noteworthy that the number of HAR procedures increased more than twofold over only a 2-year period. This increases likely because a specially designed device for frozen elephant trunk technique became available, or because HAR procedures for aortic arch pathology began

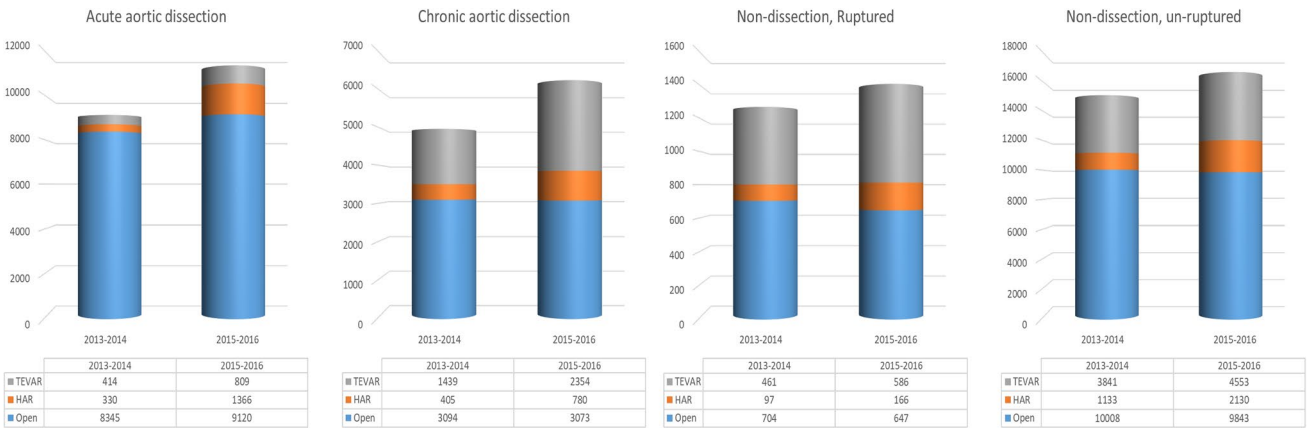

Fig. 2 Number of cases by aortic pathology in the Japan Cardiovascular Surgery Database (JCVSD) in 2013–2014 and 2015–2016

Table 2 Number of cases and major morbidity (stroke, paraplegia, and renal failure) by aortic pathology, site of treatment, and procedure

	Acute aortic dissection			Chronic aortic dissection			Non-dissection, ruptured			Non-dissection, un-ruptured			Total		
	Cases	Morbidity		Cases	Morbidity		Cases	Morbidity		Cases	Morbidity		Cases	Morbidity	
		n	Percentage		*n*	Percentage		*n*	Percentage		*n*	Percentage		*n*	Percentage
(a) Stroke															
Arch															
Open	2372	282	11.9	844	42	5.0	214	29	13.6	2938	184	6.3	6368	537	8.4
Hybrid	677	72	10.6	324	23	7.1	62	13	21.0	958	97	10.1	2021	205	10.1
TEVAR	87	1	1.1	215	8	3.7	62	5	8.1	689	63	9.1	1053	77	7.3
Descending															
Open	327	30	9.2	873	36	4.1	146	16	11.0	998	60	6.0	2344	142	6.1
Hybrid	450	54	12.0	384	17	4.4	89	10	11.2	950	85	8.9	1873	166	8.9
TEVAR	636	26	4.1	1880	27	1.4	450	25	5.6	3411	113	3.3	6377	191	3.0
Thoracoabdominal															
Open	30	2	6.7	379	14	3.7	66	2	3.0	617	19	3.1	1092	37	3.4
Hybrid	8	1	12.5	19	0	0.0	4	0	0.0	46	2	4.3	77	3	3.9
TEVAR	70	3	4.3	240	3	1.3	64	3	4.7	373	10	2.7	747	19	2.5
(b) Paraplegia															
Arch															
Open	2372	77	3.2	844	13	1.5	214	3	1.4	2938	58	2.0	6368	151	2.4
Hybrid	677	44	6.5	324	23	7.1	62	7	11.3	958	52	5.4	2021	126	6.2
TEVAR	87	5	5.7	215	3	1.4	62	5	8.1	689	23	3.3	1053	36	3.4
Descending															
Open	327	19	5.8	873	27	3.1	146	11	7.5	998	44	4.4	2344	101	4.3
Hybrid	450	27	6.0	384	19	4.9	89	7	7.9	950	65	6.8	1873	118	6.3
TEVAR	636	39	6.1	1880	34	1.8	450	24	5.3	3411	121	3.5	6377	218	3.4
Thoracoabdominal															
Open	30	3	10.0	379	33	8.7	66	10	15.2	617	51	8.3	1092	97	8.9
Hybrid	8	1	12.5	19	3	15.8	4	0	0.0	46	4	8.7	77	8	10.4
TEVAR	70	7	10.0	240	4	1.7	64	5	7.8	373	18	4.8	747	34	4.6
(c) Renal failure															
Arch															
Open	2372	275	11.6	844	44	5.2	214	39	18.2	2938	143	4.9	6368	501	7.9
Hybrid	677	81	12.0	324	19	5.9	62	12	19.4	958	68	7.1	2021	180	8.9
TEVAR	87	4	4.6	215	8	3.7	62	4	6.5	689	18	2.6	1053	34	3.2
Descending															
Open	327	39	11.9	873	48	5.5	146	20	13.7	998	67	6.7	2344	174	7.4
Hybrid	450	60	13.3	384	15	3.9	89	15	16.9	950	64	6.7	1873	154	8.2
TEVAR	636	48	7.5	1880	30	1.6	450	31	6.9	3411	75	2.2	6377	184	2.9
Thoracoabdominal															
Open	30	2	6.7	379	47	12.4	66	12	18.2	617	77	12.5	1092	138	12.6
Hybrid	8	0	0.0	19	1	5.3	4	2	50.0	46	3	6.5	77	6	7.8
TEVAR	70	4	5.7	240	4	1.7	64	7	10.9	373	16	4.3	747	31	4.1

to be reimbursed in July 2014, and then its use spread widely and rapidly.

Although the number of aortic repairs increased for all aortic pathologies, the number of OAR increased only in acute dissection and decreased slightly in the other 3 pathologies. The rate of operations using an OAR decreased for all 4 categories. Conversely, HAR and TEVAR increased across all aortic pathologies. It was noteworthy that the number of HAR for acute dissection increased greater than fourfold, which is likely due to the introduction of the new device mentioned above. Although the rate of OAR in acute dissection was approximately 80%, which was still higher than

Table 3 Number of cases and rate of operative mortality, stroke, paraplegia, and renal failure after open surgery with and without arch replacement for acute aortic dissection

	Cases	Operative mortality	Stroke	Paraplegia	Renal failure
Arch (−)	6166	703 (11.4%)	669 (10.8%)	184 (3.0%)	633 (10.3%)
Arch (+)	2597	296 (11.4%)	309 (11.9%)	89 (3.4%)	311 (12.0%)*

*$p<0.05$

rates in other aortic pathologies, it might decrease given the more widespread use of HAR for acute dissection, and preemptive TEVAR for uncomplicated type B aortic dissection, and other indications.

The operative mortality in OAR, HAR, and TEVAR was 8.1%, 7.7%, and 5.2%, respectively. On comparison of our nationwide data, which were extracted not only from leading hospitals but from all hospitals in Japan, with the previous reports from the other countries, our operative mortality was excellent (e.g., 11.4% (999/8763) vs. 16.9% to 18.4% [3–5] in operative mortality of OAR for acute aortic dissection).

Although the mortality of OAR, HAR, and TEVAR was comparable in acute aortic diseases including acute dissection and ruptured aneurysm, there was a significant difference in mortality for chronic diseases including chronic dissection (OAR > HAR > TEVAR) and unruptured aneurysm (HAR > OAR > TEVAR). However, a simple comparison of mortality by approach is not meaningful as the surgical approach is chosen under strong selection bias (patient background, site and range of repair, etc.).

The incidence of stroke after an entire aortic arch repair was highest for HAR procedures, followed by OAR and TEVAR. Again, simple comparison is inappropriate, because acute dissection, which definitely presents a higher risk for stroke, is predominantly treated by OAR. In unruptured arch aneurysm, with a large number of cases, the stroke rate after OAR (6.3%) was significantly lower than HAR (10.1%) and TEVAR (9.1%) ($p < 0.01$). The occurrences of mortality, stroke, and paraplegia after ascending aortic repair for acute dissection were comparable with and without concomitant arch repair, despite the higher incidence of renal failure in concomitant arch repair cases (Table 3).

The incidence of paraplegia after HAR for unruptured arch aneurysm was 5.4%, which was comparable to a previous report [6], and was significantly higher after OAR (2.0%) and TEVAR (3.3%) procedures. This issue remains to be resolved. The incidence of paraplegia after repair of the entire descending aortic and thoracoabdominal aortic repair was the highest following HAR and the lowest following TEVAR procedures. The same order (HAR > OAR > TEVAR) was also shown for chronic dissection ($p < 0.01$) and unruptured aneurysm (n.s.).

The incidence of renal failure after entire arch repair and descending aortic repair was the highest in HAR and the lowest in TEVAR, and after entire thoracoabdominal aortic repair the incidence of renal failure was the highest in OAR and the lowest in TEVAR. In almost all categories except thoracoabdominal aortic repair for acute dissection, which consisted of a small number of cases, the lowest incidence of renal failure was observed in TEVAR procedures.

As the purpose of this study was to examine the current trends in treatment by extracting nationwide data from the JCVSD, and not to demonstrate the superiority or inferiority of any specific procedure, the results should be interpreted accordingly. Conversely, we believe that this study provided very useful information for treatment selection and forecast of prognosis. Of course, treatment selection should be determined based on a comprehensive assessment of patient factors (comorbidity, frailty, anatomical features, etc.) as well as long-term results, and not only early mortality.

Conclusions

The current trend in aortic treatment was studied. The number of thoracic and thoracoabdominal aortic repair procedures was 35,427, which was increased by 17.0% from 2014 and 2015. The rate of OAR decreased (from 73.2 to 60%), although the number of OAR procedures remained unchanged. Overall, the operative mortality was 7.3%. Although, TEVAR showed the lowest mortality and morbidity rates in general, OAR demonstrated the lowest postoperative stroke rate for unruptured arch aneurysms.

Mortality and stroke after ascending aortic repair for acute dissection were comparable irrespective of concomitant arch repair.

The incidence of paraplegia after HAR for unruptured arch aneurysm was 5.4% and was significantly higher than following OAR and TEVAR procedures.

In this annual report, we analysed 2 years' worth of data. In JCVSD, a penetration rate of participating hospitals all over Japan almost reached 100% in 2013.

We started writing the annual reports in 2014, when we were already lagging behind by 4 years. To catch up with the latest year, we combined and analysed the data of 2 years. We have finished the report for the first 2 years (2013–2014) and are now preparing the same for 2015–2016. As we

gradually catch up with the real-time year, we will analyse each year separately.

References

1. Shimizu H, Hirahara N, Motomura N, et al. Current status of cardiovascular surgery in Japan, 2013 and 2014: a report based on the Japan Cardiovascular Surgery Database (JCVSD) 5. Thoracic aortic surgery (in Japanese). Jpn J Cardiovasc Surg. 2017;46:205–11.
2. Shimizu H, Hirahara N, Motomura N, et al. Current status of cardiovascular surgery in Japan, 2013 and 2014: a report based on the Japan Cardiovascular Surgery Database 5. Thoracic aortic surgery. Gen Thorac Cardiovasc Surg. 2017;65:671–8.
3. Pape LA, Awais M, Woznicki EM, et al. Presentation, diagnosis, and outcomes of acute aortic dissection: 17-year trends from the international registry of acute aortic dissection. J Am Coll Cardiol. 2015;66(4):350–8.
4. Conzelmann LO, Weigang E, Mehlhorn U, et al. Mortality in patients with acute aortic dissection type A: analysis of pre- and intraoperative risk factors from the German Registry for Acute Aortic Dissection Type A (GERAADA). Eur J Cardiothorac Surg. 2016;49:e44–52.
5. Bashir M, Shaw MA, Grayson AD, et al. Development and validation of elective and nonelective risk prediction models for in-hospital mortality in proximal aortic surgery using the national institute for cardiovascular outcomes research (NICOR) database. Ann Thorac Surg. 2016;101(5):1670–6.
6. Tian DH, Wan B, Di Eusanio M, et al. A systematic review and meta-analysis on the safety and efficacy of the frozen elephant trunk technique in aortic arch surgery. Ann Cardiothorac Surg. 2013;2(5):581–91.