



Thoracic and cardiovascular surgeries in Japan during 2019

Annual report by the Japanese Association for Thoracic Surgery

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Since 1986, the Japanese Association for Thoracic Surgery has conducted annual thoracic surgery surveys throughout Japan to determine statistics on the number of procedures performed by surgical categories. Herein, we summarize the results of the association's annual thoracic surgery surveys in 2019. We regret that, for various reasons, this report has been delayed to 2023.

Adhering to the norm thus far, thoracic surgery had been classified into three categories, including cardiovascular, general thoracic, and esophageal surgeries, with patient data for each group being examined and analyzed. We honor and value all members' continued professional support and contributions.

Incidence of hospital mortality was included in the survey to determine nationwide status, which has contributed to Japanese surgeons' understanding of the present status of thoracic surgery in Japan while helping in surgical outcome improvements by enabling comparisons between their work and that of others. This approach has enabled the association to gain a better understanding of present problems and prospects, which is reflected in its activities and member education.

The 30-day mortality (also known as *operative mortality*) is defined as death within 30 days of surgery, regardless of the patient's geographic location, including post-discharge from the hospital. *Hospital mortality* is defined as death within any time interval following surgery among patients yet to be discharged from the hospital.

Transfer to a nursing home or a rehabilitation unit is considered hospital discharge unless the patient subsequently dies of complications from surgery, while hospital-to-hospital transfer during esophageal surgery is not considered a form of discharge. In contrast, hospital-to-hospital transfer 30 days following cardiovascular and general thoracic surgeries are considered discharge given that National Clinical Database (NCD)-related data were used in these categories.

Survey abstract

All data on cardiovascular, general thoracic, and esophageal surgeries were obtained from the NCD. In 2018, the data collection method for general thoracic and esophageal surgeries had been modified from self-reports using questionnaire sheets following each institution belonging to the Japanese Association for Thoracic Surgery to an automatic package downloaded from the NCD in Japan.

The data collection related to cardiovascular surgery (initially self-reported using questionnaire sheets in each participating institution up to 2014) changed to downloading an automatic package from the Japanese Cardiovascular Surgery Database (JCVSD), which is a cardiovascular subsection of the NCD in 2015.

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Extended author information available on the last page of the article

Final report: 2019

(A) Cardiovascular surgery

We are extremely pleased with the cooperation of our colleagues (members) in completing the cardiovascular surgery survey, which has undoubtedly improved the quality of this annual report. We are truly grateful for the significant efforts made by all participants within each participating institution in completing the JCVSD/NCD.

Figure 1 illustrates the development of cardiovascular surgery in Japan over the past 33 years. Aneurysm surgery includes only surgeries for thoracic and thoracoabdominal aortic aneurysms. Extra-anatomic bypass surgery for thoracic aneurysm and pacemaker implantation have been excluded from the survey since 2015. Assist device implantations were not included in the total number of surgical procedures but were included in the survey.

A total of 70,769 cardiovascular surgeries, including 84 heart transplants, had been performed in 2019, with a 0.32% increase compared to that in 2018 ($n=70,537$).

Compared to data for 2018 [1] and 2009 [2], data for 2019 showed 2.7% (9006 vs 9253) and 4.0% fewer surgeries for congenital heart disease, 0.6% (23,340 vs 23,205) more and 36.5% more surgeries for valvular heart disease, 5.9% (12,693 vs 13,445) and 42.3% fewer surgeries for ischemic heart procedures, and 5.0% (22,708 vs. 21,624) and 89.9% more surgeries for thoracic aortic aneurysm,

respectively. Data for individual categories are summarized in Tables 1, 2, 3, 4, 5, 6.

Among the 9006 procedures for congenital heart disease conducted in 2019, 6890 were open-heart surgeries, with an overall hospital mortality rate of 1.7%. The number of surgeries for neonates and infants in 2019 did not significantly differ compared to that in 2009; however, hospital mortality improved from 10.7% to 7.1% for neonates and from 3.7% to 2.1% for infants. In 2019, atrial septal defect was the most common disease (1449 cases) as previously reported, with patients aged ≥ 18 years accounting for 60.2% of atrial septal defect surgery. Ventricular septal defect (perimembranous/muscular), which had been the most common disease in 2015 and 2016, was the second most common disease (1072 cases).

Hospital mortality for complex congenital heart disease within the past 10 years was as follows (2009 [2], 2014 [3], and 2019): complete atrioventricular septal defect (4.3%, 1.7%, and 1.4%); tetralogy of Fallot (1.8%, 1.1%, and 0.7%); transposition of the great arteries with the intact septum (4.2%, 6.6%, and 1.9%), ventricular septal defect (6.5%, 3.9%, and 1.8%), and single ventricle (4.3%, 4.3%, and 3.5%); and hypoplastic left heart syndrome (16.5%, 9.8%, and 7.4%). Currently, right heart bypass surgery has been commonly performed (329 bidirectional Glenn procedures, excluding 44 Damus–Kaye–Stansel procedures, and 395 Fontan type procedures, including total cavopulmonary connection) with acceptable hospital mortality rates

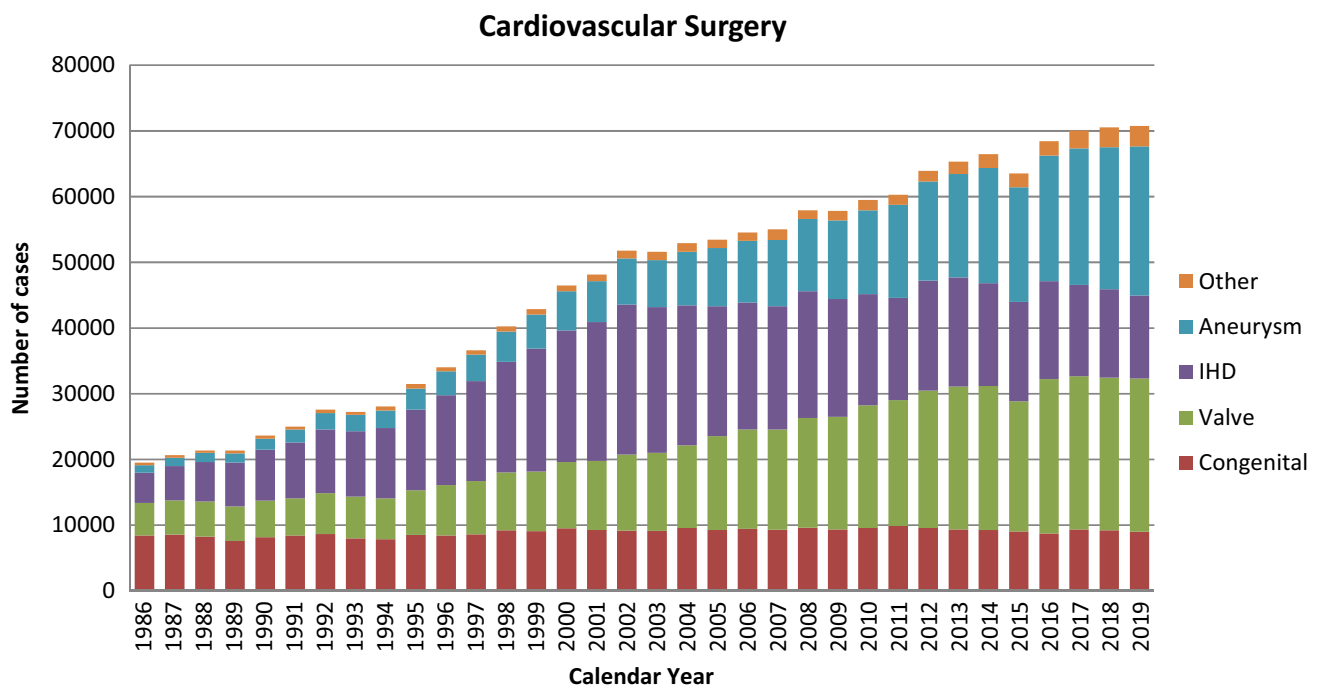


Fig. 1 Cardiovascular surgery. IHD ischemic heart disease

Table 1 Congenital (total; 9006)
(1) CPB (+) (total; 6890)

	Neonate				Infant				1–17 years				≥ 18 years				Total									
	Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality							
	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge						
PDA	5		4	1 (25.0)	1 (25.0)		4	1 (25.0)		15		24	1 (4.2)		33	2 (6.1)		51	1 (2.0)		2 (6.1)		2 (6.1)			
Coarctation (simple)	10	1 (10.0)	13	1 (10.0)			13					13			13	1 (2.3)		13	1 (2.3)		13	1 (7.7)		2 (3.9)		
+ VSD	48	1 (2.1)	44	1 (2.1)	1 (2.3)		44	1 (2.3)				0			44			105	2 (1.9)		7			2 (1.9)		
+ DORV	3		4				4					0			4			7			7					
+ AVSD	1		2	1 (100.0)			2					0			2			4			4				1 (25.0)	
+ TGA	0		2				2					0			2			2			2					
+ SV	1		0				0					0			0			2			2					
+ Others	7		4				4					0			4			14			14					
Interrupt. of Ao (simple)	0		0				0					0			0			0			0					
+ VSD	20		25	1 (4.0)	1 (4.0)		25	1 (4.0)				12			25			57	1 (1.8)		57	1 (1.8)			1 (1.8)	
+ DORV	0		0				0					0			0			0			0					
+ Truncus	4	1 (25.0)	7	1 (25.0)	1 (14.3)		7	1 (14.3)				2			7			13	1 (7.7)		13	1 (7.7)			2 (15.4)	
+ TGA	0		0				0					0			0			0			0					
+ Others	1		2				2					2			2			6			6					
Vascular ring	0		1				1					0			0			0			0					
PS	1		22				22	1 (1.6)				62	1 (1.6)		26	1 (3.8)		111	2 (1.8)		111	2 (1.8)			2 (1.8)	
PAVSD or Critical PS	10	1 (10.0)	52	1 (10.0)	2 (3.8)		52	1 (10.0)				65			9			136	1 (0.7)		136	1 (0.7)			3 (2.2)	
TAPVR	106	7 (6.6)	49	1 (2.0)	1 (2.0)		49	1 (2.0)				20			0			175	8 (4.6)		175	8 (4.6)			12 (6.9)	
PAPVR ± ASD	1		6				6					46			23			76			76					
ASD	1		49				49					526			873	6 (0.7)		1,449	6 (0.4)		1,449	6 (0.4)			6 (0.4)	
Cor triatriatum	1		10				10					8			1			20			20					
AVSD (partial)	2		10	1 (10.0)	1 (10.0)		10	1 (10.0)				32			8			52			52				1 (1.9)	
AVSD (complete)	6		102	1 (1.0)	1 (1.0)		102	1 (1.0)				110			4			222	1 (0.5)		222	1 (0.5)			3 (1.4)	
+ TOF or DORV	0		8				8					18			3			29			29					
+ Others	0		0				0					0			0			0			0					
VSD (subarterial)	1		85				85					156			7			249			249					
VSD (perimemb./muscular)	14		663	2 (0.3)	2 (0.3)		663	2 (0.3)				372			23			1,072			1,072				4 (0.4)	
VSD (Type Unknown)	0		1				1					1			132	2 (1.5)		134	2 (1.5)		134	2 (1.5)			2 (1.5)	
VSD ± PS	1		24				24					12			3			40			40					
DCRV ± VSD	1		5				5					33			24			63			63					
Aneurysm of sinus of Valsalva	0		0				0					1			2			3			3					
TOF	11		172	1 (0.6)	1 (0.6)		172	1 (0.6)				184			35			402	1 (0.2)		402	1 (0.2)			3 (0.7)	

Table 1 (continued)

	Neonate			Infant			1-17 years			≥ 18 years			Total		
	Cases	30-day mortality		Cases	30-day mortality		Cases	30-day mortality		Cases	30-day mortality		Cases	30-day mortality	
		Hospital	After discharge		Hospital	After discharge		Hospital	After discharge		Hospital	After discharge		Hospital	After discharge
PA + VSD	5			56			115	2 (1.7)	2 (1.7)	9			185	2 (1.1)	2 (1.1)
DORV	28	1 (3.6)	1 (3.6)	122	1 (0.8)	2 (1.6)	160	1 (0.6)	1 (0.6)	9			319	2 (0.6)	4 (1.3)
TGA (simple)	92	2 (2.2)	2 (2.2)	5			3			3			103	2 (1.9)	2 (1.9)
+ VSD	23		1 (4.3)	19			13			2			57		1 (1.8)
VSD + FS	0			0			2			0			2		
Corrected TGA	3			9	1 (11.1)	1 (11.1)	37			4			53	1 (1.9)	1 (1.9)
Truncus arteriosus	5		1 (20.0)	16		1 (6.3)	24			3			48		2 (4.2)
SV	28	2 (7.1)	4 (14.3)	143	4 (2.8)	4 (2.8)	160	2 (1.3)	3 (1.9)	16			347	8 (2.3)	12 (3.5)
TA	5		1 (20.0)	34			38			9			86		1 (1.2)
HLHS	28		7 (25.0)	114	1 (0.9)	8 (7.0)	72	1 (1.4)	1 (1.4)	1			215	2 (0.9)	16 (7.4)
Aortic valve lesion	3			25		1 (4.0)	115	1 (0.9)	1 (0.9)	42	1 (2.4)		185	2 (1.1)	1 (0.5)
Mitral valve lesion	0			31	1 (3.2)	1 (3.2)	70		1 (1.4)	26			127	1 (0.8)	2 (1.6)
Ebstein	14		2 (14.3)	13		1 (7.7)	19			17			63		3 (4.8)
Coronary disease	2			9	1 (11.1)	2 (22.2)	18			4			33	1 (3.0)	2 (6.1)
Others	10	1 (10.0)	1 (10.0)	30	2 (6.7)	4 (13.3)	39			191	4 (2.1)		270	7 (2.6)	9 (3.3)
Conduit failure	0			0			16			5			21		
Redo (excluding conduit failure)	3			56	2 (3.6)	6 (10.7)	100	2 (2.0)	5 (5.0)	89	1 (1.1)		248	5 (2.0)	13 (5.2)
Total	505	16 (3.2)	1 (0.2)	2,048	19 (0.9)	42 (2.1)	2,696	10 (0.4)	21 (0.8)	1,641	16 (1.0)	0	6,890	61 (0.9)	118 (1.7)

(), % mortality
 CPB cardiopulmonary bypass; PDA patent ductus arteriosus; FSD ventricular septal defect; DORV double outlet right ventricle; AVSD atrioventricular septal defect; TGA transposition of great arteries; SV single ventricle; Interruption of Ao. interruption of aorta; PS pulmonary stenosis; PA-I/PS pulmonary atresia with intact ventricular septum; HLHS total anomalous pulmonary venous return; PAPVR partial anomalous pulmonary venous return; ASD atrial septal defect; TOF tetralogy of Fallot; DORV double-chambered right ventricle; TA truncus arteriosus; HLHS hypoplastic left heart syndrome; RI/PA right ventricle-pulmonary artery

Table 1 (continued)
(2) CPB (-) (total; 2116)

	Neonate				Infant				1-17 years				≥ 18 years				Total			
	Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality	
	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge
PDA	246	5 (2.0)	11 (4.5)	1 (0.7)	137	1 (0.7)	3 (2.2)	13	0	0	0	0	396	6 (1.5)	14 (3.5)					
Coarctation (simple)	12				16			2	1	1			31							
+ VSD	48	3 (6.3)	1 (5.3)	1 (5.3)	19	1 (5.3)	2 (10.5)	3	0	0	0	0	70	1 (1.4)	5 (7.1)					
+ DORV	3				0			0	0	0	0	0	3							
+ AVSD	2				0			0	0	0	0	0	2							
+ TGA	2				1			0	0	0	0	0	3							
+ SV	0				0			0	0	0	0	0	0							
+ Others	5				5			0	1	1			11							
Interrupt. of Ao (simple)	0				0			0	0	0	0	0	0							
+ VSD	20	1 (5.0)	1 (5.0)	1 (5.0)	9	1 (5.0)		1	1	1			30	1 (3.3)	1 (3.3)					
+ DORV	0				0			1	1	1			1							
+ Truncus	8	1 (12.5)	1 (12.5)		0			0	0	0			8	1 (12.5)	1 (12.5)					
+ TGA	0				0			0	0	0			0							
+ Others	3	1 (33.3)	1 (33.3)		1			0	0	0			4	1 (25.0)	1 (25.0)					
Vascular ring	5				17			10	1	1			33							
PS	1				3			0	0	0			4							
PAIVS or Critical PS	14				19	1 (5.3)	2 (10.5)	10	0	0			43	1 (2.3)	2 (4.7)					
TAPVR	16	5 (31.3)	6 (37.5)	2 (11.8)	17	2 (11.8)	2 (11.8)	1	1	1			34	7 (20.6)	8 (23.5)					
PAPVR ± ASD	0				0			1	1	1			1							
ASD	1				2			2	2	2			9							
Cor triatriatum	0				0			0	0	0			0							
AVSD (partial)	1				0			3	0	0			4							
AVSD (complete)	34				81	1 (1.2)	1 (1.2)	9	1 (11.1)	1 (11.1)			126	1 (0.8)	1 (0.8)					
+ TOF or DORV	1				3			2	2	2			6							
+ Others	0				0			0	0	0			0							
VSD (subarterial)	1				6			2	2	2			9							
VSD (perimemb./muscular)	56	1 (1.8)	2 (3.6)	1 (0.8)	127	1 (0.8)	2 (1.6)	13	1 (7.7)	1 (7.7)			196	2 (1.0)	5 (2.6)					
VSD (Type Unknown)	0				0			0	2	2			2							
VSD + PS	0				0			0	0	0			0							
DCRV ± VSD	0				0			0	0	0			0							
Aneurysm of sinus of Valsalva	0				0			0	0	0			0							
TOF	13				62			19	1 (5.3)	1 (5.3)			97	1 (1.0)	1 (1.0)					

Table 1 (continued)

	Neonate		Infant		1-17 years		≥ 18 years		Total	
	Cases	Hospital mortality 30-day mortality After discharge	Cases	Hospital mortality 30-day mortality After discharge	Cases	Hospital mortality 30-day mortality After discharge	Cases	Hospital mortality 30-day mortality After discharge	Cases	Hospital mortality 30-day mortality After discharge
PA + VSD	12		40		12		2		66	
DORV	41	2 (4.9)	61	2 (4.9)	14	1 (1.6)	2	1 (7.1)	118	2 (1.7)
TGA (simple)	4		4	1 (25.0)	1	1 (25.0)	2		11	1 (9.1)
+ VSD	7		2		0		1		10	
VSD + PS	0		0		0		0		0	
Corrected TGA	5	1 (20.0)	6		7		1		19	
Truncus arteriosus	24	1 (4.2)	1		1		0		26	
SV	60	1 (1.7)	40	3 (5.0)	18	3 (7.5)	6	2 (11.1)	124	4 (3.2)
TA	13		7		0		1		21	
HLHS	85	2 (2.4)	31	3 (9.7)	23	5 (16.1)	0	2 (8.7)	139	7 (5.0)
Aortic valve lesion	4		3	1 (33.3)	0		0		7	1 (14.3)
Mitral valve lesion	3		2	1 (50.0)	1	1 (50.0)	1		7	1 (14.3)
Ebstein	10	1 (10.0)	3	2 (20.0)	5		0		18	1 (5.6)
Coronary disease	0		6	1 (16.7)	2	2 (33.3)	2		10	1 (10.0)
Others	6		11		17		2	4 (23.5)	36	3 (8.3)
Conduit failure	0		0		0		0		0	
Redo (excluding conduit failure)	37	9 (24.3)	154	9 (5.8)	165	24 (15.6)	25	14 (8.5)	381	25 (6.6)
Total	803	29 (3.6)	896	58 (7.2)	358	48 (5.4)	59	26 (7.3)	2,116	66 (3.1)

(), % mortality

CPB cardiopulmonary bypass; *PDA* patent ductus arteriosus; *VSD* ventricular septal defect; *DORV* double outlet right ventricle; *AVSD* atrioventricular septal defect; *TGA* transposition of the great arteries; *SV* single ventricle; *Interrupt. of Ao.* interruption of aorta; *PS* pulmonary stenosis; *PA-PS* pulmonary atresia with intact ventricular septum; *TAPVR* total anomalous pulmonary venous return; *ASD* atrial septal defect; *TOF* tetralogy of Fallot; *DCRV* double-chambered right ventricle; *T1* truncus arteriosus; *HLHS* hypoplastic left heart syndrome; *RL-PA* right ventricle-pulmonary artery

Table 1 (continued)
(3) Main procedure

	Neonate				Infant				1-17 years				≥ 18 years				Total			
	Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality	
	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge
1	SP Shunt	96	2 (2.1)	4 (4.2)	330	4 (1.2)	9 (2.7)	51	1 (2.0)	2 (3.9)	4		481	7 (1.5)	15 (3.1)					
2	PAB	293	8 (2.7)	19 (6.5)	306	3 (1.0)	8 (2.6)	15			2		616	11 (1.8)	27 (4.4)					
3	Bifunctional Glenn or hemi-Fontan ±a	0			215	4 (1.9)	6 (2.8)	109			5		329	4 (1.2)	6 (1.8)					
4	Damus-Kaye-Stansel operation	3				28	1 (3.6)	12			1		44	1 (2.3)	1 (2.3)					
5	PA reconstruction/repair (including redo)	12	1 (8.3)	2 (16.7)	164	1 (0.6)	4 (2.4)	177	1 (0.6)	2 (1.1)	31		384	3 (0.8)	8 (2.1)					
6	RVOT reconstruction/repair	6			206	1 (0.5)	2 (1.0)	281	1 (0.4)	2 (0.7)	42		535	2 (0.4)	4 (0.7)					
7	Rastelli procedure	0			33			109			5		147		1 (0.7)					
8	Arterial switch procedure	130	3 (2.3)	5 (3.8)	24			4			1		159	3 (1.9)	5 (3.1)					
9	Atrial switch procedure	1			2		1 (50.0)	4			1		8		1 (12.5)					
10	Double switch procedure	0			1			7			0		8							
11	Repair of anomalous origin of CA	0			8	1 (12.5)	2 (25.0)	5			0		13	1 (7.7)	2 (15.4)					
12	Closure of coronary AV fistula	3			2			2			4		11							
13	Fontan / TPCP	0			1			360	2 (0.6)	4 (1.1)	34	1 (2.9)	395	3 (0.8)	6 (1.5)					
14	Norwood procedure	25		3 (12.0)	88	1 (1.1)	6 (6.8)	3			0		116	1 (0.9)	9 (7.8)					
15	Ventricular septation	0			0			0			0		0							
16	Left side AV valve repair (including Redo)	1			38			73			22		134							
17	Left side AV valve replace (including Redo)	0			12			45		1 (2.2)	22		79		3 (3.8)					
18	Right side AV valve repair (including Redo)	24		3 (12.5)	77	2 (2.6)	6 (7.8)	91	1 (1.1)	1 (1.1)	81		273	3 (1.1)	11 (4.0)					
19	Right side AV valve replace (including Redo)	1		1 (100.0)	1			13		1 (7.7)	22		37		2 (5.4)					
20	Common AV valve repair (including Redo)	9	2 (22.2)	2 (22.2)	8	2 (25.0)	2 (25.0)	25	1 (4.0)	1 (4.0)	1		43	5 (11.6)	5 (11.6)					
21	Common AV valve replace (including Redo)	0			5			11		1 (9.1)	1	1 (100.0)	17		1 (5.9)					
22	Repair of supra-aortic stenosis	0			9	1 (11.1)	1 (11.1)	18			2		29	1 (3.4)	1 (3.4)					
23	Repair of subaortic stenosis (including Redo)	0			1			35			6		42							
24	Aortic valve plasty ± VSD Closure	5			16			48	1 (2.1)	1 (2.1)	1		70	1 (1.4)	1 (1.4)					
25	Aortic valve replacement	0			0			32	1 (3.1)	1 (3.1)	43	1 (2.3)	75	2 (2.7)	2 (2.7)					
26	AVR with annular enlargement	0			0			13			3	1 (33.3)	16		1 (6.3)					
27	Aortic root Replace (except Ross)	0			0			6		1 (16.7)	18	1 (5.6)	24	1 (4.2)	1 (4.2)					

Table 1 (continued)

	Neonate				Infant				1-17 years				≥ 18 years				Total							
	Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality		Cases		Hospital mortality					
	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge	30-day mortality	After discharge				
28	0		5		14		19		0		173		3		17		4,277		52		10			
29	160	2 (1.3)	15	9.4	12	1 (8.3)	2	16.7	1		352	3	0.9	6	1.7	6	1.7	52	1.2	10	0.23	129	3.0	
Total	769	18 (2.3)	1	0.1	1,592	22 (1.4)	2	0.1	50	3.1	1,564	9	0.6	1	0.1	19	1.2	4,277	52	1.2	10	0.23	129	3.0

(), % mortality

SP systemic-pulmonary; PAB pulmonary artery; RVO right ventricular outflow tract; CA coronary artery; AV fistula arteriovenous fistula; TPC total cavopulmonary connection; AV valve atrioventricular valve; VSD ventricular septal defect; AVR aortic valve replacement

(1.8% and 1.5%). The Norwood type I procedure was performed in 116 cases, with a relatively low hospital mortality rate (7.8%).

Valvular heart disease procedures, excluding transcatheter procedures, were slightly performed more than that in the previous year. Moreover, isolated aortic valve replacement/repair with/without coronary artery bypass grafting (CABG) ($n=10,268$) was 3.0% lower than that in the previous year ($n=10,584$) but 0.5% higher than that 5 years ago ($n=10,219$), despite the rapid utilization of transcatheter aortic valve replacement ($n=8664$ in 2019). Isolated mitral valve replacement/repairs with/without CABG ($n=5239$) was 7.0% higher than that in the previous year ($n=4898$) and 8.0% higher than that 5 years ago ($n=4851$). Aortic and mitral valve replacement with bioprosthesis were performed in 11,207 and 2987 cases, respectively. The rate at which bioprosthesis was used had dramatically increased from 30% in the early 2000s [4, 5] to 83.0% and 73.0% in 2019 for aortic and mitral positions, respectively. Additionally, CABG was performed concurrently in 16.5% of all valvular procedures (17.2% in 2009 [2] and 17.3% in 2014 [3]). Valve repair was common in mitral and tricuspid valve positions (7632 and 6154 cases, respectively) but less common in aortic valve positions (257 patients, only 1.9% of all aortic valve procedures). Mitral valve repair accounted for 70.9% of all mitral valve procedures. Hospital mortality rates for single valve replacement for aortic and mitral positions were 2.9% and 6.4%, respectively, but only 1.2% for mitral valve repair. Moreover, hospital mortality rates for redo valve surgery for the aortic and mitral positions were 6.7% and 6.1%, respectively. Finally, overall hospital mortality rates did not significantly improve over the past 10 years (4.0% in 2009 [2], 3.1% in 2014 [3], and 3.3% in 2019).

Isolated CABG had been performed in 11,307 cases, accounting for only 68.3% of the procedures performed 10 years ago ($n=16,536$) [2]. Of the aforementioned cases, 6509 (57.6%) underwent off-pump CABG, with a success rate of 97.8%. The percentage of planned off-pump CABG in 2019 was similar to that in 2018 when it fell below 60% for the first time since 2004 [4]. Hospital mortality associated with primary elective CABG procedures among 9218 cases accounted for 1.6%, which is slightly higher than that in 2009 (1.2%) [2]. Hospital mortality for primary emergency CABG among 1667 cases remained high (8.0%). The percentage of conversion from off-pump to on-pump CABG or on-pump beating-heart CABG was 2.2% among the primary elective CABG cases, with a hospital mortality rate of 8.9%. Patients with end-stage renal failure on dialysis had higher hospital mortality rates than overall mortality, regardless of surgical procedure (on-pump arrest, on-pump beating, and off-pump). This study excluded concomitant CABGs alongside other major procedures under

Table 2 Acquired (total, (1) + (2) + (4) + (5) + (6) + (7) + isolated operations for arrhythmia in (3); 38,592 (1) Valvular heart disease (total; 23,340)

Valve	Cases	Operation				30-Day mortality				Hospital mortality				Redo		Hospital mortality	
		Mechanical	Bioprostheses	Repair	Unknown	With CABG		After discharge		Hospital	Replace	Repair	Replace	Repair	Cases		
						Replace	Repair	Replace	Repair						Hospital		After discharge
Isolated																	
A	10,268	1,271	8,720	178	99	2,489	175 (1.8)	4 (2.3)	2 (0.02)	0	294 (2.9)	5 (2.8)	670	31 (4.6)	0	45 (6.7)	
M	5,239	428	970	3,810	31	560	56 (4.0)	30 (0.8)	2 (0.1)	0	89 (6.4)	47 (1.2)	620	25 (4.0)	0	38 (6.1)	
T	629	6	107	511	5	58	2 (1.8)	18 (3.5)	0	0	7 (6.2)	32 (6.3)	122	7 (5.7)	0	15 (12.3)	
P	31	0	26	5	0	0	0	0	0	0	0	0	19	0	0	0	
A+M	1,345					202	54 (4.0)		0		88 (6.5)		173	12 (6.9)	0	21 (12.1)	
A	238		1,057	42	8												
M	160		463	714	8	94	10 (1.8)		0		30 (5.3)		77	2 (2.6)	0	6 (7.8)	
A+T	564																
A	61		485	11	7												
T	2		12	547	3												
M+T	4,033					327	58 (1.8)		1 (0.02)		99 (2.5)		466	16 (3.4)	0	23 (4.9)	
M	378		1,118	2,519	18												
T	1		51	3,961	20	122	42 (3.7)		0		70 (6.1)		111	5 (4.5)	0	12 (10.8)	
A+M+T	1,143																
A	161		945	26	11												
M	112		436	589	6												
T	2		3	1,135	3	7	2 (2.3)		0		3 (3.4)		22	0	0	1 (4.6)	
Others	88																
Unknown						3859	456 (2.0)		5 (0.02)		770 (3.3)		2,280	98 (4.3)	0	161 (7.1)	
Total	23,340																

(), % mortality

TAVR	Cases		30-day mortality
	Cases	8664	
			103 (1.2)

Table 2 (continued)

(2) Ischemic heart disease (total, (A) + (B) : 12,603)

(A) Isolated CABG (total: 6)+ (B): 11307

(a-1) On-pump arrest CABG (total:2491)

	Primary, elective				Primary, emergent				Redo, elective				Redo, emergent				Artery only	Artery + ssg	Svg only	Others	Unclear
	30 Day mortality		Hospital mortality		30 Day mortality		Hospital mortality		30 Day mortality		Hospital mortality		30 day mortality		Hospital mortality						
	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Cases	Hospital	After discharge	Cases	Hospital	After discharge	Cases	Hospital					
IVD	45				11				4				0				18	29	10	2	1
2VD	273	2 (0.7)	2 (0.7)	5 (10.6)	47	3 (6.4)	5 (10.6)	2	2	5 (10.6)	2	0	0	0	0	0	37	257	23	3	2
3VD	926	8 (0.9)	1 (0.1)	13 (1.4)	130	9 (6.9)	12 (9.2)	2	2	12 (9.2)	2	0	0	0	0	45	946	47	6	14	
LMT	781	10 (1.3)	20 (2.6)	22 (9.2)	240	14 (5.8)	22 (9.2)	5	5	22 (9.2)	5	0	0	0	0	60	890	60	9	7	
No info	16	0		2 (25.0)	8		2 (25.0)	1	1	2 (25.0)	1	1	1 (100.0)	1	1 (100.0)	6	7	10	1	2	
Total	2041	20 (1.0)	1 (0.0)	35 (1.7)	436	26 (6.0)	41 (9.4)	14	14	41 (9.4)	14	1	1 (100.0)	1	1 (100.0)	166	2129	150	21	26	
Kawasaki	2				1			0	0		0	0	0	0	0	1	2	0	0	0	
On dialysis	237	5 (2.1)	1 (0.4)	9 (18.4)	49	4 (8.2)	9 (18.4)	1	1	9 (18.4)	1	0	0	0	0	11	248	25	2	1	

(), % mortality
LMT includes LMT alone or LMT with other branch diseases
CABG coronary artery bypass grafting; 1VD one-vessel disease; 2VD two-vessel disease; 3VD three-vessel disease; LMT left main trunk; SVG saphenous vein graft

(a-2) On-pump beating CABG (total:2,307)

	Primary, elective				Primary, emergent				Redo, elective				Redo, emergent				Artery only	Artery + ssg	Svg only	Others	Unclear
	30 day Mortality		Hospital mortality		30 day mortality		Hospital mortality		30 day mortality		Hospital mortality		30 day mortality		Hospital mortality						
	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Cases	Hospital	After discharge	Cases	Hospital	After discharge	Cases	Hospital					
IVD	28		0 (0.0)		10	1 (10.0)	2 (20.0)	3	3	2 (20.0)	1	1	1 (100.0)	14	1 (100.0)	19	8	0	1		
2VD	211	1 (0.5)	1 (0.5)	14 (28.6)	49	10 (20.4)	14 (28.6)	2	2	14 (28.6)	2	0	0	46	1 (2.5.0)	186	24	1	5		
3VD	765	14 (1.8)	2 (0.3)	24 (3.1)	187	13 (7.0)	22 (11.8)	9	9	22 (11.8)	1	1 (11.1)	1 (100.0)	72	1 (100.0)	841	36	9	4		
LMT	676	5 (0.7)	14 (2.1)	27 (8.2)	330	14 (4.2)	27 (8.2)	10	10	27 (8.2)	2	2 (100.0)	2 (100.0)	127	2 (100.0)	834	50	2	5		
no info	16	1 (6.3)	1 (6.3)	1 (9.1)	11	1 (9.1)	1 (9.1)	0	0	1 (9.1)	0	4	1 (25.0)	8	1 (25.0)	15	7	1	0		
Total	1696	21 (1.2)	2 (0.1)	40 (2.4)	587	39 (6.6)	66 (11.2)	24	24	66 (11.2)	8	5 (62.5)	5 (62.5)	267	5 (62.5)	1895	125	13	15		
Kawasaki	1				0			0	0		0	0	0	0	0	1	0	0	0		
On dialysis	214	12 (5.6)	19 (8.9)	16 (20.0)	80	7 (8.8)	16 (20.0)	5	5	16 (20.0)	2	2 (40.0)	2 (100.0)	22	2 (100.0)	253	22	1	2		

(), % mortality
LMT includes LMT alone or LMT with other branch diseases
CABG coronary artery bypass grafting; 1VD one-vessel disease; 2VD two-vessel disease; 3VD three-vessel disease; LMT left main trunk; SVG saphenous vein graft

Table 2 (continued)

(b) Off-pump CABG (total:6509)

(Including cases of planned off-pump CABG in which, during surgery, the change is made to an on-pump CABG or on-pump beating-heart procedure)

	Primary, elective		Primary, emergent		Redo, elective		Redo, emergent		Artery only	Artery + srg	Srg only	Others	Unclear
	Cases		Cases		Cases		Cases						
	30 day mortality	Hospital mortality	30 day mortality	Hospital mortality	30 day mortality	Hospital mortality	30 Day mortality	Hospital mortality					
Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge						
1VD	352	2 (0.6)	44	3 (6.8)	2	5 (11.4)	3	1 (33.3)	293	71	35	1	1
2VD	860	3 (0.3)	112	3 (2.7)	7	4 (3.6)	1	1 (100.0)	335	606	33	0	6
3VD	2158	15 (0.7)	305	6 (2.0)	12	14 (4.6)	1	1 (8.3)	468	1931	50	11	16
LMT	2028	17 (0.8)	513	23 (4.5)	18	30 (5.8)	9	1 (11.1)	667	1801	86	5	9
No info	83	0 (0.0)	13	1 (7.7)	2	1 (7.7)	2	1 (50.0)	24	63	9	1	3
Total	5481	37 (0.7)	987	36 (3.6)	41	54 (5.5)	16	4 (25.0)	1787	4472	213	18	35
Kawasaki	0		0		0	0	0	0	0	0	0	0	0
On dialysis	556	8 (1.4)	90	4 (4.4)	7	6 (6.7)	5	2 (40.0)	174	448	29	2	5

(), % mortality
 LMT alone or LMT with other branch diseases
 CABG coronary artery bypass grafting, 1VD one-vessel disease; 2VD two-vessel disease; 3VD three-vessel disease; LMT left main trunk; S/G splenous vein graft

(c) Cases of conversion, during surgery, from off-pump CABG to on-pump CABG or on-pump beating-heart CABG (these cases are also included in category (b))

	Primary, elective		Primary, emergent		Redo, elective		Redo, emergent	
	Cases		Cases		Cases		Cases	
	30 Day mortality	Hospital mortality	30 Day mortality	Hospital mortality	30 Day mortality	Hospital mortality	30 Day mortality	Hospital mortality
Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	
Converted to arrest	21	2 (9.5)	3				0	
Converted to beating	102	6 (5.9)	39	3 (7.7)	6	7 (17.9)	1	1 (100.0)
Total	123	6 (4.9)	42	3 (7.1)	6	7 (16.7)	1	1 (100.0)
On dialysis	21	2 (9.5)	7	1 (14.3)	5	3 (42.9)	0	

(), % mortality
 CABG coronary artery bypass grafting

Table 2 (continued)

(B) Operation for complications of MI (total: 1296)

	Chronic				Acute				Concomitant operation				
	Cases	30-day mortality		Hospital mortality		Cases	30-day mortality		Hospital mortality		CABG	MVP	MYR
		Hospital	After discharge	Hospital	After discharge		Hospital	After discharge	Hospital	After discharge			
Infectiomy or Aneurysmectomy	99	6 (6.1)	8 (8.1)	24	8 (33.3)	9 (37.5)	55	25	8				
VSP closure	81	9 (11.1)	13 (16.0)	262	68 (26.0)	102 (38.9)	90	4	6				
Cardiac rupture	29	7 (24.1)	11 (37.9)	238	78 (32.8)	90 (37.8)	36	2	5				
Mitral regurgitation													
(1) Papillary muscle rupture	74	4 (5.4)	4 (5.4)	52	14 (26.9)	19 (36.5)	20	10	56				
(2) Ischemic	216	15 (6.9)	25 (11.6)	42	9 (21.4)	11 (26.2)	171	151	107				
Others	78	7 (9.0)	10 (12.8)	101	22 (21.8)	35 (34.7)	72	9	7				
Total	577	48 (8.3)	71 (12.3)	719	199 (27.7)	266 (37.0)	444	201	189				

(), % mortality
 MI myocardial infarction; CABG coronary artery bypass grafting; MVP mitral valve repair; MZR mitral valve replacement; ESP ventricular septal perforation
 Acute, within 2 weeks from the onset of myocardial infarction

(3) Operation for arrhythmia (total:6880)

	Cases	30-day mortality		Hospital mortality		Concomitant operation			Multiple combination				
		After discharge		Hospital		Isolated	Congenital	Valve	IHD	Others	2 categories		3 categories
		Hospital	After discharge	Hospital	After discharge						2 categories	3 categories	
Maze	3,898	66 (1.7)	1 (0.03)	119 (3.1)	157	169	3,345	636	364	699	61		
For WPW	0				0	0	0	0	0	0	0		
For ventricular tachyarrhythmia	32	2 (6.3)	3 (9.4)	5	3	12	18	1	8	1	1		
Others	2,950	57 (1.9)	96 (3.3)	85	129	2,500	525	285	533	48			
Total	6,880	125 (1.8)	1 (0.01)	218 (3.2)	247	301	5,857	1,179	650	1,240	110		

(), % mortality
 WPW Wolff-Parkinson-White syndrome; IHD ischemic heart disease
 Except for 247 isolated cases, all remaining 6633 cases are doubly allocated, one for this subgroup and the other for the subgroup corresponding to the concomitant operations

(4) Operation for constrictive pericarditis (total: 191)

	CPB (+)		CPB (-)			
	Cases		Cases			
	30-day mortality	Hospital mortality	30-day mortality	Hospital mortality		
Total	95	4 (4.2)	18 (18.9)	96	1 (1.0)	3 (3.1)

(), % mortality
 CPB cardiopulmonary bypass

Table 2 (continued)

(5) Curable tumor (total; 704)

Cases	30-day mortality		Hospital mortality	Concomitant operation				Others
	Hospital	After discharge		AVR	MVR	CABG	CABG	
Benign tumor	3 (0.5)		32	34	45		143	
(Cardiac myxoma)	1 (0.3)		13	3	24		72	
Malignant tumor	2 (3.1)		2	4	4		11	
(Primary)	1 (2.3)		2	4	4		10	

(), % mortality
AVR aortic valve replacement; *MVR* mitral valve replacement; *CABG* coronary artery bypass grafting

(6) HOCM and DCM (total; 278)

Cases	30-day mortality		Hospital mortality	Concomitant operation				CABG
	Hospital	After discharge		AVR	MVR	MVP	CABG	
Myectomy	5 (3.8)		7 (5.4)	56	26	21	21	
Myotomy				1	1	1	1	
No-resection	10 (7.8)	1 (0.8)	1 (0.8)	21	74	54	6	
Volume reduction surgery of the left ventricle		1 (0.4)		1	3	1	2	
Total	15 (5.4)		8 (2.9)	79	104	77	30	

(), % mortality
HOCM hypertrophic obstructive cardiomyopathy; *DCM* dilated cardiomyopathy; *AVR* aortic valve replacement; *MVR* mitral valve replacement; *MVP* mitral valve repair; *CABG* coronary artery bypass grafting

(7) Other open-heart operation (total; 1229)

Cases	30-day mortality		Hospital mortality	
	Hospital	After discharge	Hospital	After discharge
Open-heart operation	523	52 (9.9)	75 (14.3)	1 (0.2)
Non-open-heart operation	706	88 (12.5)	120 (17.0)	
Total	1229	140 (11.4)	195 (15.9)	1 (0.1)

(), % mortality

Table 3 Thoracic aortic aneurysm (total; 22,708)
(1) Dissection (total; 10,847)

Stanford type	Acute						Chronic						Concomitant operation											
	A			B			A			B			AVP			MVP			CABG			Others		
	Cases	30-day mortality Hospital	After discharge	Hospital mortality	Cases	30-day mortality Hospital	After discharge	Hospital mortality	Cases	30-day mortality Hospital	After discharge	Hospital mortality	Cases	30-day mortality Hospital	After discharge	Hospital mortality	AVP	AVR	MVP	MVR	CABG	Others		
Ascending Ao.	2376	177 (7.4)	0	235 (9.9)	2				211	8 (3.8)		12 (5.7)	6	1 (16.7)		1 (16.7)	74	139	13	19	135	30		
Aortic Root	232	29 (12.5)	3 (1.29)	36 (15.5)	0				92	7 (7.6)		11 (12.0)	5				47	206	4	2	72	3		
Arch	2045	144 (7.0)	2 (0.10)	175 (8.6)	23	2 (8.7)	2 (8.7)		353	6 (1.7)		9 (2.5)	166	5 (3.0)		5 (3.0)	63	141	10	10	130	27		
Aortic root + asc. Ao. + Arch	173	20 (11.6)	0	26 (15.0)	1				51	3 (5.9)		4 (7.8)	8	2 (25.0)		3 (37.5)	37	149	2	1	53	3		
Descending Ao.	43	3 (7.0)	0	3 (7.0)	42	4 (9.5)	5 (11.9)		80	1 (1.3)		4 (5.0)	249	12 (4.8)		17 (6.8)	4	5	0	0	6	0		
Thoracoabdominal	2	0	0	0	11	2 (18.2)	2 (18.2)		49	3 (6.1)		5 (10.2)	171	10 (5.8)		16 (9.4)	0	0	0	0	0	0		
Simple TEVAR	69	14 (20.3)	0	16 (23.2)	412	22 (5.3)	32 (7.8)		233	2 (0.9)		4 (1.7)	1067	15 (1.4)	1 (0.1)	20 (1.9)	0	0	0	0	1	2		
Open SG with BR	993	75 (7.6)	0	106 (10.7)	52	7 (13.5)	12 (23.1)		191	4 (2.1)		8 (4.2)	193	4 (2.1)		5 (2.6)	49	99	3	1	90	10		
Open SG without BR	370	36 (9.7)	1 (0.27)	52 (14.1)	29	3 (10.3)	5 (17.2)		67	5 (7.5)		6 (9.0)	74	2 (2.7)		4 (5.4)	18	44	4	1	36	4		
Arch TEVAR with BR	18	2 (11.1)	0	2 (11.1)	108	7 (6.5)	1 (0.9)		57			9 (8.3)	374	5 (1.3)		7 (1.9)	0	1	0	0	0	0		
Thoracoabdominal TEVAR with BR	2	0	0	0	6	1 (16.7)	1 (16.7)		12			1 (6.7)	29	2 (6.9)		4 (13.8)	0	1	0	0	0	0		
Other	24	9 (37.5)	0	10 (41.7)	17	1 (5.9)	1 (5.9)		16	1 (6.3)		1 (6.3)	43			1 (6.3)	1	1	0	1	3	2		
Total	6347	387 (6.1)	6 (0.09)	661 (10.4)	703	49 (7.0)	1 (0.1)	69 (9.8)	1412	40 (2.8)	0	64 (4.5)	2385	58 (2.4)	1 (0.0)	82 (3.4)	293	786	36	35	526	81		

(). % mortality
Ao aorta; AVR aortic valve repair; MVP mitral valve repair; MVR mitral valve replacement; TEVAR thoracic endovascular aortic (aneurysm) repair
Acute, within 2 weeks from the onset

Table 3 (continued)
(2) Non-dissection (total; 11861)

Replaced site	Unruptured				Ruptured				Concomitant operation					
	Cases		Hospital mortality		Cases		Hospital mortality		AVP	AVR	MVP	MVR	CABG	Others
	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge	Hospital	After discharge						
Ascending Ao.	1440	22 (1.5)	45 (3.1)		60	13 (21.7)	14 (23.3)	79	1012	84	57	189	120	
Aortic Root	1174	35 (3.0)	51 (4.3)		45	5 (11.1)	5 (11.1)	304	818	71	36	162	63	
Arch	2243	38 (1.7)	76 (3.4)		103	10 (9.7)	16 (15.5)	39	589	41	24	302	68	
Aortic root + asc. Ao. + Arch	286	9 (3.1)	12 (4.2)		8	1 (12.5)	1 (12.5)	45	214	13	5	33	14	
Descending Ao.	344	16 (4.7)	20 (5.8)		35	11 (31.4)	15 (42.9)	1	7	2	0	21	1	
Thoracoabdominal	356	24 (6.7)	34 (9.6)		27	6 (22.2)	8 (29.6)	0	0	0	0	0	0	
Simple TEVAR	2496	46 (1.8)	67 (2.7)		340	37 (10.9)	56 (16.5)	0	0	0	0	1	8	
Open SG with BR	1066	37 (3.5)	62 (5.8)		52	6 (11.5)	8 (15.4)	15	120	11	1	192	18	
Open SG without BR	354	9 (2.5)	21 (5.9)		27	2 (7.4)	4 (14.8)	13	52	6	1	54	3	
Arch TEVAR with BR	1042	33 (3.2)	57 (5.5)	1 (0.10)	85	12 (14.1)	18 (21.2)	0	1	0	1	6	0	
Thoracoabdominal TEVAR with BR	95	3 (3.2)	12 (12.6)		14	6 (42.9)	8 (57.1)	0	0	0	0	0	0	
Other	142	7 (4.9)	11 (7.7)		27	5 (18.5)	9 (33.3)	0	15	0	3	6	2	
Total	11038	279 (2.5)	468 (4.2)	1 (0.01)	823	114 (13.9)	162 (19.7)	496	2828	228	128	966	297	

(), % mortality
 Ao aorta; AVP aortic valve repair; AVR aortic valve replacement; MVP mitral valve repair; MVR mitral valve replacement; CABG coronary artery bypass grafting; TEVAR thoracic endovascular aortic (aneurysm) repair
 Acute, within 2 weeks from the onset

Table 4 Pulmonary thromboembolism (total; 187)

	Cases	30-day mortality		Hospital mortality
		Hospital	After discharge	
Acute	125	20 (16.0)		22 (17.6)
Chronic	62	2 (3.2)		2 (3.2)
Total	187	22 (11.8)		24 (12.8)

(), % mortality

Table 5 Implantation of VAD (total; 192)

	Cases	30-day mortality		Hospital mortality
		Hospital	After discharge	
Implantation of VAD	192	2 (1.0)		9 (4.7)

(), % mortality

VAD ventricular assist devise

Table 6 Heart transplantation (total; 84)

	Cases	30-day mortality		Hospital mortality
		Hospital	After discharge	
Heart transplantation	84	1 (1.2)		2 (2.4)
Heart and lung transplantation	0			
Total	84	1 (1.2)		2 (2.4)

(), % mortality

the ischemic heart disease category but rather under other categories, such as valvular heart disease and thoracic aortic aneurysm. Accordingly, the overall number of CABGs in 2019, including concomitant CABG with other major procedures, was 17,256.

Arrhythmia management was primarily performed as concomitant procedures in 6880 cases, with a hospital mortality rate of 3.2%. Pacemaker and implantable cardioverter-defibrillator implantation were not included in this category.

In 2019, 22,708 procedures for thoracic and thoracoabdominal aortae diseases were performed, among which aortic dissection and non-dissection accounted for 10,847 and 11,861, respectively. The number of surgeries for aortic dissection this year was 3.8% higher than that in the preceding year ($n=10,453$). Hospital mortality rates for the 6347 Stanford type A acute aortic dissections remained high (10.4%). The number of procedures for non-dissected

aneurysms decreased by 1.2%, with a hospital mortality rate of 5.7% for all aneurysms and 4.2% and 19.7% for unruptured and ruptured aneurysms, respectively. Thoracic endovascular aortic repair (TEVAR) has been performed for aortic diseases at an increasing rate. Stent graft placement was performed in 4356 patients with aortic dissection, including 2387 TEVARs and 1969 open stent graftings. Moreover, 1470 and 267 cases underwent TEVAR and open stent grafting for type B chronic aortic dissection, accounting for 61.6% and 13.6% of the total number of cases, respectively. Hospital mortality rates associated with simple TEVAR for type B aortic dissection were 8.0% and 2.1% for acute and chronic cases, respectively. Stent graft placement was performed in 5087 patients with non-dissected aortic aneurysms, among which 4072 were TEVARs (an 11.8% increase compared to that in 2018, $n=3641$) and 1499 were open stent graftings (a 3.7% increase compared to that in 2018, $n=1446$). Hospital mortality rates were 3.7% and 18.7% for TEVARs and 5.8% and 15.2% for open stenting in unruptured and ruptured aneurysms, respectively.

(B) General thoracic surgery

The 2019 survey of general thoracic surgeries comprised 679 surgical units, with bulk data submitted via a web-

Table 7 Total cases of general thoracic surgery during 2019

	Cases	%
Benign pulmonary tumor	2543	2.8
Primary lung cancer	48,052	52.4
Other primary malignant pulmonary tumor	432	0.5
Metastatic pulmonary tumor	9329	10.2
Tracheal tumor	117	0.1
Mesothelioma	682	0.7
Chest wall tumor	689	0.8
Mediastinal tumor	5861	6.4
Thymectomy for MG without thymoma	162	0.2
Inflammatory pulmonary disease	2,358	2.6
Empyema	3298	3.6
Bullous disease excluding pneumothorax	394	0.4
Pneumothorax	15,082	16.5
Chest wall deformity	208	0.2
Diaphragmatic hernia including traumatic	36	0.0
Chest trauma excluding diaphragmatic hernia	469	0.5
Lung transplantation	92	0.1
Others	1822	2.0
Total	91,626	100.0

based collection system established by the NCD [1]. General thoracic surgery departments reported 91,626 procedures in 2019 (Table 7), which is 2.2 times more than that in 2000 and approximately 14,500 more procedures than that in 2014 (Fig. 2).

In 2019, 48,052 procedures for primary lung cancer had been performed which continued to increase annually. Accordingly, the number of procedures in 2019 was 2.6 times higher than that in 2000, with lung cancer procedures accounting for 52% of all general thoracic surgeries.

Information about the number of video-assisted thoracoscopic surgery (VATS), which is defined as surgical procedures using a skin incision less than 8 cm including a mini-thoracotomy (hybrid) approach, have been available since the 2015 annual report. Tables 8, 9, 11, 14, 15, 16, 18, 19, 20, 21, 22, and 24, 25, 26 present the number of VATS procedures for benign pulmonary tumors, primary lung cancer, metastatic pulmonary tumor, chest wall tumor, mediastinal tumor, thymectomy for myasthenia gravis, non-neoplastic disease, empyema, descending necrotizing mediastinitis, bullous diseases, diaphragmatic hernia, chest trauma and the total number of VATS procedures in 2019, respectively.

A total of 2543 procedures for benign pulmonary tumors had been conducted in 2019 (Table 8). Hamartomas were the most frequent benign pulmonary tumors diagnosed, with 2437 patients (96%) undergoing VATS.

Tables 9 and 10 show additional information on primary malignant pulmonary tumors. Accordingly, the most frequently diagnosed lung cancer subtype was adenocarcinoma (71% of all lung cancers), followed by squamous cell carcinoma (18%). Sublobar resection was performed in 13,999 lung cancer cases (29% of all cases) and lobectomy

Table 8 Benign pulmonary tumor

	Cases	30-Day mortality		Hospital mortality	By VATS
		Hospital	After discharge		
Benign pulmonary tumor					
Hamartoma	565				549
Sclerosing hemangioma	108				102
Papilloma	27				27
Mucous gland adenoma bronchial	10				10
Fibroma	136				132
Lipoma	7				6
Neurogenic tumor	11				10
Clear cell tumor	2				2
Leiomyoma	24				23
Chondroma	3				1
Inflammatory myofibroblastic tumor	0				0
Pseudolymphoma	18				17
Histiocytosis	17				16
Teratoma	6				6
Others	1609	1 (0.1)		3 (0.2)	1536
Total	2543	1 (0.04)		3 (0.12)	2437

(), Mortality %

in 33,455 cases (70% of all cases). Sleeve lobectomy was performed in 483 cases, while pneumonectomy was required in 278 cases (0.6% of all cases). VATS lobectomy was performed in 25,487 cases of lung cancer (76% of all lobectomy cases). Patients aged ≥ 80 years who underwent lung cancer surgery accounted for 6739 (14%). Among

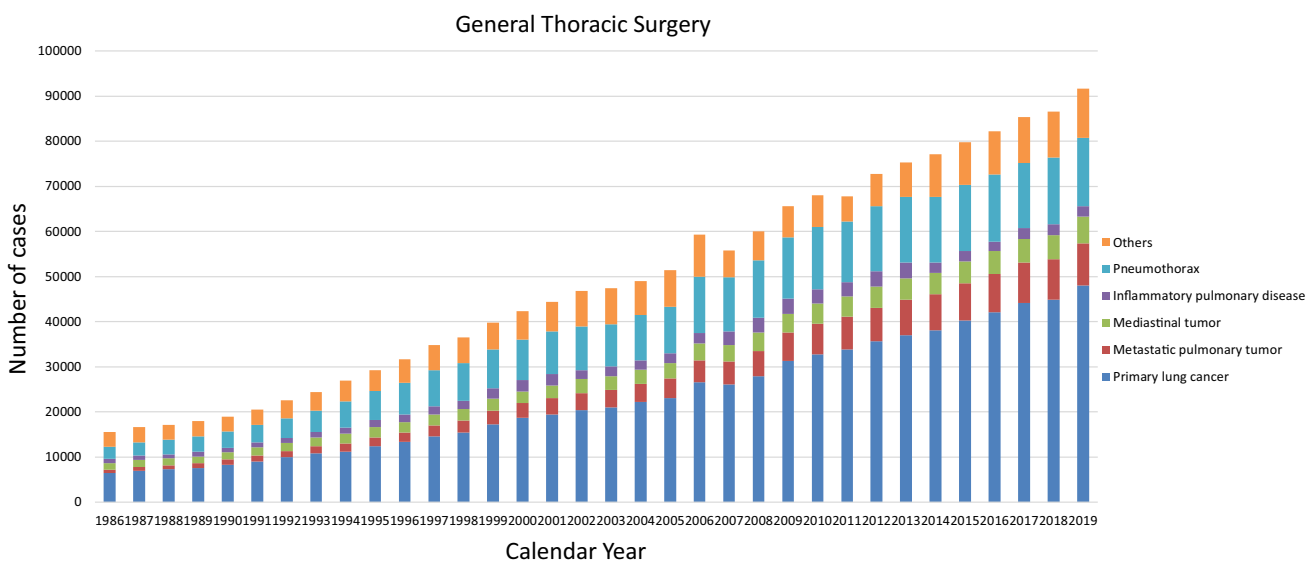


Fig. 2 General thoracic surgery

Table 9 Primary malignant pulmonary tumor

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
2. Primary malignant pulmonary tumor	48,484	109 (0.2)	66 (0.1)	240 (0.5)	38,158
Lung cancer	48,052	107 (0.2)	66 (0.1)	238 (0.5)	38,158
Adenocarcinoma	34,290	49 (0.1)	39 (0.11)	99 (0.3)	
Squamous cell carcinoma	8,642	47 (0.5)	23 (0.3)	107 (1.2)	
Large cell carcinoma	311				
LCNEC	611	1 (0.2)	1 (0.2)	5 (0.8)	
Small cell carcinoma	776	1 (0.1)	3 (0.4)	5 (0.6)	
Adenosquamous carcinoma	538	1 (0.2)		3 (0.6)	
Carcinoma with pleomorphic, sarcomatoid or sarcomatous elements	540	4 (0.7)		6 (1.1)	
Carcinoid	282			1 (0.4)	
Carcinomas of salivary-gland type	45				
Unclassified	42	1 (2.4)		2 (4.8)	
Multiple lung cancer	1,623	3 (0.2)		7 (0.4)	
Others	352			3 (0.9)	
Unknown		1	1	2	
Wedge resection	8,532	10 (0.1)	9 (0.1)	28 (0.3)	7,770
Segmental excision	5,467	5 (0.1)	6 (0.11)	19 (0.3)	4,674
(<i>Sleeve segmental excision</i>)	20				12
Lobectomy	33,445	85 (0.3)	49 (0.15)	177 (0.5)	25,487
(<i>Sleeve lobectomy</i>)	483	8 (1.7)	3 (0.6)	9 (1.9)	70
Pneumonectomy	278	4 (1.4)		10 (3.6)	31
(<i>Sleeve pneumonectomy</i>)	5				0
Other bronchoplasty	38			1 (2.6)	5
Pleuropneumonectomy	1				0
Others	291	4 (1.4)	3 (1.0)	5 (1.7)	191
Unknown	0				
Sarcoma	47	2 (4.3)		2 (4.3)	
AAH	120				
Others	265				

(), Mortality %

those who died within 30 days postoperatively, 107 and 66 died before and after hospital discharge, respectively. Overall, 173 patients died within 30 days postoperatively (30-day mortality rate, 0.4%), while 238 died before discharge (hospital mortality rate, 0.5%). Moreover, 30-day mortality rates according to the procedure were 0.1%, 0.3%, and 1.4% for segmentectomy, lobectomy, and pneumonectomy, respectively. Interstitial pneumonia had been the leading cause of death after lung cancer surgery, followed

by pneumonia, respiratory failure, and cardiovascular events.

Table 11 shows the procedures for metastatic pulmonary tumors, of which 9329 were performed in 2019. Among such procedures, the most frequent primary tumor was colorectal cancer (51% of all cases).

A total of 117 procedures for tracheal tumors, including 60, 30, and 27 cases of primary malignant, metastatic, and benign tracheal tumors, respectively, were performed in

Table 10 Details of lung cancer operations

TNM	Cases
c-Stage	Cases
IA1	8727
IA2	13,908
IA3	8400
IB	5295
IIA	1687
IIB	4018
IIIA	2694
IIIB	457
IIIC	15
IVA	383
IVB	80
NA	2,388
Total	48,052
Sex	Cases
Male	29,065
Female	18,987
Total	48,052
Cause of death	Cases
Cardiovascular	30
Pneumonia	50
Pyothorax	2
Bronchopleural fistula	14
Respiratory failure	32
Pulmonary embolism	2
Interstitial pneumonia	87
Brain infarction or bleeding	10
Others	70
Unknown	10
Total	307
p-Stage	Cases
0 (pCR)	3532
IA1	9737
IA2	10,819
IA3	5323
IB	6496
IIA	1343
IIB	4712
IIIA	3949
IIIB	770
IIIC	10
IVA	942
IVB	92

Table 10 (continued)

p-Stage	Cases
NA	327
Total	48,052
Age (y)	Cases
<20	19
20–29	48
30–39	259
40–49	1299
50–59	3987
60–69	12,825
70–79	22,874
80–89	6,614
≥90	125
NA	2
Total	48,052

2019. Further, 35 patients underwent sleeve resection and reconstruction (Table 12).

Overall, 682 pleural tumors had been diagnosed in 2019 (Table 13), with diffuse malignant pleural mesothelioma as the most frequent histologic diagnosis. Total pleurectomy was performed in 140 cases and extrapleural pneumonec-tomy in 43 cases. The 30-day mortality rate was 0% and 2.3% after total pleurectomy and extrapleural pneumonec-tomy, respectively, both of which had better outcomes than previously reported.

Overall, 689 chest wall tumor resections had been per-formed in 2019, including 116, 209, and 364 cases of pri-mary malignant, metastatic, and benign tumors, respectively (Table 14).

In 2019, 5,881 mediastinal tumors were resected, which is 10% higher compared to that in the previous year (Table 15). Thymic epithelial tumors, including 2280 thy-momas, 351 thymic carcinomas, and 44 thymic carcinoids, were the most frequently diagnosed mediastinal tumor subtype in 2019.

A total of 499 patients underwent thymectomy for myasthenia gravis (Table 16), among which 337 procedures were associated with thymoma.

Overall, 23,717 patients underwent procedures for non-neoplastic disease. Accordingly, 2358 patients underwent lung resection for inflammatory lung diseases (Tables 17, 18), among which 475 and 336 patients were associated

Table 11 Metastatic pulmonary tumor

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
3. Metastatic pulmonary tumor	9329	9 (0.1)	6 (0.06)	16 (0.2)	8709
Colorectal	4379	3 (0.07)		5 (0.1)	4083
Hepatobiliary/Pancreatic	525	1 (0.2)		1 (0.2)	497
Uterine	516	2 (0.4)		2 (0.4)	490
Mammary	568				547
Ovarian	75				72
Testicular	57				53
Renal	770				732
Skeletal	144				133
Soft tissue	246		3 (1.2)		229
Otorhinolaryngological	559				525
Pulmonary	449	1 (0.2)	1 (0.2)	2 (0.4)	386
Others	1041	2 (0.2)	2 (0.2)	6 (0.6)	962

(), Mortality %

with mycobacterial and fungal infections, respectively. Procedures for inflammatory nodules were performed in cases where lung cancer was suspected preoperatively (928 cases, 39%).

A total of 3298 procedures were performed for empyema (Table 19), among which 2597 (77%) were acute and 701 were chronic. Further, bronchopleural fistulas developed in 478 and 320 patients with acute and chronic empyema, respectively. The hospital mortality rate was 13% among patients with acute empyema with fistula.

Further, 93 operations were performed for descending necrotizing mediastinitis (Table 20), with a hospital mortality rate of 4.3%.

A total of 394 procedures were conducted for bullous diseases (Table 21), while only 13 patients underwent lung volume reduction surgery.

A total of 15,082 procedures were performed for pneumothorax (Table 22). Among the 11,200 procedures for spontaneous pneumothorax, 2762 (25%) were bullectomies

alone, while 7714 (69%) required additional procedures, such as coverage with artificial material, as well as parietal pleurectomy. A total of 3,882 procedures for secondary pneumothorax were performed, with chronic obstructive pulmonary disease (COPD) being the most prevalent associated disease (2693 cases, 69%). The hospital mortality rate for secondary pneumothorax associated with COPD was 1.7%.

The 2019 survey reported 208 procedures for chest wall deformity (Table 23). However, this may have been underestimated because the Nuss procedure for pectus excavatum was more likely performed in pediatric surgery centers not associated with the Japanese Association for Thoracic Surgery.

Surgical treatment for diaphragmatic hernia was performed in 36 patients (Table 24). This figure may have been underestimated because procedures may have been classified as gastrointestinal surgery.

Table 12 Tracheal tumor

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
4. Tracheal tumor	117	2 (1.7)	3 (2.6)	5 (4.3)
A. Primary malignant tumor				
Histological classification				
Squamous cell carcinoma	14			2 (14.3)
Adenoid cystic carcinoma	31		1 (3.2)	
Mucoepidermoid carcinoma	1			
Others	14			
Total	60		1 (1.7)	2 (3.3)
B. Metastatic/invasive malignant tumor, e.g. invasion of thyroid cancer	30	2 (6.7)	2 (6.7)	3 (10.0)
C. Benign tracheal tumor				
Histological classification				
Papilloma	3			
Adenoma	2			
Neurofibroma	1			
Chondroma	1			
Leiomyoma	2			
Others	18			
Histology unknown	0			
Total	27	0	0	0
Operation				
Sleeve resection with reconstruction	35		1 (2.9)	1 (2.9)
Wedge with simple closure	4			
Wedge with patch closure	0			
Total laryngectomy with tracheostomy	0			
Others	1			
Unknown	0			
Total	40	0	1 (2.5)	1 (2.5)

(), Mortality %

Table 13 Tumor of pleural origin

Histological classification	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
5. Tumor of pleural origin				
Solitary fibrous tumor	133			
Diffuse malignant pleural mesothelioma	292	2 (0.7)		10 (3.4)
Localized malignant pleural mesothelioma	37			1 (2.7)
Others	220	2 (0.9)		4 (1.8)
Total	682	4 (0.6)		15 (2.2)
Operative procedure	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
Extrapleural pneumonectomy	43	1 (2.3)		3 (7.0)
Total pleurectomy	140			3 (2.1)
Others	109	1 (0.9)		4 (3.7)
Total	292	2 (0.7)		10 (3.4)

(), Mortality %

Table 14 Chest wall tumor

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
6. Chest wall tumors					
Primary malignant tumor	116	1 (0.9)	1 (0.9)	1 (0.9)	56
Metastatic malignant tumor	209				84
Benign tumor	364				283
Total	689	1 (0.1)	1 (0.1)	1 (0.1)	423

(), Mortality %

Table 15 Mediastinal tumor

	Cases	30-Day mortality		Hospital mortality	By VATS
		Hospital	After discharge		
7. Mediastinal tumor	5881	2 (0.03)	10 (0.17)	10 (0.2)	4599
Thymoma*	2280		2 (0.1)	2 (0.1)	1612
Thymic cancer	351		1 (0.3)	1 (0.3)	222
Thymus carcinoid	44				25
Germ cell tumor	111				66
<i>Benign</i>	89				59
<i>Malignant</i>	22				7
Neurogenic tumor	526	1 (0.2)			490
Congenital cyst	1376		1 (0.1)	1 (0.1)	1293
Goiter	96			0	36
Lymphatic tumor	160			0	125
Excision of pleural recurrence of thymoma	30			0	23
Thymolipoma	15	1 (6.7)		0	9
Others	892		6 (0.7)	6 (0.7)	698

(), Mortality %

Table 16 Thymectomy for myasthenia gravis

	Cases	30-Day mortality		Hospital mortality	By VATS
		Hospital	After discharge		
8. Thymectomy for myasthenia gravis	499	1 (0.2)	0	3 (0.6)	298
With thymoma	337	0	0	0	202

(), Mortality %

Table 17 Operations for non-neoplastic diseases:A+B+C+D+E+F+G+H+I

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
9. Operations for non-neoplastic diseases	23,717	221 (0.9)	33 (0.1)	491 (2.1)

The survey reported 469 procedures for chest trauma, excluding iatrogenic injuries (Table 25), with a hospital mortality rate of 5.5%.

Table 26 summarizes the procedures for other diseases, including 110 and 118 cases of arteriovenous malformation and pulmonary sequestration, respectively.

Table 18 A. Inflammatory pulmonary disease

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
A. Inflammatory pulmonary disease	2358	7 (0.3)	1 (0.0)	15 (0.6)	2130
Tuberculous infection	41				35
Mycobacterial infection	475	1 (0.2)		2 (0.4)	425
Fungal infection	336	1 (0.3)		2 (0.6)	267
Bronchiectasis	52				42
Tuberculous nodule	70			1 (1.4)	69
Inflammatory pseudotumor	928	2 (0.2)	1 (0.1)	4 (0.4)	876
Interpulmonary lymph node	66				65
Others	390	3 (0.8)		6 (1.5)	351

(), Mortality %

Table 19 B. Empyema

	Cases	30-Day mortality		Hospital mortality	By VATS
		Hospital	After discharge		
Acute empyema	2597	53 (2.0)	3 (0.1)	144 (5.5)	2,233
With fistula	478	10 (2.1)		62 (13.0)	287
Without fistula	2096	43 (2.1)	3 (0.1)	81 (3.9)	1,925
Unknown	23			1 (4.3)	21
Chronic empyema	701	20 (2.9)	2 (0.3)	55 (7.8)	404
With fistula	320	16 (5.0)	1 (0.3)	36 (11.3)	127
Without fistula	342	3 (0.9)	1 (0.3)	18 (5.3)	246
Unknown	39	1 (2.6)		1 (2.6)	31
Total	3298	73 (2.2)	5 (0.2)	199 (6.0)	2637

(), Mortality %

Table 20 C. Descending necrotizing mediastinitis

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
C. Descending necrotizing mediastinitis	93	2 (2.2)		4 (4.3)	78

(), Mortality %

Table 21 D. Bullous diseases

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
D. Bullous diseases	394	1 (0.3)		1 (0.3)	359
Emphysematous bulla	296	1 (0.3)		1 (0.3)	270
Bronchogenic cyst	22				20
Emphysema with <u>LVRS</u>	13				13
Others	63				56

(), Mortality %

LVRS lung volume reduction surgery

Table 22 E. Pneumothorax

Cases	30-Day mortality		Hospital mortality	VATS	
	Hospital	After discharge			
15,082	78 (0.5)	22 (0.1)	163 (1.1)	14,711	
Spontaneous pneumothorax					
Operative procedure	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
Bullectomy	2762	5 (0.2)	1 (0.0)	6 (0.2)	2702
Bullectomy with additional procedure	7714	4 (0.1)	1 (0.01)	11 (0.1)	7596
Coverage with artificial material	7442	4 (0.1)	1 (0.01)	11 (0.1)	7327
Parietal pleurectomy	33				33
Coverage and parietal pleurectomy	71				71
Others	168				165
Others	721	2 (0.3)		10 (1.4)	688
Unknown	3				3
Total	11,200	11 (0.1)	2 (0.0)	27 (0.2)	10,989
Secondary pneumothorax					
Associated disease	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
COPD	2693	25 (0.9)	9 (0.3)	57 (2.1)	2,611
Tumorous disease	168	11 (6.5)	4 (2.4)	19 (11.3)	158
Catamenial	164				162
LAM	49	0			48
Others (excluding pneumothorax by trauma)	808	31 (3.8)	7 (0.9)	60 (7.4)	745
Operative procedure					
Operative procedure	Cases	30 Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
Bullectomy	627	7 (1.1)	3 (0.5)	13 (2.1)	615
Bullectomy with additional procedure	2285	21 (0.9)	8 (0.4)	42 (1.8)	2233
Coverage with artificial material	2190	19 (0.9)	8 (0.4)	39 (1.8)	2140
Parietal pleurectomy	6				6
Coverage and parietal pleurectomy	24	1 (4.2)		1 (4.2)	22
Others	65	1 (1.5)		2 (3.1)	65
Others	966	39 (4.0)	9 (0.9)	81 (8.4)	872
Unknown	4			0	4
Total	3882	67 (1.7)	20 (0.5)	136 (3.5)	3724

(), Mortality %

Table 23 F. Chest wall deformity

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
F. Chest wall deformity	208			
Funnel chest	196			
Others	12			

(), Mortality %

Table 24 G. Diaphragmatic hernia

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
G. Diaphragmatic hernia	36				21
Congenital	6				5
Traumatic	10				4
Others	20				12

(), Mortality %

Table 25 H. Chest trauma

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
H. Chest trauma	469	26 (5.5)	1 (0.2)	29 (6.2)	302

(), Mortality %

Table 26 I. Other respiratory surgery

	Cases	30-Day mortality		Hospital mortality	VATS
		Hospital	After discharge		
I. Other respiratory surgery	1783	34 (1.9)	4 (0.2)	80 (4.5)	1400
Arteriovenous malformation*	110		1 (0.9)	1 (0.9)	104
Pulmonary sequestration	118				105
Postoperative bleeding *air leakage	555	9 (1.6)		34 (6.1)	404
Chylothorax	85	2 (2.4)		2 (2.4)	77
Others	915	23 (2.5)	3 (0.3)	43 (4.7)	710

(), Mortality %

Table 27 Lung transplantation

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
10. Lung transplantation				
Lung transplantation from brain-dead donor	44			2 (4.5)
Bilateral lung transplantation from brain-dead donor	36	1 (2.8)		1 (2.8)
Lung transplantation from living donor	12			1 (8.3)
Total lung transplantation	92	1 (1.1)		4 (4.3)
Donor of living donor lung transplantation	23			

(), Mortality %

Table 28 Video-assisted thoracic surgery

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
11. Video-assisted thoracic surgery	77,059	221 (0.3)	78 (0.1)	455 (0.6)

(), Mortality % (including thoracic sympathectomy 160)

Table 29 Tracheobronchoplasty

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
12. Tracheobronchoplasty	787	13 (1.7)	6 (0.8)	21 (2.7)
Trachea	52	1 (1.9)	1 (1.9)	2 (3.8)
Sleeve resection with reconstruction	37	0	1 (2.7)	1 (2.7)
Wedge with simple closure	6	0	0	0
Wedge with patch closure	0	0	0	0
Total laryngectomy with tracheostomy	0	0	0	0
Others	9	1 (11.1)	0	1 (11.1)
Carinal reconstruction	23	2 (8.7)	0	2 (8.7)
Sleeve pneumonectomy	5	0	0	0
Sleeve lobectomy	486	6 (1.2)	3 (0.6)	7 (1.4)
Sleeve segmental excision	25	0	0	0
Bronchoplasty without lung resection	22	0	0	1 (4.5)
Others	174	4 (2.3)	2 (1.1)	9 (5.2)

(), Mortality %

Table 30 Pediatric surgery

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
13. Pediatric surgery	341	7 (2.1)		9 (2.6)

(), Mortality %

Table 31 Combined resection of neighboring organ(s)

Organ resected	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
14. Combined resection of neighboring organ(s)	1355	3 (0.2)		15 (1.1)

Organ resected	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
A. Primary lung cancer				
Aorta	10			
Superior vena cava	22	1 (4.5)		2 (9.1)
Brachiocephalic vein	4			
Pericardium	82	1 (1.2)		2 (2.4)
Pulmonary artery	124	3 (2.4)		4 (3.2)
Left atrium	19			
Diaphragm	65			1 (1.5)
Chest wall (including ribs)	327			5 (1.5)
Vertebra	12			
Esophagus	3			
Total	668	5 (0.7)	0	14 (2.1)
B. Mediastinal tumor				
Aorta	2	0	0	2 (100.0)
Superior vena cava	56	0	0	1 (1.8)
Brachiocephalic vein	121	0	0	1 (0.8)
Pericardium	345	0	0	2 (0.6)
Pulmonary artery	6	0	0	1 (16.7)
Left atrium	1	0	0	0
Diaphragm	39	0	0	0
Chest wall (including ribs)	10	0	0	0
Vertebra	11	0	0	0
Esophagus	4	0	0	0
Lung	510	0	0	2 (0.4)
Total	1105	0	0	9 (0.8)

(), Mortality %

Table 32 Operation of lung cancer invading the chest wall of the apex

	Cases	30-Day mortality		Hospital mortality
		Hospital	After discharge	
15. Operation of lung cancer invading the chest wall of the apex	782	3 (0.4)	1 (0.1)	11 (1.4)

(), Mortality %

Includes tumors invading the anterior apical chest wall and posterior apical chest wall (superior sulcus tumor, so called Pancoast type)

A total of 92 lung transplantations were performed in 2019 (Table 27), among which 80 and 12 were from brain-dead and living-related donors, respectively.

The number of VATS procedures has continued to increase annually, ultimately reaching 77,059 (84% of all general thoracic surgeries) in 2019 (Table 28).

Tables 29, 30, 31, 32 present the details regarding tracheobronchoplasty, pediatric surgery, and combined resection of neighboring organs.

(C) Esophageal surgery

In 2018, the data collection method for esophageal surgery had been modified from self-reports using questionnaire sheets following each institution belonging to the Japanese Association for Thoracic Surgery to an automatic package downloaded from the NCD in Japan. Consequently, the registry excluded data for non-surgical cases with esophageal diseases. Furthermore, data regarding the histological classification of malignant tumors, multiple primary cancers, and mortality rates for cases with combined resection of other organs could not be registered because they were not included in the NCD. Instead, detailed data regarding postoperative surgical and non-surgical complications were collected from the NCD. Moreover, data regarding surgeries for corrosive esophageal strictures and salvage surgeries for esophageal cancer had been exceptionally registered by participating institutions.

Throughout 2019, 7235 patients underwent surgery for esophageal diseases (1074 and 6161 for benign and malignant esophageal diseases, respectively) from 499 institutions across Japan. Among them, 296 (59.3%) and 379 (76.0%) institutions performed surgeries for benign and malignant esophageal diseases, respectively. Among 379 institutions performing surgeries for malignant esophageal diseases, 53 (14.0%) had ≥ 30 patients, while 299 (78.9%) had < 20 patients (i.e., 1–19 patients) who underwent esophageal surgeries within 2019 (Table 33). This distribution was different from that in 2018 (10.4% and 87.3%,

Table 33 Distribution of number of esophageal operations in 2019 in each institution

Esophageal surgery			
Number of operations in 2019	Benign esophageal diseases	Malignant Esophageal disease	Benign+ Malignant
0	203	120	85
1–4	240	139	145
5–9	42	77	82
10–19	9	83	84
20–29	1	27	44
30–39	0	18	14
40–49	2	9	13
≥ 50	2	26	32
Total	499	499	499

respectively), suggesting that hospital centralization for esophagectomy might be gradually proceeding in Japan. Annual trends among registered in-patients with benign or malignant esophageal diseases have remained unchanged for the past 6 years (Fig. 3).

Concerning benign esophageal diseases (Table 34), thoracoscopic and/or laparoscopic surgeries were performed in 91.1% (72/79), 84.8% (451/532), 46.8% (22/47), and 44.6% (90/202) of patients with esophagitis (including esophageal ulcer), hiatal hernia, benign tumors, and achalasia, respectively. Conversely, 95.7% (134/140) of patients with spontaneous rupture of the esophagus underwent open surgery. Hospital mortality rates within 30 postoperative days were 0.8% (4/532), 5.7% (8/140), 16.7% (1/6), 1.3% (1/79), and 3.3% (1/30) for hiatal hernia, esophagus, esophagi-tracheal fistula, esophagitis, including esophageal ulcer, and corrosive stricture of the esophagus, respectively.

Fig. 3 Annual trend of in-patients with esophageal diseases

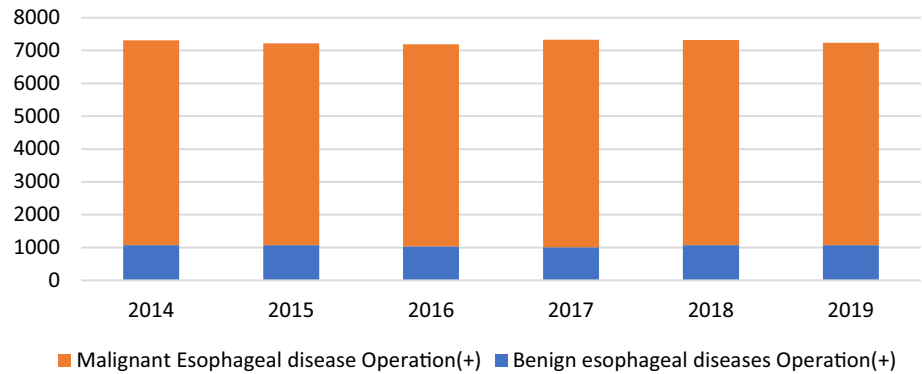


Table 34 Benign esophageal diseases

	Operation (+)				T/L*3			
	Cases	Hospital mortality			Cases	Hospital mortality		
		~30 days	31–90 days	Total (including after 91 days mortality)		~30 days	31–90 days	Total (including after 91 days mortality)
1. Achalasia	202				90			
2. Benign tumor	47				22			
3. Diverticulum	38				6			
4. Hiatal hernia	532	4 (0.8)	1 (0.2)	5 (0.9)	451	2 (0.4)		2 (0.4)
5. Spontaneous rupture of the esophagus	140	8 (5.7)	3 (2.1)	11 (7.9)	6			
6. Esophago-tracheal fistula	6	1 (16.7)		1 (16.7)	1	1 (100.0)		1 (100.0)
7. Esophagitis, Esophageal ulcer	79	1 (1.3)	1 (1.3)	2 (2.5)	72	1 (1.4)	1 (1.4)	2 (2.8)
8. Corrosive stricture of the esophagus	30	1 (3.3)	1 (3.3)	2 (6.7)	18			
Total	1074	15 (1.4)	6 (0.6)	21 (2.0)	666	4 (0.6)	1 (0.2)	5 (0.8)

(), Mortality %

T/L Thoracoscopic and/or laparoscopic

Table 35 Malignant esophageal disease

Location	Operation (+)				Thorascopic and/or laparoscopic procedure			
	Cases		Hospital mortality		Cases		Hospital mortality	
	~30 days	31–90 days	Total (including after 91 days mortality)	Total (including after 91 days mortality)	Conversion to thoracotomy	~30 days	31–90 days	Total (including after 91 days mortality)
(1) Cervical esophagus	155	3 (1.9)	3 (1.9)	3 (1.9)	57	28 (0.7)	26 (0.6)	54 (1.3)
(2) Thoracic esophagus	5142	38 (0.7)	74 (1.4)	74 (1.4)	4145	39 (0.9)	1 (0.3)	6 (1.7)
(3) Abdominal esophagus	508	6 (1.2)	4 (0.8)	10 (2.0)	350	5 (1.4)	33 (0.7)	27 (0.6)
Total	5805	44 (0.8)	87 (1.5)	87 (1.5)	4552	39 (0.9)	4 (0.3)	9 (0.6)
Tumor depth								
(A) Superficial cancer (T1)								
(1) Transhiatal esophagectomy	13				0			
(2) Mediastinoscopic esophagectomy and reconstruction	126				126			
(3) Transthoracic (rt.) esophagectomy and reconstruction	1659	5 (0.3)	5 (0.3)	10 (0.6)	1409	6 (0.4)	4 (0.3)	9 (0.6)
(4) Transthoracic (lt.) esophagectomy and reconstruction	29				14			
(5) Cervical esophageal resection and reconstruction	26				0			
(6) Robot-assisted esophagectomy and reconstruction	295	2 (0.7)	2 (0.7)	2 (0.7)	294	1 (0.3)	2 (0.7)	2 (0.7)
(7) Others	19				0			
(8) Esophagectomy without reconstruction	233				0			
Subtotal	2400	7 (0.3)	5 (0.2)	12 (0.5)	1843	7 (0.4)	6 (0.3)	11 (0.6)
(B) Advanced cancer (T2–T4)								
(1) Transhiatal esophagectomy	21	1 (4.8)	2 (9.5)	3 (14.3)	0			
(2) Mediastinoscopic esophagectomy and reconstruction	112	1 (0.9)	2 (1.8)	3 (2.7)	112	1 (0.9)	2 (1.8)	3 (2.7)
(3) Transthoracic (rt.) esophagectomy and reconstruction	2910	30 (1.0)	26 (0.9)	56 (1.9)	2178	27 (1.2)	22 (1.0)	37 (1.7)
(4) Transthoracic (lt.) esophagectomy and reconstruction	74	1 (1.4)	1 (1.4)	2 (2.7)	23	1 (4.3)	1 (4.3)	1 (4.3)
(5) Cervical esophageal resection and reconstruction	68				0			
(6) Robot-assisted esophagectomy and reconstruction	374	2 (0.5)	4 (1.1)	6 (1.6)	374	4 (1.1)	2 (0.5)	6 (1.6)
(7) Others	59	1 (1.7)	1 (1.7)	2 (3.4)	0			

Table 35 (continued)

Location	Operation (+)		Thoracoscopic and/or laparoscopic procedure							
	Cases		Cases			Hospital mortality				
	~30 days	31–90 days	~30 days	Conversion to thoracotomy	31–90 days	Total (including after 91 days mortality)				
(8) Esophagectomy without reconstruction	143	4 (2.8)	6 (4.2)	10 (7.0)	0					
Subtotal	3761	40 (1.1)	42 (1.1)	82 (2.2)	2687	31 (1.2)	26 (1.0)	21 (0.8)	47 (1.7)	
Total	6161	47 (0.8)	47 (0.8)	94 (1.5)	4530	38 (0.8)	32 (0.7)	26(0.6)	58 (1.3)	
		Cases	Overall morbidity	Morbidity ≥CD III	Surgical complications					
					Superficial incision	Deep incision	Organ space	Anastomotic leakage	Recurrent nerve palsy	Wound dehiscence
Tumor depth										
(A) Superficial cancer (T1)										
(1) Transhiatal esophagectomy	13	9 (69.2)	7 (53.8)	3 (23.1)	2 (15.4)	2 (15.4)	2 (15.4)	2 (15.4)	1 (7.7)	0
(2) Mediastinoscopic esophagectomy and reconstruction	126	77 (61.1)	28 (22.2)	9 (7.1)	3 (2.4)	7 (5.6)	19 (15.1)	35 (27.8)	2 (1.6)	
(3) Trans thoracic (rt.) esophagectomy and reconstruction	1659	891 (53.7)	325 (19.6)	116 (7.0)	58 (3.5)	146 (8.8)	236 (14.2)	222 (13.4)	25 (1.5)	
(4) Trans thoracic (lt.) esophagectomy and reconstruction	29	15 (51.7)	6 (20.7)	2 (6.9)	2 (6.9)	5 (17.2)	4 (13.8)	4 (13.8)	2 (6.9)	
(5) Cervical esophageal resection and reconstruction	26	19 (73.1)	10 (38.5)	1 (3.8)	2 (7.7)	1 (3.8)	2 (7.7)	2 (7.7)	6 (23.1)	1 (3.8)
(6) Robot-assisted esophagectomy and reconstruction	295	172 (58.3)	75 (25.4)	21 (7.1)	15 (5.1)	32 (10.8)	47 (15.9)	46 (15.6)	3 (1.0)	
(7) Others	19	10 (52.6)	5 (26.3)	1 (5.3)	4 (21.1)	6 (31.6)	1 (5.3)	0		
(8) Esophagectomy without reconstruction	233	34 (14.6)	9 (3.9)	153 (6.4)	82 (3.4)	197 (8.2)	316 (13.2)	315 (13.1)	33 (1.4)	
Subtotal	2400	1227 (51.1)	465 (19.4)	153 (6.4)	82 (3.4)	197 (8.2)	316 (13.2)	315 (13.1)	33 (1.4)	
(B) Advanced cancer (T2–T4)										
(1) Transhiatal esophagectomy	21	12 (57.1)	9 (42.9)	7 (33.3)	5 (23.8)	2 (9.5)	3 (14.3)	1 (4.8)	2 (9.5)	
(2) Mediastinoscopic esophagectomy and reconstruction	112	74 (66.1)	27 (24.1)	11 (9.8)	4 (3.6)	8 (7.1)	27 (24.1)	24 (21.4)	2 (1.8)	
(3) Trans thoracic (rt.) esophagectomy and reconstruction	2910	1693 (58.2)	675 (23.2)	222 (7.6)	120 (4.1)	275 (9.5)	404 (13.9)	427 (14.7)	45 (1.5)	
(4) Trans thoracic (lt.) esophagectomy and reconstruction	74	40 (54.1)	18 (24.3)	6 (8.1)	3 (4.1)	3 (4.1)	7 (9.5)	4 (5.4)	3 (4.1)	

Table 35 (continued)

	Cases	Overall morbidity	Morbidity ≥CD III	Surgical complications							
				Surgical site infection				Anastomotic leakage	Recurrent nerve palsy	Wound dehiscence	
				Superficial incision	Deep incision	Organ space					
(5) Cervical esophageal resection and reconstruction	68	43 (63.2)	21 (30.9)	9 (13.2)	3 (4.4)	8 (11.8)	8 (11.8)	1 (1.5)			
(6) Robot-assisted esophagectomy and reconstruction	374	218 (58.3)	82 (21.9)	22 (5.9)	5 (1.3)	35 (9.4)	52 (13.9)	5 (1.3)			
(7) Others	59	20 (33.9)	7 (11.9)	1 (1.7)		4 (6.8)	5 (8.5)				
(8) Esophagectomy without reconstruction	143	84 (58.7)	42 (29.4)								
Subtotal	3761	2184 (58.1)	881 (23.4)	278 (7.4)	140 (3.7)	489 (13.0)	516 (13.7)	58 (1.5)			
Total	6161	3411 (55.4)	1346 (21.8)	431 (7.0)	222 (3.6)	805 (13.1)	831 (13.5)	91 (1.5)			

Cases Nonsurgical complications												
Location	Cases	Pneumonia	Unplanned intubation	Prolonged ventilation>48h	Pulmonary embolism	Atelectasis	Renal failure	CNS events	Cardiac events	Septic shock	Readmission within 30d	Reoperation within 30d
(2) Thoracic esophagus	5142	815 (15.8)	246 (4.8)	333 (6.5)	42 (0.8)	272 (5.3)	20 (0.4)	29 (0.6)	18 (0.4)	33 (0.6)	125 (2.4)	334 (6.5)
(3) Abdominal esophagus	508	63 (12.4)	19 (3.7)	23 (4.5)	11 (2.2)	25 (4.9)	6 (1.2)	1 (0.2)	3 (0.6)	8 (1.6)	11 (2.2)	32 (6.3)
Total	5805	900 (15.5)	275 (4.7)	373 (6.4)	54 (0.9)	303 (5.2)	28 (0.5)	31 (0.5)	22 (0.4)	43 (0.7)	137 (2.4)	389 (6.7)

Tumor depth												
(A) Superficial cancer (T1)	13	2 (15.4)	3 (23.1)	3 (23.1)		1 (7.7)						2 (15.4)
(2) Mediastinoscopic esophagectomy and reconstruction	126	19 (15.1)	5 (4.0)	7 (5.6)		7 (5.6)						4 (3.2)
(3) Trans thoracic (tt) esophagectomy and reconstruction	1659	214 (12.9)	61 (3.7)	84 (5.1)	16 (1.0)	89 (5.4)	7 (0.4)	6 (0.4)	7 (0.4)	7 (0.4)	44 (2.7)	97 (5.8)
(4) Trans thoracic (lt) esophagectomy and reconstruction	29	3 (10.3)	2 (6.9)	2 (6.9)		3 (10.3)		1 (3.4)		1 (3.4)		3 (10.3)
(5) Cervical esophageal resection and reconstruction	26	4 (15.4)	2 (7.7)	3 (11.5)		1 (3.8)				1 (3.8)		5 (19.2)
(6) Robot-assisted esophagectomy and reconstruction	295	41 (13.9)	16 (5.4)	17 (5.8)	5 (1.7)	10 (3.4)	1 (0.3)	2 (0.7)	2 (0.7)	2 (0.7)	4 (1.4)	16 (5.4)
(7) Others	19	1 (5.3)		2 (10.5)		2 (10.5)					1 (5.3)	3 (15.8)
(8) Esophagectomy without reconstruction	233										3 (1.3)	

Table 35 (continued)

Cases	Nonsurgical complications										
	Pneumonia	Unplanned intubation	Prolonged ventilation>48h	Pulmonary embolism	Atelectasis	Renal failure	CNS events	Cardiac events	Septic shock	Readmission within 30d	Reoperation within 30d
Subtotal	2400	284 (11.8)	89 (3.7)	118 (4.9)	21 (0.9)	113 (4.7)	9 (0.4)	7 (0.3)	11 (0.5)	52 (2.2)	130 (5.4)
(B) Advanced cancer(T2-T4)											
(1) Transhiatal esophagectomy	21	7 (33.3)	3 (14.3)	4 (19.0)		1 (4.8)	1 (4.8)			1 (4.8)	2 (9.5)
(2) Mediastinosopic esophagectomy and reconstruction	112	21 (18.8)	8 (7.1)	7 (6.3)		5 (4.5)		2 (1.8)	1 (0.9)	1 (0.9)	7 (6.3)
(3) Trans thoracic (rt.) esophagectomy and reconstruction	2910	487 (16.7)	146 (5.0)	210 (7.2)	25 (0.9)	155 (5.3)	17 (0.6)	11 (0.4)	22 (0.8)	71 (2.4)	200 (6.9)
(4) Trans thoracic (lt.) esophagectomy and reconstruction	74	11 (14.9)	3 (4.1)	6 (8.1)		6 (8.1)	1 (1.4)			2 (2.7)	8 (10.8)
(5) Cervical esophageal resection and reconstruction	68	9 (13.2)	2 (2.9)	6 (8.8)		2 (2.9)	1 (1.5)	1 (1.5)	1 (1.5)	1 (1.5)	10 (14.7)
(6) Robot-assisted esophagectomy and reconstruction	374	72 (19.3)	18 (4.8)	18 (4.8)	8 (2.1)	19 (5.1)	2 (0.5)	2 (0.5)	6 (1.6)	11 (2.9)	27 (7.2)
(7) Others	59	2 (3.4)	3 (5.1)	2 (3.4)		1 (1.7)		1 (1.7)		1 (1.7)	4 (6.8)
(8) Esophagectomy without reconstruction	143									6 (4.2)	
Subtotal	3761	609 (16.2)	183 (4.9)	253 (6.7)	33 (0.9)	189 (5.0)	19 (0.5)	15 (0.4)	30 (0.8)	94 (2.5)	258 (6.9)
Total	6161	893 (14.5)	272 (4.4)	371 (6.0)	54 (0.9)	302 (4.9)	28 (0.5)	22 (0.4)	41 (0.7)	146 (2.4)	388 (6.3)

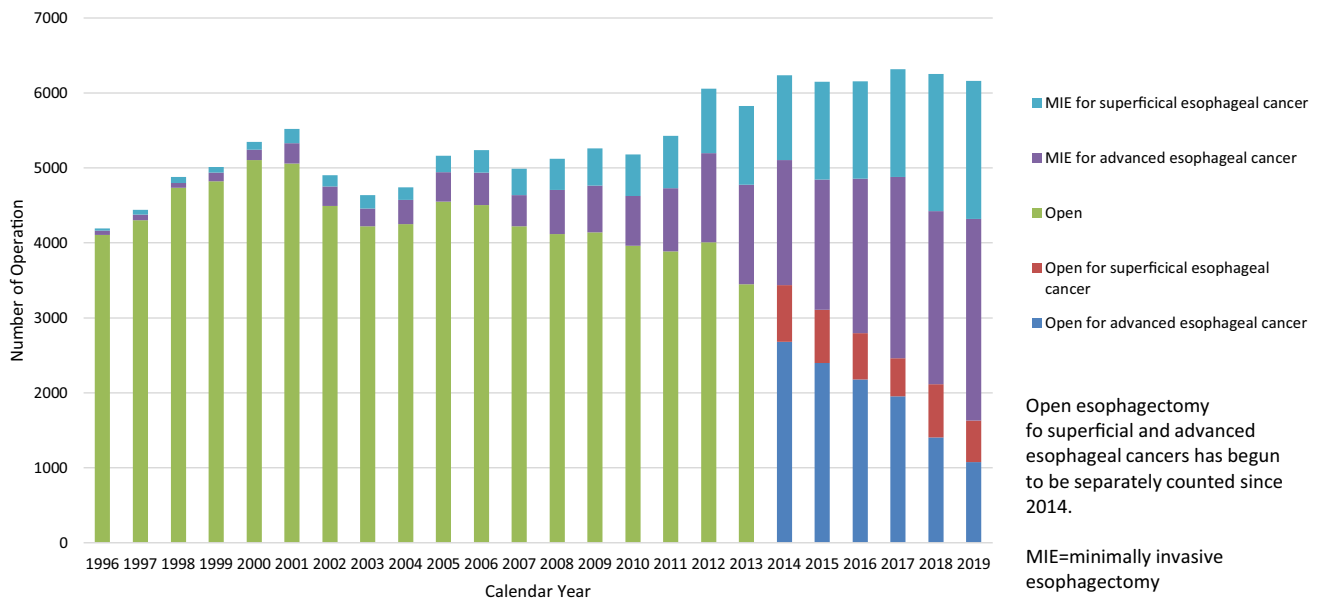


Fig. 4 Annual trend of esophagectomy

Table 36 Salvage surgery

	Operation (+)			Thoracoscopic and/or laparoscopic procedure			EMR or ESD			
	Cases	Hospital mortality		Cases	Conversion to thoracotomy	Hospital mortality				
		~ 30 days	31–90 days			Total (including after 91 days mortality)		~ 30 days	31–90 days	Total (including after 91 days mortality)
Salvage surgery	500	4 (0.8)	6 (1.2)	10 (2.0)	329	14 (4.3)	2 (0.6)	4 (1.2)	6 (1.8)	148

The most common tumor location for malignant esophageal diseases was the thoracic esophagus (Table 35). Among 6161 cases with esophageal malignancies, esophagectomy for superficial and advanced cancers was performed in 2400 (39.0%) and 3761 (61.0%), respectively. Hospital mortality rates within 30 days after esophagectomy were 0.3% and 1.1% for patients with superficial and advanced cancer, respectively.

Among esophagectomy procedures, transthoracic esophagectomy via right thoracotomy or right thoracoscopy was most commonly adopted for patients with superficial (1659/2400, 69.1%) and advanced cancer (2910/3761, 77.4%) (Table 35). Transhiatal esophagectomy, which is commonly performed in Western countries, was adopted in only 13 (0.5%) and 21 (0.6%) patients with superficial and advanced cancer who underwent esophagectomy in Japan, respectively. Thoracoscopic and/or laparoscopic esophagectomy was utilized in 1843 (76.8%) and 2687

(71.4%) patients with superficial and advanced cancer, respectively. Patients who underwent thoracoscopic and/or laparoscopic surgery (minimally invasive esophagectomy: MIE) for superficial or advanced cancer have been increasing, whereas that of open surgery, especially for advanced cancer, has been decreasing annually (Fig. 4). Mediastinoscopic esophagectomy was performed for 126 (5.3%) and 112 (3.0%) patients with superficial and advanced esophageal cancer, respectively. Robot-assisted esophagectomy was performed for 295 (12.3%) and 374 (9.9%) patients with superficial and advanced esophageal cancer, respectively. Patients who underwent robot-assisted surgery are increasing for both superficial and advanced esophageal cancers compared to that in 2018 (6.8% and 4.2% in 2018, respectively). Hospital mortality rates within 30 days after thoracoscopic and/or laparoscopic esophagectomy were 0.3% and 1.0% for patients with superficial and advanced cancer, respectively (Table 35).

Detailed data collection regarding postoperative surgical and non-surgical complications was initiated in 2018. Overall, 1346 (21.8%) of 6161 patients developed grade III or higher complications based on the Clavien–Dindo classification in 2019. Among surgical complications, anastomotic leakage and recurrent nerve palsy occurred in 14.0% and 14.3% of the patients who underwent right transthoracic esophagectomy, in 12.3% and 14.6% of those who underwent robot-assisted esophagectomy, and in 19.7% and 24.8% of those who underwent mediastinoscopic esophagectomy, respectively. Among non-surgical postoperative complications, pneumonia occurred in 14.5% of the patients, 4.4% of whom underwent unplanned intubation. The possible advantage in postoperative pneumonia in patients with mediastinoscopic esophagectomy in 2018 was not observed this year. Postoperative pulmonary embolism occurred in 0.9% of the patients. These complication rates, including the others, were similar to those in 2018.

Salvage surgery following definitive (chemo)radiotherapy was performed in 500 patients, with hospital mortality rates of 0.8% within 30 days postoperatively. Thoracoscopic and/or laparoscopic esophagectomy were performed in 329 (65.8%) patients (47.7% in 2018) (Table 36).

We aim to continue our efforts in collecting comprehensive survey data through more active collaboration with the Japan Esophageal Society and other related institutions.

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Declarations

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