



Thoracic and cardiovascular surgeries in Japan during 2020

Annual report by the Japanese Association for Thoracic Surgery

Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery¹ · Goro Matsumiya² · Yukio Sato³ · Hiroya Takeuchi⁴ · Tomonobu Abe⁵ · Shunsuke Endo⁶ · Yasutaka Hirata⁷ · Michiko Ishida⁸ · Hisashi Iwata⁹ · Takashi Kamei¹⁰ · Nobuyoshi Kawaharada¹¹ · Shunsuke Kawamoto¹² · Kohji Kohno¹³ · Hiraku Kumamaru¹⁴ · Kenji Minatoya¹⁵ · Noboru Motomura¹⁶ · Rie Nakahara¹⁷ · Morihito Okada¹⁸ · Hisashi Saji¹⁹ · Aya Saito²⁰ · Hideyuki Shimizu²¹ · Kenji Suzuki²² · Hirofumi Takemura²³ · Tsuyoshi Taketani²⁴ · Yasushi Toh²⁵ · Wataru Tatsuishi⁵ · Hiroyuki Yamamoto¹⁴ · Takushi Yasuda²⁶ · Masayuki Watanabe²⁷ · Naoki Yoshimura²⁸ · Masanori Tsuchida²⁹ · Yoshiki Sawa³⁰

Received: 11 September 2023 / Accepted: 11 September 2023 / Published online: 28 November 2023
© The Author(s) 2023

Keywords Japan Cardiovascular Surgery Database (JCVSD) · National Clinical Database (NCD) · Annual report in Japan · Cardiovascular surgery · General thoracic surgery · Esophageal surgery

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 2020. 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.

Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), the causative pathogen for the coronavirus disease 2019 (COVID-19), first emerged in Wuhan, China, in December 2019 and by March 2020, it was declared a pandemic [1]. The pandemic of SARS-CoV-2 resulted in a global healthcare and financial crisis. There was a significant estimated reduction in national case volume of cardiac surgeries and the cumulative backlog of patients in the United State [2]. We have to estimate the nationwide effect of SARS-CoV-2 pandemic on cardiovascular, general thoracic, and esophageal surgeries in Japan, with surgical volume, outcomes and patient data for each group.

Goro Matsumiya, Yukio Sato, Hiroya Takeuchi, and Naoki Yoshimura contributed equally to this work.

Annual report by the Japanese Association for Thoracic Surgery: Committee for Scientific Affairs.

Extended author information available on the last page of the article

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.

Final report: 2020

(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 34 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 64,075 cardiovascular surgeries, including 54 heart transplants, had been performed in 2020, with a 9.5%

decrease compared to that in 2019 ($n=70,769$). For the first time since the beginning of data collection, except for the year 2015 when there was a decrease due to a change in data collection and aggregation methods, a decline in the number of cases has been observed. Although the impact of the COVID-19 pandemic is suggested, this will be reported separately.

Compared to data for 2019 [3] and 2010 [4], data for 2020 showed 4.6% (8595 vs. 9006) and 10.1% fewer surgeries for congenital heart disease, 21.3% (18,366 vs. 23,340) fewer and 1.9% fewer surgeries for valvular heart disease, 8.6% (11,524 vs. 12,603) and 31.9% fewer surgeries for ischemic heart procedures, and 0.7% (22,540 vs. 22,708) fewer and 77.3% more surgeries for thoracic aortic aneurysm, respectively. Data for individual categories are summarized in Tables 1, 2, 3, 4, 5, 6.

Among the 8595 procedures for congenital heart disease conducted in 2020, 6543 were open-heart surgeries, with an overall hospital mortality rate of 2.0%. The number of surgeries for neonates and infants in 2020 did not significantly differ compared to that in 2010; however, hospital mortality improved from 11.5 to 8.2% for neonates and from 3.0 to 2.1% for infants. In 2020, atrial septal defect was the most common disease (1188 cases) as previously reported, with patients aged ≥ 18 years accounting for 63% 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 (1043 cases).

Hospital mortality for complex congenital heart disease within the past 10 years was as follows (2010 [4], 2015 [5], and 2020): complete atrioventricular septal defect (4.2%, 5.4%, and 2.2%); tetralogy of Fallot (0.8%, 2.1%, and 0.8%); transposition of the great arteries with the intact septum (4.1%, 7.1%, and 0%), ventricular septal defect (7.4%, 7.1%, and 0%), and single ventricle (7.5%, 3.9%,

Fig. 1 Annual trend of cardiovascular surgery

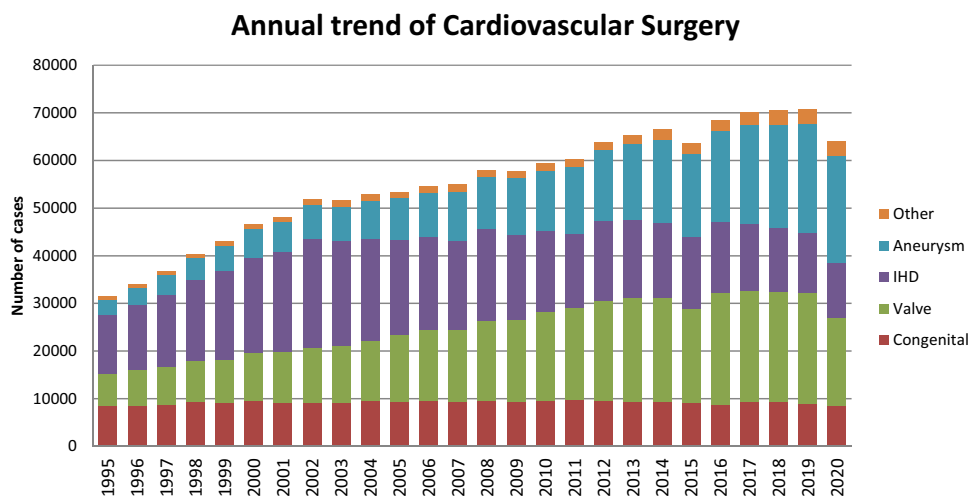


Table 1 Congenital (total; 8595)
(1) CPB (+) (total; 6543)

| | Neonate | | | | Infant | | | | 1–17 years | | | | ≥ 18 years | | | | Total | | | |
|-------------------------------|------------------|-----------------|--------------------|-------|------------------|-----------------|--------------------|----------|------------------|-----------------|--------------------|----------|------------------|-----------------|--------------------|----------|------------------|-----------------|--------------------|-------|
| | 30-Day mortality | | Hospital mortality | Cases | 30-Day mortality | | Hospital mortality | Cases | 30-Day mortality | | Hospital mortality | Cases | 30-Day mortality | | Hospital mortality | Cases | 30-Day mortality | | Hospital mortality | Cases |
| | Hospital | After discharge | | | Hospital | After discharge | | | Hospital | After discharge | | | Hospital | After discharge | | | Hospital | After discharge | | |
| PDA | 2 | 0 | 0 | 4 | 0 | 0 | 2 | 0 | 0 | 1 (50.0) | 16 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 1 (4.2) | |
| Coarctation (simple) | 10 | 0 | 0 | 13 | 0 | 0 | 9 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 47 | 0 | 0 | 0 | 0 | |
| + VSD | 57 | 1 (1.8) | 3 (5.3) | 45 | 1 (2.2) | 2 (4.4) | 19 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 123 | 2 (1.6) | 0 | 0 | 5 (4.1) | |
| + DORV | 4 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | |
| + AVSD | 5 | 0 | 0 | 7 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | |
| + TGA | 2 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | |
| + SV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| + Others | 7 | 0 | 0 | 8 | 0 | 1 (12.5) | 4 | 0 | 0 | 1 (25.0) | 1 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 2 (10.0) | |
| Interrupt. of Ao (simple) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| + VSD | 13 | 0 | 0 | 19 | 1 (5.3) | 1 (5.3) | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 | 1 (2.0) | 0 | 0 | 1 (2.0) | |
| + DORV | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | |
| + Tumors | 1 | 0 | 0 | 5 | 1 (20.0) | 1 (20.0) | 3 | 1 (33.3) | 0 | 1 (33.3) | 0 | 0 | 0 | 0 | 9 | 2 (22.2) | 0 | 0 | 2 (22.2) | |
| + TGA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| + Others | 3 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | |
| Vascular ring | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | |
| PS | 2 | 0 | 0 | 23 | 0 | 0 | 78 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 120 | 0 | 0 | 0 | 0 | |
| PA-IVS or critical PS | 15 | 0 | 0 | 56 | 1 (1.8) | 1 (1.8) | 57 | 0 | 0 | 2 (3.5) | 5 | 0 | 0 | 0 | 133 | 1 (0.8) | 0 | 0 | 3 (2.3) | |
| TAPVR | 109 | 2 (1.8) | 8 (7.3) | 52 | 2 (3.8) | 3 (5.8) | 17 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 180 | 4 (2.2) | 0 | 0 | 11 (6.1) | |
| PAPVR±ASD | 0 | 0 | 0 | 3 | 0 | 0 | 43 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 55 | 0 | 0 | 0 | 0 | |
| ASD | 1 | 0 | 0 | 40 | 0 | 0 | 398 | 0 | 0 | 0 | 749 | 8 (1.1) | 0 | 8 (1.1) | 1188 | 8 (0.7) | 0 | 0 | 8 (0.7) | |
| Cor triatriatum | 2 | 0 | 0 | 6 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | |
| AVSD (partial) | 3 | 1 (33.3) | 1 (33.3) | 8 | 0 | 0 | 34 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 54 | 1 (1.9) | 0 | 0 | 1 (1.9) | |
| AVSD (complete) | 6 | 0 | 1 (16.7) | 101 | 1 (1.0) | 1 (1.0) | 115 | 1 (0.9) | 0 | 3 (2.6) | 4 | 0 | 0 | 0 | 226 | 2 (0.9) | 0 | 0 | 5 (2.2) | |
| + TOF or DORV | 0 | 0 | 0 | 6 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | |
| + Others | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| VSD (subarterial) | 2 | 0 | 0 | 98 | 0 | 0 | 144 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 253 | 0 | 0 | 0 | 0 | |
| VSD (perimemb./muscular) | 13 | 0 | 0 | 675 | 1 (0.1) | 2 (0.3) | 329 | 0 | 0 | 0 | 26 | 1 (3.8) | 0 | 1 (3.8) | 1043 | 2 (0.2) | 0 | 0 | 3 (0.3) | |
| VSD (type unknown) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 105 | 1 (1.0) | 0 | 1 (1.0) | 105 | 1 (1.0) | 0 | 0 | 1 (1.0) | |
| VSD±PS | 0 | 0 | 0 | 33 | 0 | 0 | 16 | 0 | 0 | 0 | 2 | 1 (50.0) | 0 | 1 (50.0) | 51 | 1 (2.0) | 0 | 0 | 1 (2.0) | |
| DCRV±VSD | 0 | 0 | 0 | 8 | 0 | 0 | 27 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | |
| Aneurysm of sinus of Valsalva | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | |
| TOF | 7 | 0 | 0 | 156 | 0 | 1 (0.6) | 156 | 0 | 0 | 0 | 45 | 1 (2.2) | 0 | 2 (4.4) | 364 | 1 (0.3) | 0 | 0 | 3 (0.8) | |

Table 1 (continued)

| | Neonate | | | Infant | | | 1–17 years | | | ≥ 18 years | | | Total | | | | | |
|----------------------------------|------------------|-----------------|--------------------|------------------|-----------------|--------------------|------------------|-----------------|--------------------|------------------|-----------------|--------------------|------------------|-----------------|--------------------|----------|---------|-----------|
| | 30-Day mortality | | Hospital mortality | 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 | | Hospital | After discharge | | | | |
| PA+VSD | 8 | 0 | 1 (12.5) | 76 | 2 (2.6) | 3 (3.9) | 108 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 203 | 2 (1.0) | 0 | 4 (2.0) |
| DORV | 14 | 0 | 0 | 111 | 1 (0.9) | 3 (2.7) | 160 | 2 (1.3) | 0 | 2 (1.3) | 0 | 7 | 0 | 0 | 292 | 3 (1.0) | 0 | 5 (1.7) |
| TGA (simple) | 89 | 0 | 1 (1.1) | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 102 | 0 | 1 (1.0) | 0 |
| +VSD | 32 | 0 | 0 | 12 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 51 | 0 | 0 | 0 |
| VSD+PS | 0 | 0 | 0 | 33 | 0 | 0 | 16 | 0 | 0 | 0 | 1 (50.0) | 2 | 1 (50.0) | 0 | 51 | 1 (2.0) | 0 | 1 (2.0) |
| Corrected TGA | 3 | 0 | 0 | 13 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 53 | 0 | 0 | 0 |
| Truncus arteriosus | 11 | 1 (9.1) | 1 (9.1) | 18 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 56 | 1 (1.8) | 0 | 1 (1.8) |
| SV | 30 | 4 (13.3) | 10 (33.3) | 167 | 7 (4.2) | 12 (7.2) | 176 | 1 (0.6) | 0 | 1 (0.6) | 0 | 20 | 0 | 0 | 393 | 12 (3.1) | 0 | 23 (5.9) |
| TA | 3 | 0 | 0 | 30 | 1 (3.3) | 1 (3.3) | 49 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 84 | 1 (1.2) | 0 | 1 (1.2) |
| HLHS | 38 | 4 (10.5) | 13 (34.2) | 119 | 5 (4.2) | 7 (5.9) | 78 | 2 (2.6) | 0 | 2 (2.6) | 0 | 1 | 0 | 0 | 236 | 11 (4.7) | 0 | 22 (9.3) |
| Aortic valve lesion | 3 | 0 | 0 | 13 | 0 | 0 | 102 | 0 | 0 | 1 (1.0) | 0 | 29 | 0 | 0 | 147 | 0 | 0 | 1 (0.7) |
| Mitral valve lesion | 1 | 0 | 0 | 37 | 1 (2.7) | 1 (2.7) | 64 | 0 | 0 | 1 (1.6) | 0 | 24 | 0 | 0 | 126 | 1 (0.8) | 0 | 4 (3.2) |
| Ebstein | 8 | 1 (12.5) | 2 (25.0) | 13 | 0 | 0 | 30 | 0 | 0 | 1 (3.3) | 0 | 7 | 0 | 0 | 58 | 1 (1.7) | 0 | 3 (5.2) |
| Coronary disease | 0 | 0 | 0 | 6 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 32 | 0 | 0 | 0 |
| Others | 7 | 1 (14.3) | 1 (14.3) | 14 | 0 | 0 | 37 | 0 | 0 | 1 (2.7) | 0 | 211 | 2 (0.9) | 0 | 269 | 3 (1.1) | 0 | 4 (1.5) |
| Conduit failure | 1 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 19 | 0 | 0 | 0 |
| Redo (excluding conduit failure) | 2 | 1 (50.0) | 1 (50.0) | 50 | 3 (6.0) | 4 (8.0) | 71 | 2 (2.8) | 0 | 3 (4.2) | 0 | 88 | 3 (3.4) | 0 | 211 | 9 (4.3) | 0 | 12 (5.7) |
| Total | 515 | 16 (3.1) | 1 (0.2) | 2093 | 28 (1.3) | 44 (2.1) | 2475 | 9 (0.4) | 0 | 20 (0.8) | 0 | 1460 | 18 (1.2) | 0 | 6543 | 71 (1.1) | 1 (0.0) | 128 (2.0) |

0, % 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, *Interrupt. of Ao.* interruption of aorta, *PS* pulmonary stenosis, *PLV/PS* pulmonary atresia with intact ventricular septum, *TA/PLV* total anomalous pulmonary venous return, *PLV/PR* partial anomalous pulmonary venous return, *ASD* atrial septal defect, *TOF* tetralogy of Fallot, *DCRV* double-chambered right ventricle, *HLHS* hypoplastic left heart syndrome, *RV-PA* right ventricle-pulmonary artery

Table 1 (continued)
(2) CPB (-) (total; 2052)

| | 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 | | | | | | |
| PDA | 291 | 7 (2.4) | 0 | 14 (4.8) | 115 | 0 | 0 | 1 (0.9) | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 420 | 7 (1.7) | 0 | 15 (3.6) |
| Coarctation (simple) | 11 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 27 | 0 | 0 | 0 |
| +VSD | 44 | 0 | 0 | 3 (6.8) | 19 | 1 (5.3) | 0 | 2 (10.5) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | 1 (1.6) | 0 | 5 (7.9) |
| +DORV | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| +AVSD | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 1 (33.3) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 1 (20.0) |
| +TGA | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| +SV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Others | 7 | 1 (14.3) | 0 | 1 (14.3) | 4 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 1 (7.1) | 0 | 1 (7.1) |
| Interrupt. of Ao (simple) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +VSD | 17 | 0 | 0 | 0 | 11 | 1 (9.1) | 0 | 1 (9.1) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 1 (3.4) | 0 | 1 (3.4) |
| +DORV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Truncus | 5 | 0 | 0 | 0 | 1 | 1 (100.0) | 0 | 1 (100.0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 (16.7) | 0 | 1 (16.7) |
| +TGA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Others | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Vascular ring | 4 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 |
| PS | 2 | 0 | 0 | 0 | 5 | 0 | 0 | 1 (20.0) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 1 (12.5) |
| PA=VSD or critical PS | 12 | 2 (16.7) | 0 | 2 (16.7) | 23 | 1 (4.3) | 0 | 1 (4.3) | 6 | 1 (16.7) | 0 | 1 (16.7) | 1 | 0 | 0 | 0 | 42 | 4 (9.5) | 0 | 4 (9.5) |
| TAPVR | 24 | 2 (8.3) | 0 | 3 (12.5) | 13 | 1 (7.7) | 0 | 2 (15.4) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 3 (8.1) | 0 | 5 (13.5) |
| PAPVR±ASD | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ASD | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 1 (100.0) | 0 | 6 | 1 (16.7) | 0 | 1 (16.7) |
| Cor triatriatum | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AVSD (partial) | 3 | 1 (33.3) | 0 | 1 (33.3) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 (25.0) | 0 | 1 (25.0) |
| AVSD (complete) | 51 | 1 (2.0) | 0 | 2 (3.9) | 75 | 2 (2.7) | 0 | 2 (2.7) | 9 | 1 (11.1) | 0 | 1 (11.1) | 0 | 0 | 0 | 0 | 135 | 4 (3.0) | 0 | 5 (3.7) |
| +TOF or DORV | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 |
| +Others | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VSD (subarterial) | 3 | 0 | 0 | 1 (33.3) | 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 1 (8.3) |
| VSD (perimemb./muscular) | 55 | 1 (1.8) | 0 | 1 (1.8) | 148 | 2 (1.4) | 0 | 2 (1.4) | 2 | 0 | 0 | 0 | 0 | 3 | 1 (33.3) | 0 | 208 | 4 (1.9) | 0 | 4 (1.9) |
| VSD (type unknown) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| VSD+PS | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| DORV±VSD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aneurysm of sinus of Valsalva | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOF | 13 | 0 | 0 | 0 | 49 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 68 | 0 | 0 | 0 |

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 | Hospital |
| PA+VSD | 7 | 0 | 0 | 44 | 1 (2.3) | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 68 | 1 (1.5) | 0 | 1 (1.5) |
| DORV | 54 | 2 (3.7) | 0 | 56 | 1 (1.8) | 0 | 11 | 0 | 0 | 1 | 1 (100.0) | 0 | 122 | 4 (3.3) | 0 | 8 (6.6) |
| TGA (simple) | 11 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 14 | 0 | 0 | 0 |
| +VSD | 9 | 1 (11.1) | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 14 | 1 (7.1) | 0 | 1 (7.1) |
| VSD+FS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Corrected TGA | 17 | 0 | 0 | 9 | 0 | 0 | 13 | 0 | 0 | 1 | 0 | 0 | 40 | 0 | 0 | 0 |
| Truncus arteriosus | 19 | 1 (5.3) | 0 | 12 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 34 | 1 (2.9) | 0 | 1 (2.9) |
| SV | 47 | 1 (2.1) | 0 | 57 | 3 (5.3) | 0 | 16 | 0 | 0 | 4 | 0 | 0 | 124 | 4 (3.2) | 0 | 10 (8.1) |
| TA | 17 | 0 | 0 | 16 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 36 | 0 | 0 | 3 (8.3) |
| HLHS | 76 | 2 (2.6) | 0 | 26 | 2 (7.7) | 0 | 12 | 1 (8.3) | 0 | 0 | 0 | 0 | 114 | 5 (4.4) | 0 | 15 (13.2) |
| Aortic valve lesion | 6 | 1 (16.7) | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 13 | 1 (7.7) | 0 | 1 (7.7) |
| Mitral valve lesion | 1 | 0 | 0 | 5 | 1 (20.0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 (16.7) | 0 | 1 (16.7) |
| Ebstein | 5 | 1 (20.0) | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 1 (14.3) | 0 | 1 (14.3) |
| Coronary disease | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Others | 6 | 0 | 0 | 13 | 2 (15.4) | 0 | 10 | 0 | 0 | 4 | 0 | 0 | 33 | 2 (6.1) | 0 | 3 (9.1) |
| Conduit failure | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Redo (excluding conduit failure) | 36 | 1 (2.8) | 0 | 118 | 9 (7.6) | 0 | 120 | 2 (1.7) | 0 | 4 | (3.3) | 0 | 300 | 16 (5.3) | 0 | 33 (11.0) |
| Total | 867 | 25 (2.9) | 0 | 868 | 28 (3.2) | 0 | 268 | 5 (1.9) | 0 | 7 (2.6) | 0 | 49 | 7 (14.3) | 0 | 0 | 124 (6.0) |

0, % mortality

CPB cardiopulmonary bypass, FDI 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, PAPVR partial anomalous pulmonary venous return, ASD atrial septal defect, TOF tetralogy of Fallot, DCRV double-chambered right ventricle, TA truncus arteriosus, HLHS hypoplastic left heart syndrome, RT-PA right ventricle-pulmonary artery

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 | Hospital | After discharge | 30-Day mortality | After discharge | Hospital | After discharge | 30-Day mortality | After discharge | Hospital | After discharge | 30-Day mortality | After discharge | Hospital | After discharge | 30-Day mortality | After discharge | Hospital | After discharge | |
| 28 Ross procedure | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 Bilateral pulmonary artery banding | 166 | 6 (3.6) | 0 | 24 (14.5) | 15 | 0 | 0 | 2 (13.3) | 1 | 0 | 0 | 0 | 0 | 182 | 6 (3.3) | 0 | 0 | 0 | 26 | (14.3) | 0 |
| Total | 759 | 23 (3.0) | 1 (0.1) | 65 (8.6) | 1613 | 31 (1.9) | 0 | 48 (3.0) | 1459 | 6 (0.4) | 0 | 13 (0.9) | 287 | 3 (1.0) | 0 | 9 (3.1) | 4118 | 63 (1.5) | 1 (0.02) | 135 (3.3) | 0 |

0, % mortality

SP systemic-pulmonary, PHB pulmonary artery banding, PA pulmonary artery, RTO right ventricular outflow tract, CA coronary artery, AV fistula arteriovenous fistula, TCPC total cavopulmonary connection, AV valve atriocentric valve, FSD ventricular septal defect, AVR aortic valve replacement

and 5.9%); and hypoplastic left heart syndrome (13.1%, 8.0%, and 9.3%). Currently, right heart bypass surgery has been commonly performed (335 bidirectional Glenn procedures, excluding 35 Damus–Kaye–Stansel procedures, and 378 Fontan type procedures, including total cavopulmonary connection) with acceptable hospital mortality rates (1.2% and 0.8%). The Norwood type I procedure was performed in 117 cases, with a relatively low hospital mortality rate (16.2%).

Valvular heart disease procedures, excluding transcatheter procedures, were performed less than that in the previous year. Isolated aortic valve replacement/repair with/without coronary artery bypass grafting (CABG) ($n=8592$) was 16.3% fewer than that in the previous year ($n=10,268$) and 0.7% fewer than that 5 years ago ($n=8651$), as opposed to the rapid increase of transcatheter aortic valve replacement ($n=9774$ in 2020). Isolated mitral valve replacement/repairs with/without CABG ($n=4471$) was 14.7% fewer than that in the previous year ($n=5239$) and 1.2% fewer than that 5 years ago ($n=4524$). Aortic and mitral valve replacement with bioprosthesis were performed in 9278 and 2376 cases, respectively. The rate at which bioprosthesis was used had dramatically increased from 30% in the early 2000s [6, 7] to 87.9% and 72.6% in 2020 for aortic and mitral positions, respectively. Additionally, CABG was performed concurrently in 18.6% of all valvular procedures (17.8% in 2010 [4] and 19.8% in 2015 [5]). Valve repair was common in mitral and tricuspid valve positions (5803 and 4033 cases, respectively) but less common in aortic valve positions (173 patients, only 1.6% of all aortic valve procedures). Mitral valve repair accounted for 63.7% of all mitral valve procedures. Hospital mortality rates for single valve replacement for aortic and mitral positions were 3.2% and 7.7%, respectively, but only 1.1% for mitral valve repair. Moreover, hospital mortality rates for redo valve surgery for the aortic and mitral positions were 7.3% and 6.3%, respectively. Finally, overall hospital mortality rates did not significantly improve over the past 10 years (3.4% in 2010 [4], 4.0% in 2015 [5], and 3.6% in 2020).

Isolated CABG had been performed in 10,311 cases, accounting for only 66.4% of the procedures performed 10 years ago ($n=15,521$) [4]. Of the aforementioned cases, 6014 (58.3%) underwent off-pump CABG, with a success rate of 98.0%. The percentage of planned off-pump CABG in 2020 was similar to that in 2019. Hospital mortality associated with primary elective CABG procedures among 8904 cases accounted for 1.7%, which is slightly higher than that in 2010 (1.1%) [4]. Hospital mortality for primary emergency CABG among 1307 cases remained high (9.2%). The percentage of conversion from off-pump to on-pump CABG or on-pump beating-heart CABG was 2.3% among the primary elective CABG cases, with a hospital mortality rate of 10.7%. Patients with end-stage renal failure

Table 2 Acquired (total, (1)+(2)+(4)+(5)+(6)+(7)+isolated operations for arrhythmia in (3); 32,509 (1) Valvular heart disease (total; 18,366)

| | Valve | Cases | Operation | | | | 30-Day mortality | | | | Redo | | | | | | | |
|----------|-------|--------|------------|---------|---------------|---------|------------------|-----------|-----------|----------|----------|-----------|-----------------|---------|--------------------|---------|-----------|---------|
| | | | Mechanical | | Bioprosthesis | | Unknown | | with CABG | | Hospital | | After discharge | | Hospital mortality | | Cases | |
| | | | Repair | Replace | Repair | Replace | Repair | Replace | Repair | Replace | Repair | Replace | Repair | Replace | Repair | Replace | Repair | Replace |
| Isolated | A | 8592 | 949 | 7465 | 125 | 53 | 2115 | 146 (1.7) | 2 (1.6) | 2 (0.02) | 0 | 268 (3.2) | 3 (2.4) | 629 | 30 (4.8) | 0 | 46 (7.3) | |
| | M | 4471 | 414 | 849 | 3177 | 31 | 607 | 50 (4.0) | 17 (0.5) | 1 (0.08) | 1 (0.03) | 97 (7.7) | 36 (1.1) | 622 | 15 (2.4) | 0 | 39 (6.3) | |
| | T | 226 | 5 | 63 | 157 | 1 | 30 | 3 (4.4) | 5 (3.2) | 0 | 0 | 5 (7.4) | 8 (5.1) | 64 | 1 (1.6) | 0 | 4 (6.3) | |
| | P | 11 | 0 | 11 | 0 | 0 | 1 | 0 | 2 (40) | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | |
| A+M | A | 1064 | 202 | 827 | 31 | 4 | 189 | 45 (4.2) | 1 (0.09) | 1 (0.09) | 0 | 80 (7.5) | 0 | 158 | 9 (5.7) | 0 | 17 (10.8) | |
| | M | 381 | 140 | 381 | 538 | 5 | 68 | 16 (4.2) | 1 (0.3) | 1 (0.3) | 0 | 25 (6.6) | 0 | 58 | 2 (3.4) | 0 | 3 (5.2) | |
| A+T | A | 48 | 48 | 331 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | T | 0 | 0 | 0 | 371 | 10 | 292 | 48 (1.7) | 1 (0.04) | 1 (0.04) | 0 | 92 (3.3) | 1 (0.3) | 358 | 9 (2.5) | 1 (0.3) | 19 (5.3) | |
| M+T | M | 260 | 260 | 811 | 1734 | 13 | 104 | 25 (3.3) | 0 | 0 | 0 | 50 (6.6) | 1 (1.0) | 104 | 4 (3.8) | 1 (1.0) | 9 (8.7) | |
| | T | 8 | 8 | 24 | 2762 | 24 | 4 | 1 (2.1) | 0 | 0 | 0 | 1 (2.1) | 0 | 19 | 1 (5.3) | 0 | 1 (5.3) | |
| A+M+T | A | 756 | 84 | 655 | 15 | 2 | 3410 | 35% (1.9) | 7 (0.04) | 7 (0.04) | 0 | 665 (3.6) | 2 (0.1) | 2022 | 71 (3.5) | 2 (0.1) | 138 (6.8) | |
| | M | 57 | 57 | 335 | 354 | 10 | 4 | 1 (2.1) | 0 | 0 | 0 | 1 (2.1) | 0 | 19 | 1 (5.3) | 0 | 1 (5.3) | |
| | T | 0 | 0 | 10 | 743 | 3 | 3410 | 35% (1.9) | 7 (0.04) | 7 (0.04) | 0 | 665 (3.6) | 2 (0.1) | 2022 | 71 (3.5) | 2 (0.1) | 138 (6.8) | |
| Others | | 47 | | | | | | | | | | | | | | | | |
| Total | | 18,366 | | | | | | | | | | | | | | | | |

| | Cases | 30-Day mortality |
|------|-------|------------------|
| TAVR | 9774 | 99 (1.0) |

Table 2 (continued)

(2) Ischemic heart disease (total, (A)+(B); 11,524)

(A) Isolated CABG (total; (a)+(b); 10,311)

(a-1) On-pump arrest CABG (total; 2263)

| | Primary, elective | | | Primary, emergent | | | Redo, elective | | | Redo, emergent | | | Artery only | Artery + svg | svg only | Others | Unclear | |
|-------------|-------------------|------------------|-----------------|-------------------|--------------------|-----------------|----------------|--------------------|-----------------|----------------|--------------------|-----------------|-------------|--------------|----------|--------|---------|--------------------|
| | Cases | 30 day mortality | | Cases | 30 day mortality | | Cases | 30 day mortality | | Cases | 30 day mortality | | | | | | | |
| | | Hospital | After discharge | | Hospital mortality | After discharge | | Hospital mortality | After discharge | | Hospital mortality | After discharge | | | | | | Hospital mortality |
| 1VD | 36 | 1 (2.8) | 0 | 12 | 2 (16.7) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 14 | 15 | 0 | 0 |
| 2VD | 257 | 4 (1.6) | 0 | 39 | 3 (7.7) | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 1 (100.0) | 34 | 235 | 30 | 1 | 0 |
| 3VD | 847 | 8 (0.9) | 0 | 80 | 2 (2.5) | 0 | 3 | 1 (33.3) | 0 | 1 | 0 | 0 | 0 | 30 | 869 | 28 | 4 | 0 |
| LMT | 792 | 15 (1.9) | 0 | 152 | 11 (7.2) | 0 | 3 | 0 | 0 | 0 | 0 | 2 | 0 | 83 | 822 | 38 | 6 | 0 |
| No info | 24 | 0 | 0 | 8 | 1 (12.5) | 0 | 1 | 1 (100.0) | 0 | 1 | 1 (100.0) | 0 | 0 | 3 | 23 | 7 | 0 | 1 |
| Total | 1956 | 28 (1.4) | 0 | 291 | 19 (6.5) | 0 | 11 | 2 (18.2) | 0 | 2 | 1 (50.0) | 0 | 2 (40.0) | 170 | 1963 | 118 | 11 | 1 |
| Kawasaki | 4 | 1 (25.0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| on dialysis | 249 | 12 (4.8) | 0 | 37 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 252 | 18 | 0 | 0 |

0, % mortality
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
LMT includes LMT alone or LMT with other branch diseases

(a-2) On-pump beating CABG (total; 2034)

| | Primary, elective | | | Primary, emergent | | | Redo, elective | | | Redo, emergent | | | Artery only | Artery + svg | svg only | Others | Unclear | |
|-------------|-------------------|------------------|-----------------|-------------------|--------------------|-----------------|----------------|--------------------|-----------------|----------------|--------------------|-----------------|-------------|--------------|----------|--------|---------|--------------------|
| | Cases | 30 day mortality | | Cases | 30 day mortality | | Cases | 30 day mortality | | Cases | 30 day mortality | | | | | | | |
| | | Hospital | After discharge | | Hospital mortality | After discharge | | Hospital mortality | After discharge | | Hospital mortality | After discharge | | | | | | Hospital mortality |
| 1VD | 30 | 1 (3.3) | 0 | 9 | 1 (11.1) | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 14 | 10 | 0 | 0 |
| 2VD | 211 | 3 (1.4) | 0 | 36 | 4 (11.1) | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 172 | 18 | 3 | 0 |
| 3VD | 679 | 13 (1.9) | 0 | 133 | 14 (10.5) | 0 | 9 | 0 | 0 | 1 | 1 (11.1) | 0 | 0 | 93 | 697 | 26 | 6 | 0 |
| LMT | 664 | 14 (2.1) | 1 | 212 | 15 (7.1) | 0 | 11 | 1 (9.1) | 0 | 2 | 1 (18.2) | 0 | 3 (75.0) | 154 | 701 | 34 | 2 | 0 |
| No info | 21 | 0 (0.0) | 0 | 6 | 3 (50.0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 11 | 8 | 2 | 0 |
| Total | 1605 | 31 (1.9) | 1 | 396 | 37 (9.3) | 0 (0.0) | 24 | 1 (4.2) | 0 | 3 | 12 (5) | 0 | 4 (44.4) | 330 | 1595 | 96 | 13 | 0 |
| Kawasaki | 6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 0 |
| on dialysis | 246 | 18 (7.3) | 0 | 54 | 14 (25.9) | 0 (0.0) | 5 | 0 (0.0) | 0 | 2 | 1 (50.0) | 0 | 3 (75.0) | 33 | 249 | 24 | 3 | 0 |

0, % mortality
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
LMT includes LMT alone or LMT with other branch diseases

Table 2 (continued)

(b) Off-pump CABG (total: 6014)

(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 + svg | svg only | Others | Unclear |
|----------------------|-------------------|--------------------|-------------------|--------------------|----------------|--------------------|----------------|--------------------|-------------|--------------|----------|--------|---------|
| | Cases | Hospital mortality | Cases | Hospital mortality | Cases | Hospital mortality | Cases | Hospital mortality | | | | | |
| 1VD | 340 | 0 (0.0) | 28 | 3 (10.7) | 5 | 0 | 0 | 0 | 256 | 76 | 41 | 0 | 1 |
| 2VD | 836 | 2 (0.2) | 63 | 1 (1.6) | 6 | 0 | 0 | 0 | 301 | 579 | 21 | 3 | 1 |
| 3VD | 2151 | 18 (0.8) | 182 | 5 (2.7) | 8 | 0 | 0 | 0 | 438 | 1857 | 32 | 21 | 0 |
| LMT | 1966 | 13 (0.7) | 328 | 11 (3.4) | 15 | 0 | 0 | 0 | 615 | 1641 | 43 | 11 | 2 |
| No info | 50 | 0 (0.0) | 19 | 0 | 4 | 0 | 0 | 0 | 26 | 41 | 8 | 0 | 0 |
| Total | 5543 | 33 (0.6) | 620 | 20 (3.2) | 38 | 0 | 0 | 0 | 1636 | 4194 | 145 | 35 | 4 |
| Kawasaki on dialysis | 11 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 7 | 0 | 0 | 0 |
| | 584 | 4 (0.7) | 56 | 2 (3.6) | 6 | 0 | 0 | 0 | 139 | 482 | 25 | 2 | 0 |

0, % mortality
 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
 LMT includes LMT alone or LMT with other branch diseases

(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 | Hospital mortality | Cases | Hospital mortality | Cases | Hospital mortality | Cases | Hospital mortality |
| Converted to arrest | 24 | 2 (8.3) | 3 | 12.5 | 5 | 2 (40.0) | 0 | 0 |
| Converted to beating | 97 | 6 (6.2) | 10 | 10.3 | 30 | 4 (13.3) | 0 | 0 |
| Total | 121 | 8 (6.6) | 13 | 10.7 | 35 | 6 (17.1) | 0 | 0 |
| On dialysis | 36 | 4 (11.1) | 7 | 19.4 | 5 | 1 (20.0) | 0 | 0 |

0, % mortality
 CABG coronary artery bypass grafting

Table 2 (continued)

(B) Operation for complications of MI (total: 1213)

| | Chronic | | | | Acute | | | | Concomitant operation | | | | | |
|---------------------------------|------------------|-----------------|--------------------|-----------------|------------------|-----------------|--------------------|-----------------|-----------------------|-----|-----|--|-----|--|
| | 30-Day mortality | | Hospital mortality | | 30-Day mortality | | Hospital mortality | | CABG | | MVP | | MVR | |
| | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | | | | | | |
| Infarctectomy or aneurysmectomy | 8 (6.7) | 0 | 10 (8.4) | 0 | 26 | 4 (15.4) | 7 (26.9) | 80 | 31 | 2 | | | | |
| VSP closure | 9 (10.6) | 0 | 13 (15.3) | 0 | 250 | 67 (26.8) | 87 (34.8) | 92 | 0 | 8 | | | | |
| Cardiac rupture | 12 (32.4) | 0 | 12 (32.4) | 0 | 247 | 63 (25.5) | 80 (32.4) | 46 | 3 | 9 | | | | |
| Mitral regurgitation | | | | | | | | | | | | | | |
| (1) Papillary muscle rupture | 0 | 0 | 0 | 0 | 51 | 10 (19.6) | 16 (31.4) | 26 | 4 | 56 | | | | |
| (2) Ischemic | 12 (5.9) | 0 | 24 (11.8) | 0 | 39 | 8 (20.5) | 12 (30.8) | 191 | 138 | 105 | | | | |
| Others | 1 (1.4) | 0 | 4 (5.8) | 0 | 77 | 25 (32.5) | 27 (35.1) | 51 | 8 | 5 | | | | |
| Total | 42 (8.0) | 0 | 63 (12.0) | 0 | 690 | 177 (25.7) | 229 (33.2) | 486 | 184 | 185 | | | | |

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

(3) Operation for arrhythmia (total: 6831)

| | Hospital mortality | | | | Concomitant operation | | | | | | | | | | | |
|---------------------------------|--------------------|-----------------|--------------------|-----------------|-----------------------|-----|------------|------|-------|------|-----|--|--------|--------------|----------------------|--|
| | 30-Day mortality | | Hospital mortality | | Isolated | | Congenital | | Valve | | IHD | | Others | | Multiple combination | |
| | Hospital | After discharge | Hospital | After discharge | | | | | | | | | | 2 categories | 3 categories | |
| Maze | 55 (1.5) | 1 (0.03) | 104 (2.8) | 0 | 204 | 158 | 3126 | 631 | 344 | 728 | 45 | | | | | |
| For WPW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| For ventricular tachyarrhythmia | 1 (4.3) | 0 | 1 (4.3) | 0 | 5 | 0 | 10 | 10 | 1 | 0 | 0 | | | | | |
| Others | 60 (1.9) | 1 (0.03) | 117 (3.7) | 0 | 68 | 139 | 2625 | 575 | 378 | 626 | 42 | | | | | |
| Total | 116 (1.7) | 2 (0.03) | 222 (3.2) | 0 | 277 | 297 | 5761 | 1216 | 723 | 1354 | 87 | | | | | |

O, % mortality
 WPW Wolff-Parkinson-White syndrome, IHD ischemic heart disease
 Except for 170 isolated cases, all remaining 5164 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: 210)

| | CPB (+) | | | | CPB (-) | | | |
|-------|------------------|-----------------|--------------------|-----------------|------------------|-----------------|--------------------|-----------------|
| | 30-Day mortality | | Hospital mortality | | 30-Day mortality | | Hospital mortality | |
| | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge |
| Total | 7 (5.9) | 0 | 18 (15.1) | 0 | 91 | 3 (3.3) | 1 (1.1) | 7 (7.7) |

O, % mortality
 CPB cardiopulmonary bypass

Table 2 (continued)

| Cases | 30-Day mortality | | Hospital mortality | | Concomitant operation | | | |
|------------------|------------------|-----------------|--------------------|-----------------|-----------------------|-----|------|--------|
| | Hospital | | After discharge | | AVR | MVP | CABG | Others |
| | Hospital | After discharge | Hospital | After discharge | | | | |
| Benign tumor | 537 | 4 (0.7) | 0 | 0 | 30 | 23 | 60 | 116 |
| (Cardiac myxoma) | 353 | 0 | 0 | 0 | 9 | 7 | 33 | 67 |
| Malignant tumor | 91 | 6 (6.6) | 1 (1.1) | 1 (1.1) | 3 | 3 | 1 | 9 |
| (Primary) | 48 | 3 (6.3) | 0 | 0 | 1 | 3 | 1 | 5 |

0, % mortality
M/R aortic valve replacement, *M/R* mitral valve replacement, *CABG* coronary artery bypass grafting

| Cases | 30-Day mortality | | Hospital mortality | | Concomitant operation | | | |
|--|------------------|-----------------|--------------------|-----------------|-----------------------|-----|-----|------|
| | Hospital | | After discharge | | AVR | MVR | MVP | CABG |
| | Hospital | After discharge | Hospital | After discharge | | | | |
| Myectomy | 118 | 3 (2.5) | 0 | 0 | 41 | 17 | 24 | 10 |
| Myotomy | 5 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| No-resection | 133 | 7 (5.3) | 0 | 0 | 27 | 60 | 73 | 14 |
| Volume reduction surgery of the left ventricle | 8 | 0 | 0 | 0 | 0 | 1 | 2 | 2 |
| Total | 264 | 10 (3.8) | 0 | 0 | 69 | 79 | 100 | 26 |

0, % mortality
HDCM hypertrophic obstructive cardiomyopathy, *DCM* dilated cardiomyopathy, *A/R* aortic valve replacement, *M/R* mitral valve replacement, *MVP* mitral valve repair, *CABG* coronary artery bypass grafting

| Cases | 30-Day mortality | | Hospital mortality | |
|--------------------------|------------------|-----------------|--------------------|-----------------|
| | After discharge | | After discharge | |
| | Hospital | After discharge | Hospital | After discharge |
| Open-heart operation | 511 | 56 (11.0) | 0 | 83 (16.2) |
| Non-open-heart operation | 729 | 81 (11.1) | 0 | 114 (15.6) |
| Total | 1240 | 137 (11.0) | 0 | 197 (15.9) |

0, % mortality

Table 3 Thoracic aortic aneurysm (total; 22,540) (1) Dissection (total; 10,855)

| Stanford type | Acute | | | | | | Chronic | | | | | | Concomitant operation | | | | | | | | | |
|--------------------------------|-------|------------------------------|-----------------|--------------------|------------------------------|-----------------|---------|------------------------------|-----------------|--------------------|------------------------------|-----------------|-----------------------|------------------------------|-----------------|--------------------|-----|-----|------|------|--------|----|
| | A | | | B | | | A | | | B | | | AVP | | MVP | | MVR | | CABG | | Others | |
| | Cases | 30-Day mortality Hospital | After discharge | Hospital mortality | 30-Day mortality Hospital | After discharge | Cases | 30-Day mortality Hospital | After discharge | Hospital mortality | 30-Day mortality Hospital | After discharge | Cases | 30-Day mortality Hospital | After discharge | Hospital mortality | AVP | MVP | MVR | CABG | Others | |
| Ascending Ao | 2071 | 146 (7.0) | 1 (0.05) | 189 (9.1) | 1 | 0 | 0 | 0 | 0 | 187 | 6 (3.2) | 0 | 8 (4.3) | 1 | 0 | 0 | 61 | 137 | 22 | 8 | 110 | 32 |
| Aortic Root | 191 | 35 (18.3) | 0 | 36 (18.8) | 0 | 0 | 0 | 0 | 0 | 80 | 4 (5.0) | 0 | 5 (6.3) | 3 | 0 | 0 | 32 | 194 | 6 | 2 | 65 | 7 |
| Arch | 1954 | 135 (6.9) | 1 (0.05) | 174 (8.9) | 31 | 0 | 0 | 0 | 0 | 355 | 9 (2.5) | 0 | 13 (3.7) | 172 | 5 (2.9) | 0 | 54 | 113 | 10 | 5 | 118 | 25 |
| Aortic root+asc. Ao.+ Arch | 167 | 23 (13.8) | 0 | 26 (15.6) | 0 | 0 | 0 | 0 | 0 | 47 | 1 (2.1) | 0 | 3 (6.4) | 6 | 0 | 0 | 23 | 143 | 2 | 0 | 35 | 2 |
| Descending Ao | 35 | 4 (11.4) | 0 | 4 (11.4) | 28 | 2 (7.1) | 0 | 2 (7.1) | 0 | 56 | 1 (1.8) | 0 | 1 (1.8) | 220 | 9 (4.1) | 0 | 2 | 4 | 0 | 0 | 4 | 0 |
| Thoracoabdominal | 1 | 1 (100.0) | 0 | 1 (100.0) | 11 | 1 (9.1) | 0 | 1 (9.1) | 0 | 46 | 5 (10.9) | 0 | 5 (10.9) | 182 | 11 (6.0) | 1 (0.5) | 0 | 0 | 0 | 0 | 1 | 0 |
| Simple TEVAR | 101 | 9 (8.9) | 0 | 11 (10.9) | 442 | 30 (6.8) | 0 | 34 (7.7) | 0 | 264 | 2 (0.8) | 0 | 3 (1.1) | 1171 | 7 (0.6) | 0 | 8 | 0 | 7 | 0 | 2 | 2 |
| Open SG with BR | 1213 | 101 (8.3) | 2 (0.16) | 133 (11.0) | 62 | 3 (4.8) | 0 | 3 (4.8) | 0 | 207 | 8 (3.9) | 0 | 11 (5.3) | 237 | 4 (1.7) | 0 | 61 | 115 | 10 | 2 | 104 | 16 |
| Open SG without BR | 435 | 32 (7.4) | 0 | 45 (10.3) | 28 | 2 (7.1) | 0 | 3 (10.7) | 0 | 52 | 2 (3.8) | 0 | 4 (7.7) | 82 | 3 (3.7) | 0 | 20 | 45 | 1 | 0 | 30 | 2 |
| Arch TEVAR with BR | 14 | 1 (7.1) | 0 | 1 (7.1) | 123 | 6 (4.9) | 0 | 10 (8.1) | 0 | 73 | 2 (2.7) | 0 | 2 (2.7) | 364 | 7 (1.9) | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Thoracoabdominal TEVAR with BR | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 1 (16.7) | 33 | 2 (6.1) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 18 | 6 (33.3) | 0 | 6 (33.3) | 13 | 3 (23.1) | 0 | 3 (23.1) | 0 | 10 | 0 | 0 | 0 | 51 | 2 (3.9) | 0 | 0 | 2 | 0 | 0 | 1 | 1 |
| Total | 6200 | 353 (5.7) | 4 (0.06) | 626 (10.1) | 750 | 47 (6.3) | 0 | 56 (7.5) | 0 | 1383 | 40 (2.9) | 0 | 56 (4.0) | 2522 | 50 (2.0) | 1 (0.0) | 255 | 755 | 51 | 17 | 470 | 87 |

(), % mortality
Ao aorta, AIVP aortic valve repair, AIVP aortic valve repair, MTR mitral valve repair, MTR mitral valve repair, TEVAR thoracic endovascular aortic (aneurysm) repair
Acute, within 2 weeks from the onset

Table 3 (continued)
(2) Non-dissection (total; 11,685)

| Replaced site | Unruptured | | | | Ruptured | | | | Concomitant operation | | | | | | | | | | | |
|--------------------------------|------------------|-----------------|--------------------|-----------------|------------------|-----------------|--------------------|-----------------|-----------------------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|
| | Cases | | Hospital mortality | | Cases | | Hospital mortality | | AVP | | AVR | | MVP | | MVR | | CABG | | Others | |
| | 30-Day mortality | After discharge | Hospital | After discharge | 30-Day mortality | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge | Hospital | After discharge |
| Ascending Ao | 1423 | 33 (2.3) | 0 | 51 (3.6) | 56 | 7 (12.5) | 0 | 11 (19.6) | 43 | 1055 | 65 | 68 | 181 | 115 | | | | | | |
| Aortic Root | 1056 | 22 (2.1) | 0 | 35 (3.3) | 59 | 10 (16.9) | 0 | 11 (18.6) | 243 | 783 | 73 | 27 | 144 | 77 | | | | | | |
| Arch | 2035 | 38 (1.9) | 0 | 67 (3.3) | 113 | 10 (8.8) | 0 | 14 (12.4) | 33 | 569 | 37 | 23 | 304 | 76 | | | | | | |
| Aortic root+asc. Ao.+Arch | 306 | 10 (3.3) | 0 | 14 (4.6) | 10 | 0 | 0 | 2 (20.0) | 53 | 225 | 12 | 0 | 39 | 10 | | | | | | |
| Descending Ao | 305 | 5 (1.6) | 2 (0.66) | 14 (4.6) | 32 | 5 (15.6) | 0 | 5 (15.6) | 1 | 8 | 0 | 0 | 16 | 3 | | | | | | |
| Thoracoabdominal | 377 | 14 (3.7) | 0 | 27 (7.2) | 45 | 5 (11.1) | 0 | 8 (17.8) | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| Simple TEVAR | 2457 | 32 (1.3) | 5 (0.20) | 55 (2.2) | 373 | 56 (15.0) | 1 (0.27) | 74 (19.8) | 0 | 2 | 0 | 0 | 1 | 5 | | | | | | |
| Open SG with BR | 1115 | 40 (3.6) | 0 | 68 (6.1) | 66 | 7 (10.6) | 0 | 13 (19.7) | 7 | 121 | 13 | 2 | 166 | 12 | | | | | | |
| Open SG without BR | 398 | 8 (2.0) | 0 | 24 (6.0) | 33 | 3 (9.1) | 0 | 7 (21.2) | 6 | 67 | 7 | 2 | 55 | 8 | | | | | | |
| Arch TEVAR with BR | 1080 | 21 (1.9) | 3 | 33 (3.1) | 58 | 8 (13.8) | 0 | 9 (15.5) | 0 | 0 | 1 | 0 | 3 | 2 | | | | | | |
| Thoracoabdominal TEVAR with BR | 107 | 9 (8.4) | 1 (0.93) | 11 (10.3) | 15 | 1 (6.7) | 0 | 2 (13.3) | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| Other | 137 | 2 (1.5) | 0 | 6 (4.4) | 29 | 7 (24.1) | 0 | 8 (27.6) | 0 | 14 | 2 | 0 | 8 | 4 | | | | | | |
| Total | 10,796 | 234 (2.2) | 11 (0.10) | 405 (3.8) | 889 | 119 (13.4) | 1 (0.11) | 164 (18.4) | 386 | 2844 | 210 | 122 | 917 | 312 | | | | | | |

(), % 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

Table 4 Pulmonary thromboembolism (total; 190)

| | Cases | 30-Day mortality | | Hospital mortality |
|---------|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| Acute | 131 | 25 (19.1) | | 30 (22.9) |
| Chronic | 59 | 0 | | 1 (1.7) |
| Total | 190 | 25 (13.2) | 0 | 31 (16.3) |

(), % mortality

Table 5 Implantation of VAD (total; 187)

| | Cases | 30-Day mortality | | Hospital mortality |
|---------------------|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| Implantation of VAD | 187 | 2 (1.1) | 0 | 14 (7.5) |

(), % mortality

VAD ventricular assist devise

Table 6 Heart transplantation (total; 54)

| | Cases | Age | |
|--------------------------------|-------|-----------|------------|
| | | <18 years | 18 years ≤ |
| Heart transplantation | 54 | 5 | 49 |
| Heart and lung transplantation | 0 | 0 | 0 |
| Total | 54 | 5 | 49 |

(), % mortality

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 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 2020, including concomitant CABG with other major procedures, was 15,681.

Arrhythmia management was primarily performed as concomitant procedures in 6831 cases, with a hospital mortality rate of 3.2%. Pacemaker and implantable cardioverter-defibrillator implantation were not included in this category.

In 2020, 22,540 procedures for thoracic and thoracoabdominal aortae diseases were performed, among which aortic dissection and non-dissection accounted for 10,855 and 11,685, respectively. The number of surgeries for aortic dissection this year was 0.1% higher than that in the preceding year ($n=10,847$). Hospital mortality rates for the 6200 Stanford type A acute aortic dissections remained high

(10.1%). The number of procedures for non-dissected aneurysms decreased by 1.5%, with a hospital mortality rate of 4.9% for all aneurysms and 3.8% and 18.4% 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 4918 patients with aortic dissection, including 2602 TEVARs and 2316 open stent graftings. Moreover, 1568 and 319 cases underwent TEVAR and open stent grafting for type B chronic aortic dissection, accounting for 62.2% and 12.6% of the total number of cases, respectively. Hospital mortality rates associated with simple TEVAR for type B aortic dissection were 7.7% and 0.7% for acute and chronic cases, respectively. Stent graft placement was performed in 5702 patients with non-dissected aortic aneurysms, among which 4090 were TEVARs (an 0.4% increase compared to that in 2019, $n=4072$) and 1612 were open stent graftings (a 7.5% increase compared to that in 2019, $n=1499$). Hospital mortality rates were 2.7% and 19.1% for TEVARs and 6.1% and 20.2% for open stenting in unruptured and ruptured aneurysms, respectively.

(B) General thoracic surgery

The 2020 survey of general thoracic surgeries comprised 708 surgical units, with bulk data submitted via a web-

Table 7 Total cases of general thoracic surgery during 2020

| | Cases | % |
|---|--------|-------|
| Benign pulmonary tumor | 2232 | 2.6 |
| Primary lung cancer | 45,436 | 52.3 |
| Other primary malignant pulmonary tumor | 336 | 0.4 |
| Metastatic pulmonary tumor | 9654 | 11.1 |
| Tracheal tumor | 98 | 0.1 |
| Pleural tumor including mesothelioma | 584 | 0.7 |
| Chest wall tumor | 652 | 0.8 |
| Mediastinal tumor | 5573 | 6.4 |
| Thymectomy for MG without thymoma | 130 | 0.1 |
| Inflammatory pulmonary disease | 2397 | 2.8 |
| Empyema | 3138 | 3.6 |
| Bullous disease excluding pneumothorax | 317 | 0.4 |
| Pneumothorax | 13,514 | 15.6 |
| Chest wall deformity | 180 | 0.2 |
| Diaphragmatic hernia including traumatic | 41 | 0.0 |
| Chest trauma excluding diaphragmatic hernia | 458 | 0.5 |
| Lung transplantation | 75 | 0.1 |
| Others | 1998 | 2.3 |
| Total | 86,813 | 100.0 |

based collection system established by the NCD [3]. General thoracic surgery departments reported 86,813 procedures in 2020 (Table 7), which is 2.1 times more than that in 2000 and approximately 7038 more procedures than that in 2015 (Fig. 2). However it decreased by 5.3% compared to that of 2019 (91,626), mostly because of COVID-19 pandemic, despite the steadily increase up to 2019.

In 2020, 45,436 procedures for primary lung cancer had been performed which decreased by 5.4% compared to that of 2019 (48,052) similarly to the total number of surgeries in general thoracic surgery. The number of procedures in 2020 was 2.4 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 thorascopic 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, inflammatory pulmonary disease, empyema, descending necrotizing mediastinitis, bullous diseases, pneumothorax, diaphragmatic hernia, chest trauma and other respiratory surgeries in 2020, respectively.

A total of 2232 procedures for benign pulmonary tumors had been conducted in 2020 (Table 8). Hamartomas were the most frequent benign pulmonary tumors diagnosed, with 2079 patients (93%) undergoing VATS.

Tables 9 and 10 show additional information on primary malignant pulmonary tumors. Accordingly, the most frequently diagnosed lung cancer subtype was adenocarcinoma (70% of all lung cancers), followed by squamous cell carcinoma (18%). Sublobar resection was performed in

Table 8 Benign pulmonary tumor

| | Cases | 30-Day mortality | | Hospital mortality | by VATS |
|------------------------------------|-------------|------------------|-----------------|--------------------|-------------|
| | | Hospital | After discharge | | |
| 1. Benign pulmonary tumor | | | | | |
| Hamartoma | 443 | 0 | 0 | 0 | 429 |
| Sclerosing hemangioma | 95 | 0 | 1 (1.1) | 0 | 88 |
| Papilloma | 20 | 0 | 0 | 0 | 19 |
| Mucous gland adenoma bronchial | 12 | 0 | 0 | 0 | 11 |
| Fibroma | 133 | 0 | 0 | 1 (0.8) | 123 |
| Lipoma | 9 | 0 | 0 | 0 | 7 |
| Neurogenic tumor | 14 | 0 | 0 | 0 | 14 |
| Clear cell tumor | 3 | 0 | 0 | 0 | 3 |
| Leiomyoma | 22 | 0 | 0 | 0 | 21 |
| Chondroma | 8 | 0 | 0 | 0 | 8 |
| Inflammatory myofibroblastic tumor | 0 | 0 | 0 | 0 | 0 |
| Pseudolymphoma | 22 | 0 | 0 | 0 | 20 |
| Histiocytosis | 16 | 0 | 0 | 0 | 14 |
| Teratoma | 4 | 0 | 0 | 0 | 4 |
| Others | 1431 | 0 | 0 | 1 (0.1) | 1318 |
| Total | 2232 | 0 | 1 (0.04) | 2 (0.09) | 2079 |

(), Mortality %

14,305 lung cancer cases (31% of all cases) and lobectomy in 30,604 cases (67% of all cases). Sleeve lobectomy was performed in 396 cases (0.9% of all cases), while pneumonectomy was required in 251 cases (0.6% of all cases). VATS lobectomy was performed in 21,179 cases of lung cancer (69% of all lobectomy cases). RATS lobectomy was performed in 2810 cases of lung cancer (9% of all lobectomy cases). Patients aged ≥ 80 years who underwent lung cancer surgery accounted for 6521 (14%). Among those

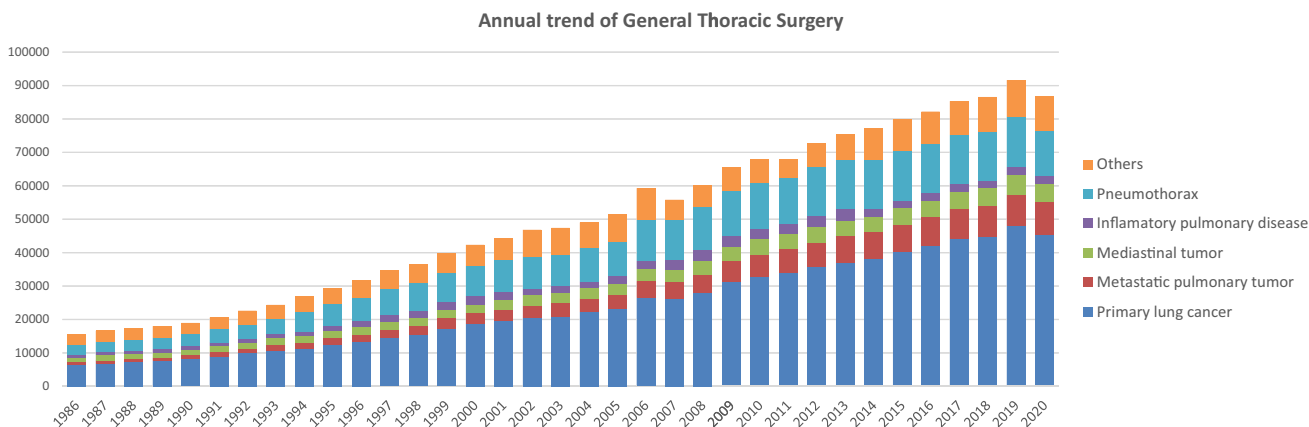


Fig. 2 Annual trend of general thoracic surgery

Table 9 Primary malignant pulmonary tumor

| | Cases | 30-Day mortality | | Hospital mortality | VATS | Robotic surgery |
|---|--------|------------------|-----------------|--------------------|--------|-----------------|
| | | Hospital | After discharge | | | |
| 2. Primary malignant pulmonary tumor | 45,772 | 122 (0.3) | 45 (0.1) | 235 (0.5) | 33,992 | 3078 |
| Lung cancer | 45,436 | 122 (0.3) | 45 (0.1) | 235 (0.5) | 33,992 | 3078 |
| Adenocarcinoma | 31,632 | 55 (0.2) | 21 (0.07) | 97 (0.3) | | |
| Squamous cell carcinoma | 8217 | 44 (0.5) | 16 (0.2) | 98 (1.2) | | |
| Large cell carcinoma | 288 | 2 (0.7) | 0 | 2 (0.7) | | |
| LCNEC | 573 | 7 (1.2) | 3 (0.5) | 10 (1.7) | | |
| Small cell carcinoma | 888 | 4 (0.5) | 2 (0.2) | 9 (1.0) | | |
| Adenosquamous carcinoma | 565 | 1 (0.2) | 0 | 3 (0.5) | | |
| Carcinoma with pleomorphic, sarcomatoid or sarcomatous elements | 553 | 2 (0.4) | 0 | 6 (1.1) | | |
| Carcinoid | 249 | 0 | 0 | 0 | | |
| Carcinomas of salivary-gland type | 18 | 0 | 0 | 0 | | |
| Unclassified | 39 | 0 | 1 (2.6) | 0 | | |
| Multiple lung cancer | 2061 | 4 (0.2) | 2 (0.1) | 7 (0.3) | | |
| Others | 306 | 3 (1.0) | 0 | 3 (1.0) | | |
| Wedge resection | 8511 | 10 (0.1) | 8 (0.1) | 24 (0.3) | 7815 | 12 |
| Segmental excision | 5794 | 10 (0.2) | 2 (0.03) | 15 (0.3) | 4784 | 253 |
| (<i>Sleeve segmental excision</i>) | 10 | 0 | 0 | 0 | 4 | 0 |
| Lobectomy | 30,604 | 94 (0.3) | 35 (0.11) | 182 (0.6) | 21,179 | 2810 |
| (<i>Sleeve lobectomy</i>) | 396 | 2 (0.5) | 0 | 9 (2.3) | 51 | 1 |
| Pneumonectomy | 251 | 5 (2.0) | 0 | 9 (3.6) | 35 | 2 |
| (<i>Sleeve pneumonectomy</i>) | 8 | 1 (12.5) | 0 | 1 (12.5) | 0 | 0 |
| Other bronchoplasty | 32 | 1 (3.1) | 0 | 1 (3.1) | 4 | 0 |
| Pleuropneumonectomy | 1 | 0 | 0 | 0 | 0 | 0 |
| Others | 198 | 2 (1.0) | 0 | 4 (2.0) | 135 | 1 |
| Multiple incision for Multiple lung cancer | 45 | 0 | 0 | 0 | 40 | 0 |
| Sarcoma | 53 | 0 | 0 | 0 | | |
| AAH | 11 | 0 | 0 | 0 | | |
| Others | 272 | 0 | 0 | 0 | | |

(), Mortality %

who died within 30 days postoperatively, 122 and 45 died before and after hospital discharge, respectively. Overall, 167 patients died within 30 days postoperatively (30-day mortality rate, 0.4%), while 122 died before discharge (hospital mortality rate, 0.3%). Moreover, 30-day mortality rates according to the procedure were 0.2%, 0.4%, and 2% 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.

The procedures for metastatic pulmonary tumors performed in 2020 increased 3.4% to 9654 cases compared to that in 2019 (9329), which showed contrastive trend to primary lung cancer (Table 11). Among such procedures, the most frequent primary tumor was colorectal cancer (48% of all cases).

A total of 98 procedures for tracheal tumors, including 49, 30, and 19 cases of primary malignant, metastatic, and benign tracheal tumors, respectively, were performed in

Table 10 Details of lung cancer operations

| TNM | |
|------------------------------|--------|
| c-Stage | Cases |
| IA1 | 8499 |
| IA2 | 13,478 |
| IA3 | 7783 |
| IB | 4886 |
| IIA | 1487 |
| IIB | 3746 |
| IIIA | 2448 |
| IIIB | 444 |
| IIIC | 19 |
| IVA | 367 |
| IVB | 105 |
| NA | 2129 |
| Total | 45,391 |
| Sex | |
| Sex | Cases |
| Male | 27,831 |
| Female | 17,560 |
| NA | 0 |
| Total | 45,391 |
| Cause of death | |
| Cause of death | Cases |
| Cardiovascular | 38 |
| Pneumonia | 96 |
| Pyothorax | 4 |
| Bronchopleural fistula | 11 |
| Respiratory failure | 32 |
| Pulmonary embolism | 4 |
| Interstitial pneumonia | 101 |
| Brain infarction or bleeding | 21 |
| Others | 140 |
| Unknown | 25 |
| Total | 472 |
| p-Stage | |
| p-Stage | Cases |
| 0 (pCR) | 3124 |
| IA1 | 9234 |
| IA2 | 10,515 |
| IA3 | 4957 |
| IB | 6300 |
| IIA | 1177 |
| IIB | 4475 |
| IIIA | 3594 |
| IIIB | 780 |
| IIIC | 11 |
| IVA | 866 |
| IVB | 99 |
| NA | 257 |

Table 10 (continued)

| p-Stage | |
|---------|--------|
| p-Stage | Cases |
| Total | 45,389 |
| Age (y) | |
| Age (y) | Cases |
| <20 | 19 |
| 20–29 | 39 |
| 30–39 | 232 |
| 40–49 | 1142 |
| 50–59 | 3595 |
| 60–69 | 11,483 |
| 70–79 | 22,360 |
| 80–89 | 6422 |
| ≥90 | 99 |
| NA | 0 |
| Total | 45,391 |

2020. Further, 17 patients underwent sleeve resection and reconstruction (Table 12).

Overall, 584 pleural tumors had been diagnosed in 2020 (Table 13), with diffuse malignant pleural mesothelioma as the most frequent histologic diagnosis. Total pleurectomy was performed in 105 cases and extrapleural pneumonec-tomy in 33 cases. The 30-day mortality rate was 2% and 3% after total pleurectomy and extrapleural pneumonec-tomy, respectively.

Overall, 652 chest wall tumor resections had been per-formed in 2020, including 103, 209, and 340 cases of pri-mary malignant, metastatic, and benign tumors, respectively (Table 14).

In 2020, 5573 mediastinal tumors were resected, which decreased by 5% compared to that in 2019 (5881) (Table 15), which showed similar trend as primary lung cancer. Thymic epithelial tumors, including 2226 thymo-mas, 341 thymic carcinomas, and 48 thymic carcinoids, were the most frequently diagnosed mediastinal tumor subtype in 2020.

A total of 484 patients underwent thymectomy for myasthenia gravis (Table 16), among which 354 procedures were associated with thymoma in 2020.

Overall, 22,043 patients underwent procedures for non-neoplastic disease. Accordingly, 2397 patients underwent lung resection for inflammatory lung diseases (Tables 17, 18), among which 492 and 311 patients were associated with mycobacterial and fungal infections, respectively. Procedures for inflammatory pseudotumor were performed in 1011 cases (42%).

A total of 3138 procedures were performed for empyema (Table 19), among which 2456 (78%) were acute and 682 (22%) were chronic. Further, bronchopleural fistulas

Table 11 Metastatic pulmonary tumor

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|-------------------------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| 3. Metastatic pulmonary tumor | 9654 | 11 (0.1) | 7 (0.07) | 21 (0.2) | 8784 |
| Colorectal | 4633 | 3 (0.06) | 1 (0.02) | 4 (0.1) | 4232 |
| Hepatobiliary/pancreatic | 528 | 2 (0.4) | 1 (0.2) | 4 (0.8) | 489 |
| Uterine | 512 | 0 | 1 (0.2) | 0 | 476 |
| Mammary | 549 | 0 | 2 (0.4) | 0 | 515 |
| Ovarian | 80 | 0 | 0 | 0 | 72 |
| Testicular | 59 | 0 | 0 | 0 | 51 |
| Renal | 768 | 0 | 0 | 0 | 712 |
| Skeletal | 115 | 0 | 0 | 0 | 100 |
| Soft tissue | 257 | 0 | 0 | 1 (0.4) | 220 |
| Otorhinolaryngological | 517 | 0 | 2 (0.4) | 1 (0.2) | 480 |
| Pulmonary | 537 | 2 (0.4) | 0 | 3 (0.6) | 431 |
| Others | 1099 | 4 (0.4) | 0 | 8 (0.7) | 1006 |

(), Mortality %

developed in 465 and 346 patients with acute and chronic empyema, respectively. The hospital mortality rate was 16% among patients with acute empyema with fistula.

Further, 99 operations were performed for descending necrotizing mediastinitis (Table 20), with a hospital mortality rate of 6%.

A total of 317 procedures were conducted for bullous diseases (Table 21), while only 14 patients underwent lung volume reduction surgery.

A total of 13,514 procedures were performed for pneumothorax (Table 22). Among the 9592 procedures for spontaneous pneumothorax, 2523 (26%) were bullectomies alone, while 6428 (67%) required additional procedures, such as coverage with artificial material, as well as parietal pleurectomy. A total of 3922 procedures for secondary pneumothorax were performed, with chronic obstructive pulmonary disease (COPD) being the most prevalent associated disease (2775 cases, 71%). The hospital mortality rate for secondary pneumothorax associated with COPD was 3%.

The 2020 survey reported 180 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 41 patients (Table 24). This may have been underestimated because procedures may have been classified as gastrointestinal surgery.

The survey reported 458 procedures for chest trauma, excluding iatrogenic injuries (Table 25), with a hospital mortality rate of 6.6%.

Table 26 summarizes the procedures for other diseases, including 92 and 99 cases of arteriovenous malformation and pulmonary sequestration, respectively.

A total of 75 lung transplantations were performed in 2020 (Table 27), among which 58 and 17 were from brain-dead and living-related donors, respectively.

In 2020, the number of VATS procedures decreased by 1.2% from 77,059 to 76,073 compared to that of 2019 with the decrease of all procedures in general thoracic surgery (–5.3%). However, the population of VATS procedures in all procedures increased to 88% in 2020 compared that in 2019 (84%) (Table 28).

A total of 665 tracheobronchoplasty procedures were performed in 2020, including 401 sleeve lobectomies, 17 carinal reconstructions and 10 sleeve pneumonectomies (Table 29). 30-day mortality for sleeve lobectomy, carinal reconstruction and sleeve lobectomy were 2, 6 and 10% respectively.

Table 12 Tracheal tumor

| | Cases | 30-Day mortality | | Hospital mortality |
|---|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| 4. Tracheal tumor | 98 | 1 (1.0) | 2 (2.0) | 1 (1.0) |
| A. Primary malignant tumor | | | | |
| Histological classification | | | | |
| Squamous cell carcinoma | 17 | 0 | 1 (5.9) | 0 |
| Adenoid cystic carcinoma | 17 | 0 | 0 | 0 |
| Mucoepidermoid carcinoma | 2 | 0 | 0 | 0 |
| Others | 13 | 0 | 0 | 0 |
| Total | 49 | 0 | 1 (2.0) | 0 |
| B. Metastatic/invasive malignant tumor, e.g. invasion of thyroid cancer | 30 | 0 | 1 (3.3) | 1 (3.3) |
| C. Benign tracheal tumor | | | | |
| Histological classification | | | | |
| Papilloma | 3 | 0 | 0 | 0 |
| Adenoma | 2 | 0 | 0 | 0 |
| Neurofibroma | 0 | 0 | 0 | 0 |
| Chondroma | 0 | 0 | 0 | 0 |
| Leiomyoma | 1 | 0 | 0 | 0 |
| Others | 13 | 0 | 0 | 0 |
| Histology unknown | 0 | 0 | 0 | 0 |
| Total | 19 | 0 | 0 | 0 |
| Operation | | | | |
| Sleeve resection with reconstruction | 17 | 0 | 0 | 0 |
| Wedge with simple closure | 2 | 0 | 0 | 0 |
| Wedge with patch closure | 0 | 0 | 0 | 0 |
| Total laryngectomy with tracheostomy | 0 | 0 | 0 | 0 |
| Others | 2 | 0 | 0 | 0 |
| Unknown | 0 | 0 | 0 | 0 |
| Total | 21 | 0 | 0 | 0 |

(), Mortality %

Table 13 Tumor of pleural origin

| Histological classification | Cases | 30-Day mortality | | Hospital mortality |
|--|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| Solitary fibrous tumor | 106 | 0 | 0 | 0 |
| Diffuse malignant pleural mesothelioma | 213 | 4 (1.9) | 0 | 7 (3.3) |
| Localized malignant pleural mesothelioma | 32 | 0 | 0 | 1 (3.1) |
| Others | 233 | 0 | 2 (0.9) | 4 (1.7) |
| Total | 584 | 4 (0.7) | 2 (0.3) | 12 (2.1) |
| Operative procedure | Cases | 30-Day mortality | | Hospital mortality |
| | | Hospital | After discharge | |
| Extrapleural pneumonectomy | 33 | 1 (3.0) | 0 | 2 (6.1) |
| Total pleurectomy | 105 | 2 (1.9) | 0 | 3 (2.9) |
| Others | 75 | 1 (1.3) | 1 (1.3) | 2 (2.7) |
| Total | 213 | 4 (1.9) | 1 (0.5) | 7 (3.3) |

(), Mortality %

Table 14 Chest wall tumor

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|----------------------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| 6. Chest wall tumor | | | | | |
| Primary malignant tumor | 103 | 0 | 0 | 0 | 42 |
| Metastatic malignant tumor | 209 | 0 | 1 (0.5) | 0 | 66 |
| Benign tumor | 340 | 0 | 0 | 0 | 251 |
| Total | 652 | 0 | 1 (0.2) | 0 | 359 |

(), Mortality %

Table 15 Mediastinal tumor

| | Cases | 30-Day mortality | | Hospital mortality | By VATS | Robotic surgery |
|---|-------|------------------|-----------------|--------------------|---------|-----------------|
| | | Hospital | After discharge | | | |
| 7. Mediastinal tumor | 5573 | 5 (0.09) | 0 | 9 (0.2) | 4224 | 938 |
| Thymoma* | 2226 | 0 | 0 | 3 (0.1) | 1511 | 366 |
| Thymic cancer | 341 | 0 | 0 | 0 | 186 | 37 |
| Thymus carcinoid | 48 | 0 | 0 | 0 | 27 | 6 |
| Germ cell tumor | 86 | 1 (1.2) | 0 | 1 (1.2) | 54 | 13 |
| <i>Benign</i> | 68 | 1 (1.5) | 0 | 1 (1.5) | 48 | 11 |
| <i>Malignant</i> | 18 | 0 | 0 | 0 | 6 | 2 |
| Neurogenic tumor | 393 | 0 | 0 | 0 | 373 | 77 |
| Congenital cyst | 1239 | 0 | 0 | 0 | 1164 | 270 |
| Goiter | 73 | 0 | 0 | 0 | 27 | 5 |
| Lymphatic tumor | 168 | 1 (0.6) | 0 | 1 (0.6) | 124 | 16 |
| Excision of pleural recurrence of thymoma | 30 | 0 | 0 | 0 | 20 | 1 |
| Thymolipoma | 19 | 0 | 0 | 0 | 8 | 1 |
| Others | 950 | 3 (0.3) | 0 | 4 (0.4) | 730 | 146 |

(), Mortality %

Table 16 Thymectomy for myasthenia gravis

| | Cases | 30-Day mortality | | Hospital mortality | By VATS | Robotic surgery |
|-------------------------------------|-------|------------------|-----------------|--------------------|---------|-----------------|
| | | Hospital | After discharge | | | |
| 8. Thymectomy for myasthenia gravis | 484 | 0 | 0 | 2 (0.4) | 319 | 19 |
| With thymoma | 354 | 0 | 0 | 2 (0.6) | 209 | 2 |

(), 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 | 22,043 | 250 (1.1) | 48 (0.2) | 502 (2.3) |

Table 18 A. Inflammatory pulmonary disease

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|-----------------------------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| A. Inflammatory pulmonary disease | 2397 | 9 (0.4) | 3 (0.1) | 26 (1.1) | 2047 |
| Tuberculous infection | 43 | 0 | 0 | 0 | 33 |
| Mycobacterial infection | 492 | 3 (0.6) | 0 | 3 (0.6) | 443 |
| Fungal infection | 311 | 1 (0.3) | 0 | 11 (3.5) | 203 |
| Bronchiectasis | 45 | 1 (2.2) | 0 | 2 (4.4) | 30 |
| Tuberculous nodule | 51 | 0 | 0 | 0 | 42 |
| Inflammatory pseudotumor | 1011 | 0 | 0 | 2 (0.2) | 936 |
| Interpulmonary lymph node | 57 | 0 | 0 | 0 | 52 |
| Others | 387 | 4 (1.0) | 3 (0.8) | 8 (2.1) | 308 |

(), Mortality %

Table 19 B. Empyema

| | Cases | 30-Day mortality | | Hospital mortality | By VATS |
|-----------------|-------|------------------|-----------------|--------------------|---------|
| | | Hospital | After discharge | | |
| Acute empyema | 2456 | 67 (2.7) | 7 (0.3) | 133 (5.4) | 2002 |
| With fistula | 465 | 32 (6.9) | 3 (0.6) | 72 (15.5) | 241 |
| Without fistula | 1952 | 34 (1.7) | 4 (0.2) | 59 (3.0) | 1727 |
| Unknown | 39 | 1 (2.6) | 0 | 2 (5.1) | 34 |
| Chronic empyema | 682 | 22 (3.2) | 3 (0.4) | 63 (9.2) | 321 |
| With fistula | 346 | 15 (4.3) | 1 (0.3) | 37 (10.7) | 116 |
| Without fistula | 303 | 7 (2.3) | 2 (0.7) | 23 (7.6) | 180 |
| Unknown | 33 | 0 | 0 | 3 (9.1) | 25 |
| Total | 3138 | 89 (2.8) | 10 (0.3) | 196 (6.2) | 2323 |

(), Mortality %

Table 20 C. Descending necrotizing mediastinitis

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|---|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| C. Descending necrotizing mediastinitis | 99 | 4 (4.0) | 0 | 6 (6.1) | 76 |

(), Mortality %

Table 21 D. Bullous diseases

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|----------------------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| D. Bullous diseases | 317 | 1 (0.3) | 0 | 2 (0.6) | 285 |
| Emphysematous bulla | 235 | 1 (0.4) | 0 | 2 (0.9) | 219 |
| Bronchogenic cyst | 10 | 0 | 0 | 0 | 8 |
| Emphysema with <u>LVRS</u> | 14 | 0 | 0 | 0 | 12 |
| Others | 58 | 0 | 0 | 0 | 46 |

(), Mortality %

LVRS lung volume reduction surgery

Table 22 E. Pneumothorax

| Cases | 30-Day mortality | | Hospital mortality | VATS | |
|---|------------------|------------------|--------------------|--------------------|--------|
| | Hospital | After discharge | | | |
| 13,514 | 67 (0.5) | 27 (0.2) | 146 (1.1) | 13,115 | |
| Spontaneous pneumothorax | | | | | |
| Operative procedure | Cases | 30-Day mortality | | Hospital mortality | VATS |
| | | Hospital | After discharge | | |
| Bullectomy | 2523 | 1 (0.0) | 3 (0.1) | 6 (0.2) | 2770 |
| Bullectomy with additional procedure | 6428 | 4 (0.1) | 4 (0.06) | 9 (0.1) | 7535 |
| Coverage with artificial material | 6220 | 4 (0.1) | 4 (0.06) | 9 (0.1) | 7291 |
| Parietal pleurectomy | 22 | 0 | 0 | 0 | 27 |
| Coverage and parietal pleurectomy | 68 | 0 | 0 | 0 | 54 |
| Others | 118 | 0 | 0 | 0 | 163 |
| Others | 639 | 3 (0.5) | 1 (0.2) | 8 (1.3) | 610 |
| Unknown | 2 | 0 | 0 | 0 | 9 |
| Total | 9592 | 8 (0.1) | 8 (0.1) | 23 (0.2) | 10,924 |
| Secondary pneumothorax | | | | | |
| Associated disease | Cases | 30-Day mortality | | Hospital mortality | VATS |
| | | Hospital | After discharge | | |
| COPD | 2775 | 41 (1.5) | 11 (0.4) | 83 (3.0) | 2644 |
| Tumorous disease | 173 | 5 (2.9) | 4 (2.3) | 10 (5.8) | 160 |
| Catamenial | 178 | 0 | 0 | 0 | 176 |
| LAM | 37 | 0 | 0 | 0 | 37 |
| Others (excluding pneumothorax by trauma) | 759 | 13 (1.7) | 4 (0.5) | 30 (4.0) | 706 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Operative procedure | Cases | 30 Day mortality | | Hospital mortality | VATS |
| | | Hospital | After discharge | | |
| Bullectomy | 718 | 4 (0.6) | 4 (0.6) | 12 (1.7) | 690 |
| Bullectomy with additional procedure | 2243 | 32 (1.4) | 8 (0.4) | 53 (2.4) | 2174 |
| Coverage with artificial material | 2152 | 29 (1.3) | 7 (0.3) | 48 (2.2) | 2088 |
| Parietal pleurectomy | 10 | 1 (10.0) | 0 | 1 (10.0) | 10 |
| Coverage and parietal pleurectomy | 23 | 0 | 0 | 2 (8.7) | 22 |
| Others | 58 | 2 (3.4) | 1 (1.7) | 2 (3.4) | 54 |
| Others | 959 | 23 (2.4) | 7 (0.7) | 58 (6.0) | 857 |
| Unknown | 2 | 0 | 0 | 0 | 2 |
| Total | 3922 | 59 (1.5) | 19 (0.5) | 123 (3.1) | 3723 |

(), Mortality %

Table 23 F. Chest wall deformity

| | Cases | 30-Day mortality | | Hospital mortality |
|-------------------------|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| F. Chest wall deformity | 180 | 0 | 0 | 0 |
| Funnel chest | 168 | 0 | 0 | 0 |
| Others | 12 | 0 | 0 | 0 |

(), Mortality %

Table 24 G. Diaphragmatic hernia

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|-------------------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| G. Diaphragmatic hernia | 41 | 0 | 0 | 1 (2.4) | 21 |
| Congenital | 8 | 0 | 0 | 0 | 2 |
| Traumatic | 11 | 0 | 0 | 0 | 6 |
| Others | 22 | 0 | 0 | 1 (4.5) | 13 |

(), Mortality %

Table 25 H. Chest trauma

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|-----------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| H. Chest trauma | 458 | 26 (5.7) | 0 | 30 (6.6) | 253 |

(), Mortality %

Table 26 I. Other respiratory surgery

| | Cases | 30-Day mortality | | Hospital mortality | VATS |
|-------------------------------------|-------|------------------|-----------------|--------------------|------|
| | | Hospital | After discharge | | |
| I. Other respiratory surgery | 1899 | 54 (2.8) | 8 (0.4) | 95 (5.0) | 1407 |
| Arteriovenous malformation* | 92 | 0 | 0 | 0 | 86 |
| Pulmonary sequestration | 99 | 0 | 0 | 0 | 83 |
| Postoperative bleeding /air leakage | 541 | 21 (3.9) | 4 (0.7) | 37 (6.8) | 362 |
| Chylothorax | 67 | 0 | 0 | 2 (3.0) | 56 |
| Others | 1100 | 33 (3.0) | 4 (0.4) | 56 (5.1) | 820 |

(), Mortality %

Table 27 Lung transplantation

| | Cases | 30-Day mortality | | Hospital mortality |
|--|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| Single lung transplantation from brain-dead donor | 31 | 0 | 0 | 0 |
| Bilateral lung transplantation from brain-dead donor | 27 | 1 (3.7) | 0 | 1 (3.7) |
| Lung transplantation from living donor | 17 | 2 (11.8) | 0 | 3 (17.6) |
| Total lung transplantation | 75 | 0 | 0 | 4 (5.3) |
| Donor of living donor lung transplantation | 29 | 0 | 0 | 0 |

(), Mortality %

Table 28 Video-assisted thoracic surgery

| | Cases | 30-Day mortality | | Hospital mortality |
|-------------------------------------|--------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| 11. Video-assisted thoracic surgery | 76,073 | 242 (0.3) | 79 (0.1) | 469 (0.6) |

(), Mortality % (including thoracic sympathectomy 330)

Table 29 Tracheobronchoplasty

| | Cases | 30-Day mortality | | Hospital mortality |
|--------------------------------------|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| 12. Tracheobronchoplasty | 665 | 5 (0.8) | 4 (0.6) | 16 (2.4) |
| Trachea | 38 | 0 | 0 | 0 |
| Sleeve resection with reconstruction | 25 | 0 | 0 | 0 |
| 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 | 7 | 0 | 0 | 0 |
| Carinal reconstruction | 17 | 0 | 0 | 1 (5.9) |
| Sleeve pneumonectomy | 10 | 1 (10.0) | 0 | 1 (10.0) |
| Sleeve lobectomy | 401 | 2 (0.5) | 0 | 8 (2.0) |
| Sleeve segmental excision | 13 | 0 | 0 | 0 |
| Bronchoplasty without lung resection | 17 | 0 | 0 | 1 (5.9) |
| Others | 169 | 2 (1.2) | 4 (2.4) | 5 (3.0) |

(), Mortality %

Table 30 Pediatric surgery

| | Cases | 30-Day mortality | | Hospital mortality |
|-----------------------|-------|------------------|-----------------|--------------------|
| | | Hospital | After discharge | |
| 13. Pediatric surgery | 297 | 9 (3.0) | 0 | 10 (3.4) |

(), 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) | 1300 | 7 (0.5) | 0 | 16 (1.2) |
| A. Primary lung cancer | | | | |
| Aorta | 9 | 0 | 0 | 0 |
| Superior vena cava | 24 | 0 | 0 | 0 |
| Brachiocephalic vein | 7 | 0 | 0 | 1 (14.3) |
| Pericardium | 63 | 2 (3.2) | 0 | 2 (3.2) |
| Pulmonary artery | 117 | 1 (0.9) | 0 | 2 (1.7) |
| Left atrium | 14 | 0 | 0 | 1 (7.1) |
| Diaphragm | 63 | 0 | 0 | 2 (3.2) |
| Chest wall (including ribs) | 276 | 3 (1.1) | 0 | 8 (2.9) |
| Vertebra | 10 | 0 | 0 | 0 |
| Esophagus | 3 | 0 | 0 | 0 |
| Total | 586 | 6 (1.0) | 0 | 16 (2.7) |
| B. Mediastinal tumor | | | | |
| Aorta | 1 | 0 | 0 | 0 |
| Superior vena cava | 63 | 1 (1.6) | 0 | 2 (3.2) |
| Brachiocephalic vein | 130 | 0 | 0 | 0 |
| Pericardium | 364 | 0 | 0 | 0 |
| Pulmonary artery | 4 | 0 | 0 | 0 |
| Left atrium | 0 | 0 | 0 | 0 |
| Diaphragm | 43 | 0 | 0 | 0 |
| Chest wall (including ribs) | 9 | 0 | 0 | 0 |
| Vertebra | 7 | 0 | 0 | 0 |
| Esophagus | 8 | 0 | 0 | 0 |
| Lung | 524 | 0 | 0 | 0 |
| Total | 1153 | 1 (0.1) | 0 | 2 (0.2) |

(), Mortality %

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

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 | 655 | 3 (0.5) | 0 | 7 (1.1) |

(), Mortality %

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

(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 2020, 5909 patients underwent surgery for esophageal diseases (860 and 5049 for benign and malignant esophageal diseases, respectively) from institutions across Japan. Compared to 2019, there was a total decrease of 1326 cases (18.3%) observed, with a decrease of 214 cases (19.9%) in benign diseases and a decrease of 1112 cases (18.0%) in malignant diseases. It is considered that this significant decline was largely influenced by the COVID-19 pandemic that began in 2020, with factors such as surgical restrictions, reduced medical visits, and postponed screenings being considered as contributing factors (Fig. 3).

Concerning benign esophageal diseases (Table 33), thoracoscopic and/or laparoscopic surgeries were performed in 90.7% (68/75), 84.6% (357/422), 100% (27/27), and 36.7% (62/169) of patients with esophagitis (including esophageal ulcer), hiatal hernia, benign tumors, and achalasia, respectively. Conversely, 100% (92/92) of patients with spontaneous rupture of the esophagus underwent open surgery. Hospital mortality rates within 30 postoperative days were 0.5% (2/422), 4.3% (4/92) for hiatal hernia and spontaneous rupture of the esophagus, respectively.

Annual trend of in-patients with esophageal diseases

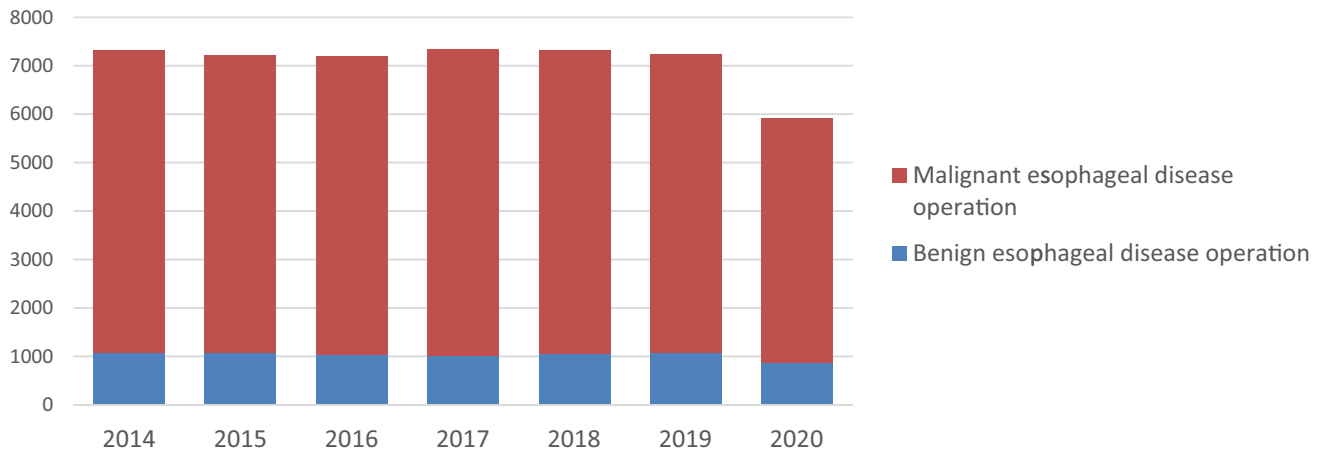


Fig. 3 Annual trend of in-patients with esophageal diseases

Table 33 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 | 169 | 0 | 0 | 0 | 62 | 0 | 0 | 0 |
| 2. Benign tumor | 27 | 0 | 0 | 0 | 27 | 0 | 0 | 0 |
| 3. Diverticulum | 28 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| 4. Hiatal hernia | 422 | 2 (0.5) | 0 | 2 (0.5) | 357 | 1 (0.3) | | 1 (0.3) |
| 5. Spontaneous rupture of the esophagus | 92 | 4 (4.3) | 3 (3.3) | 7 (7.6) | 0 | 0 | 0 | 0 |
| 6. Esophago-tracheal fistula | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7. Esophagitis, Esophageal ulcer | 75 | 0 | 0 | 0 | 68 | 0 | 0 | 0 |
| 8. Corrosive stricture of the esophagus | 44 | 0 | 0 | 0 | 17 | 0 | 0 | 0 |
| Total | 860 | 6 (0.7) | 3 (0.3) | 9 (1.0) | 536 | 1 (0.2) | 0 | 1 (0.2) |

(), Mortality %

T/L thoracoscopic and/or laparoscopic

The most common tumor location for malignant esophageal diseases was the thoracic esophagus (Table 34). Among 5049 cases with esophageal malignancies, esophagectomy for superficial and advanced cancers was performed in 1927 (38.2%) and 3122 (61.8%), respectively. Hospital mortality rates within 30 days after esophagectomy were 0.6% and 0.5% 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 (1221/1927, 63.7%) and advanced cancer (2267/3122,

72.6%) (Table 34). Transhiatal esophagectomy, which is commonly performed in Western countries, was adopted in only 8 (0.4%) and 11 (0.4%) patients with superficial and advanced cancer who underwent esophagectomy in Japan, respectively. Thoracoscopic and/or laparoscopic esophagectomy was utilized in 1646 (85.4%) and 2468 (79.0%) patients with superficial and advanced cancer, respectively. Incidence of 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

Table 34 Malignant esophageal disease

| Location | Operation (+) | | Thoracoscopic and/or laparoscopic procedure | | | |
|--|---------------|--|---|---------------------------|----------------------------|---|
| | Cases | Hospital mortality ~ 30 days 31–90 days Total (including after 91 days mortality) | Cases | Conversion to thoracotomy | Hospital mortality | |
| | | | | | ~ 30 days | 31–90 days Total (including after 91 days mortality) |
| (1) Cervical esophagus | 138 | | 64 | | | |
| (2) Thoracic esophagus | 4222 | 23 (0.5) 13 (0.3) 36 (0.9) | 3675 | 33 (0.9) | 20 (0.5) 10 (0.3) 31 (0.8) | |
| (3) Abdominal esophagus | 410 | 1 (0.2) 1 (0.2) | 331 | 2 (0.6) | 1 (0.3) 1 (0.3) | 1 (0.3) |
| Total | 4770 | 24 (0.5) 13 (0.3) 37 (0.8) | 4070 | 35 (0.9) | 21 (0.5) 10 (0.2) 32 (0.8) | |
| Tumor depth | | | | | | |
| (A) Superficial cancer (T1) | | | | | | |
| (1) Transhiatal esophagectomy | 8 | | | | | |
| (2) Mediastinoscopic esophagectomy and reconstruction | 115 | | 115 | | | |
| (3) Transthoracic (rt.) esophagectomy and reconstruction | 1221 | 9 (0.7) 4 (0.3) 13 (1.1) | 1102 | 9 (0.8) | 9 (0.8) 3 (0.3) 12 (1.1) | |
| (4) Transthoracic (lt.) esophagectomy and reconstruction | 25 | 1 (4.0) | 14 | | | |
| (5) Cervical esophageal resection and reconstruction | 20 | | | | | |
| (6) Robot-assisted esophagectomy and reconstruction | 357 | 1 (0.3) 2 (0.6) | 355 | 1 (0.3) | 1 (0.3) 1 (0.3) | 1 (0.3) |
| (7) Others | 12 | | | | | |
| (8) Esophagectomy without reconstruction | 169 | | 60 | | | |
| Subtotal | 1927 | 11 (0.6) 4 (0.2) 15 (0.8) | 1646 | 10 (0.6) | 10 (0.6) 3 (0.2) 13 (0.8) | |
| (B) Advanced cancer (T2–T4) | | | | | | |
| (1) Transhiatal esophagectomy | 11 | | | | | |
| (2) Mediastinoscopic esophagectomy and reconstruction | 127 | 1 (0.8) 1 (0.8) | 127 | | 1 (0.8) 1 (0.8) | |
| (3) Transthoracic (rt.) esophagectomy and reconstruction | 2267 | 10 (0.4) 6 (0.3) 16 (0.7) | 1836 | 23 (1.3) | 8 (0.4) 5 (0.3) 13 (0.7) | |
| (4) Transthoracic (lt.) esophagectomy and reconstruction | 42 | 1 (2.4) 1 (2.4) 2 (4.8) | 26 | | 1 (3.8) 1 (3.8) | |
| (5) Cervical esophageal resection and reconstruction | 51 | | | | | |
| (6) Robot-assisted esophagectomy and reconstruction | 479 | 2 (0.4) 1 (0.2) 3 (0.6) | 479 | 1 (0.2) | 2 (0.4) 1 (0.2) 3 (0.6) | |
| (7) Others | 35 | | | | | |

Table 34 (continued)

| | Operation (+) | | | Thoracoscopic and/or laparoscopic procedure | | | | | | |
|--|---------------|-------------------|---|---|---------------|---------------------------|------------|---------------------|-----------------------|---|
| | Cases | | | Cases | | Conversion to thoracotomy | | Hospital mortality | | Total (including after 91 days mortality) |
| | ~ 30 days | 31–90 days | Total (including after 91 days mortality) | ~ 30 days | 31–90 days | ~ 30 days | 31–90 days | ~ 30 days | 31–90 days | |
| (8) Esophagectomy without reconstruction | 110 | 2 (1.8) | 5 (4.5) | 7 (6.4) | | | | | | |
| Subtotal | 3122 | 15 (0.5) | 14 (0.4) | 29 (0.9) | 2468 | 24 (1.0) | | 11 (0.4) | 7 (0.3) | 18 (0.7) |
| Total | 5049 | 26 (0.5) | 18 (0.4) | 44 (0.9) | 4114 | 34 (0.8) | | 21 (0.5) | 10 (0.2) | 31 (0.8) |
| | Cases | Overall morbidity | Morbidity ≥ CD III | Surgical complications | | | | | | |
| | | | | Surgical site infection | | Organ space | | Anastomotic leakage | Recurrent nerve palsy | Wound dehiscence |
| | | | | Superficial incision | Deep incision | | | | | |
| Location | | | | | | | | | | |
| (1) Cervical esophagus | 138 | 87 (63.0) | 40 (29.0) | 15 (10.9) | 13 (9.4) | 13 (9.4) | 13 (9.4) | 21 (15.2) | 17 (12.3) | 2 (1.4) |
| (2) Thoracic esophagus | 4222 | 2406 (57.0) | 954 (22.6) | 322 (7.6) | 172 (4.1) | 371 (8.8) | 573 (13.6) | 622 (14.7) | 622 (14.7) | 69 (1.6) |
| (3) Abdominal esophagus | 410 | 212 (51.7) | 93 (22.7) | 28 (6.8) | 17 (4.1) | 33 (8.0) | 62 (15.1) | 30 (7.3) | 30 (7.3) | 4 (1.0) |
| Total | 4770 | 2705 (56.7) | 1087 (22.8) | 365 (7.7) | 202 (4.2) | 417 (8.7) | 656 (13.8) | 669 (14.0) | 669 (14.0) | 75 (1.6) |
| Tumor depth | | | | | | | | | | |
| (A) Superficial cancer (T1) | | | | | | | | | | |
| (1) Transhiatal esophagectomy | 8 | 3 (37.5) | 2 (25.0) | 1 (12.5) | | | | | 1 (12.5) | |
| (2) Mediastinoscopic esophagectomy and reconstruction | 115 | 77 (67.0) | 32 (27.8) | 9 (7.8) | 4 (3.5) | 6 (5.2) | 22 (19.1) | 37 (32.2) | 37 (32.2) | 1 (0.9) |
| (3) Transthoracic (rt.) esophagectomy and reconstruction | 1221 | 680 (55.7) | 270 (22.1) | 96 (7.9) | 46 (3.8) | 110 (9.0) | 185 (15.2) | 161 (13.2) | 161 (13.2) | 20 (1.6) |
| (4) Transthoracic (lt.) esophagectomy and reconstruction | 25 | 13 (52.0) | 6 (24.0) | 1 (4.0) | 2 (8.0) | 2 (8.0) | 3 (12.0) | 1 (4.0) | 1 (4.0) | |
| (5) Cervical esophageal resection and reconstruction | 20 | 12 (60.0) | 6 (30.0) | 2 (10.0) | 4 (20.0) | 1 (5.0) | 4 (20.0) | 2 (10.0) | 2 (10.0) | 1 (5.0) |
| (6) Robot-assisted esophagectomy and reconstruction | 357 | 190 (53.2) | 72 (20.2) | 27 (7.6) | 15 (4.2) | 31 (8.7) | 46 (12.9) | 42 (11.8) | 42 (11.8) | 3 (0.8) |
| (7) Others | 12 | 4 (33.3) | 1 (8.3) | | | 1 (8.3) | | | | 0 |
| (8) Esophagectomy without reconstruction | 169 | | | | | | | | | |
| Subtotal | 1927 | 979 (50.8) | 389 (20.2) | 136 (7.1) | 71 (3.7) | 151 (7.8) | 260 (13.5) | 244 (12.7) | 244 (12.7) | 25 (1.3) |
| (B) Advanced cancer (T2–T4) | | | | | | | | | | |
| (1) Transhiatal esophagectomy | 11 | 7 (63.6) | 4 (36.4) | 1 (9.1) | 1 (9.1) | 2 (18.2) | 3 (27.3) | 2 (18.2) | 2 (18.2) | |
| (2) Mediastinoscopic esophagectomy and reconstruction | 127 | 82 (64.6) | 30 (23.6) | 13 (10.2) | 10 (7.9) | 15 (11.8) | 22 (17.3) | 22 (17.3) | 22 (17.3) | 3 (2.4) |

Table 34 (continued)

| | Cases | Overall morbidity | Morbidity \geq CD III | Surgical complications | | | | | | Wound dehiscence |
|---|-------|-------------------|-------------------------|-------------------------|---------------|-------------|---------------------|-----------------------|----------------------------|------------------|
| | | | | Surgical site infection | | | Anastomotic leakage | Recurrent nerve palsy | Reoperation within 30 days | |
| | | | | Superficial incision | Deep incision | Organ space | | | | |
| (3) Trans thoracic (rt.) esophagectomy and reconstruction | 2267 | 1313 (57.9) | 544 (24.0) | 170 (7.5) | 97 (4.3) | 210 (9.3) | 313 (13.8) | 313 (13.8) | 40 (1.8) | |
| (4) Trans thoracic (lt.) esophagectomy and reconstruction | 42 | 20 (47.6) | 3 (7.1) | 3 (7.1) | 1 (2.4) | 4 (9.5) | 5 (11.9) | 2 (4.8) | 0 | |
| (5) Cervical esophageal resection and reconstruction | 51 | 33 (64.7) | 7 (13.7) | 7 (13.7) | 4 (7.8) | 3 (5.9) | 3 (5.9) | 10 (19.6) | 0 | |
| (6) Robot-assisted esophagectomy and reconstruction | 479 | 253 (52.8) | 104 (21.7) | 33 (6.9) | 16 (3.3) | 31 (6.5) | 46 (9.6) | 76 (15.9) | 7 (1.5) | |
| (7) Others | 35 | 18 (51.4) | 6 (17.1) | 2 (5.7) | 2 (5.7) | 1 (2.9) | 4 (11.4) | | | |
| (8) Esophagectomy without reconstruction | 1110 | | | | | | | | | |
| Subtotal | 3122 | 1726 (55.3) | 698 (22.4) | 229 (7.3) | 131 (4.2) | 266 (8.5) | 396 (12.7) | 425 (13.6) | 50 (1.6) | |
| Total | 5049 | 2705 (53.6) | 1087 (21.5) | 365 (7.2) | 202 (4.0) | 417 (8.3) | 656 (13.0) | 669 (13.3) | 75 (1.5) | |

| | Cases | Nonsurgical complications | | | | | | | Reoperation within 30 days | |
|---|-------|---------------------------|----------------------|------------------------------|--------------------|-------------|---------------|------------|----------------------------|----------------|
| | | Pneumonia | Unplanned intubation | Prolonged ventilation > 48 h | Pulmonary embolism | Atelectasis | Renal failure | CNS events | | Cardiac events |
| Location | | | | | | | | | | |
| (1) Cervical esophagus | 138 | 14 (10.1) | 8 (5.8) | 12 (8.7) | 1 (0.7) | 1 (0.7) | 1 (0.7) | 1 (0.7) | 1 (0.7) | 21 (15.2) |
| (2) Thoracic esophagus | 4222 | 637 (15.1) | 165 (3.9) | 192 (4.5) | 51 (1.2) | 204 (4.8) | 20 (0.5) | 15 (0.4) | 20 (0.5) | 279 (6.6) |
| (3) Abdominal esophagus | 410 | 47 (11.5) | 17 (4.1) | 19 (4.6) | 4 (1.0) | 24 (5.9) | 1 (0.2) | 1 (0.2) | 1 (0.2) | 30 (7.3) |
| Total | 4770 | 698 (14.6) | 190 (4.0) | 223 (4.7) | 56 (1.2) | 229 (4.8) | 20 (0.4) | 17 (0.4) | 22 (0.5) | 330 (6.9) |
| Tumor depth | | | | | | | | | | |
| (A) Superficial cancer (T1) | 8 | 1 (12.5) | | | | | | | | 1 (12.5) |
| (1) Transhiatal esophagectomy | 115 | 14 (12.2) | 4 (3.5) | 5 (4.3) | | 6 (5.2) | | | 4 (3.5) | 7 (6.1) |
| (2) Mediastinoscopic esophagectomy and reconstruction | 1221 | 173 (14.2) | 52 (4.3) | 63 (5.2) | 11 (0.9) | 39 (3.2) | 7 (0.6) | 6 (0.5) | 5 (0.4) | 79 (6.5) |
| (3) Trans thoracic (rt.) esophagectomy and reconstruction | | | | | | | | | | |

Table 34 (continued)

| | Cases | Nonsurgical complications | | | | | | | | Readmission within 30 days | Reoperation within 30 days |
|---|-------|---------------------------|----------------------|------------------------------|--------------------|-------------|---------------|------------|----------------|----------------------------|----------------------------|
| | | Pneumonia | Unplanned intubation | Prolonged ventilation > 48 h | Pulmonary embolism | Atelectasis | Renal failure | CNS events | Cardiac events | | |
| (4) Trans thoracic (lt.) esophagectomy and reconstruction | 25 | 3 (12.0) | 2 (8.0) | 2 (8.0) | 5 (20.0) | | | | | 1 (4.0) | |
| (5) Cervical esophageal resection and reconstruction | 20 | 4 (20.0) | 2 (10.0) | | 1 (5.0) | | | | | | 2 (10.0) |
| (6) Robot-assisted esophagectomy and reconstruction | 357 | 41 (11.5) | 6 (1.7) | 10 (2.8) | 6 (1.7) | 20 (5.6) | 1 (0.3) | | | 5 (1.4) | 21 (5.9) |
| (7) Others | 12 | 1 (8.3) | | | | 1 (8.3) | | | | | |
| (8) Esophagectomy without reconstruction | 169 | | | | | | | | | | |
| Subtotal | 1927 | 237 (12.3) | 66 (3.4) | 80 (4.2) | 17 (0.9) | 72 (3.7) | 8 (0.4) | 6 (0.3) | 9 (0.5) | 35 (1.8) | 110 (5.7) |
| (B) Advanced cancer (T2–T4) | | | | | | | | | | | |
| (1) Transhiatal esophagectomy | 11 | 1 (9.1) | | | | | | | | | |
| (2) Mediastinoscopic esophagectomy and reconstruction | 127 | 18 (14.2) | 6 (4.7) | 5 (3.9) | 1 (0.8) | 7 (5.5) | 1 (0.8) | | 1 (0.8) | 5 (3.9) | 9 (7.1) |
| (3) Trans thoracic (rt.) esophagectomy and reconstruction | 2267 | 361 (15.9) | 99 (4.4) | 116 (5.1) | 30 (1.3) | 125 (5.5) | 9 (0.4) | 9 (0.4) | 10 (0.4) | 71 (3.1) | 168 (7.4) |
| (4) Trans thoracic (lt.) esophagectomy and reconstruction | 42 | 4 (9.5) | 2 (4.8) | 2 (4.8) | 1 (2.4) | 2 (4.8) | 1 (2.4) | | | | 2 (4.8) |
| (5) Cervical esophageal resection and reconstruction | 51 | 3 (5.9) | 1 (2.0) | 2 (3.9) | | 1 (2.0) | | | 1 (2.0) | 1 (2.0) | 5 (9.8) |
| (6) Robot-assisted esophagectomy and reconstruction | 479 | 69 (14.4) | 14 (2.9) | 16 (3.3) | 7 (1.5) | 22 (4.6) | 1 (0.2) | 1 (0.2) | 2 (0.4) | 6 (1.3) | 35 (7.3) |
| (7) Others | 35 | 4 (11.4) | 2 (5.7) | 2 (5.7) | | 1 (2.9) | | | 1 (2.9) | | 1 (2.9) |
| (8) Esophagectomy without reconstruction | 110 | | | | | | | | | | |
| Subtotal | 3122 | 460 (14.7) | 124 (4.0) | 143 (4.6) | 39 (1.2) | 158 (5.1) | 12 (0.4) | 11 (0.4) | 14 (0.4) | 85 (2.7) | 220 (7.0) |
| Total | 5049 | 697 (13.8) | 190 (3.8) | 223 (4.4) | 56 (1.1) | 230 (4.6) | 20 (0.4) | 17 (0.3) | 23 (0.5) | 120 (2.4) | 330 (6.5) |

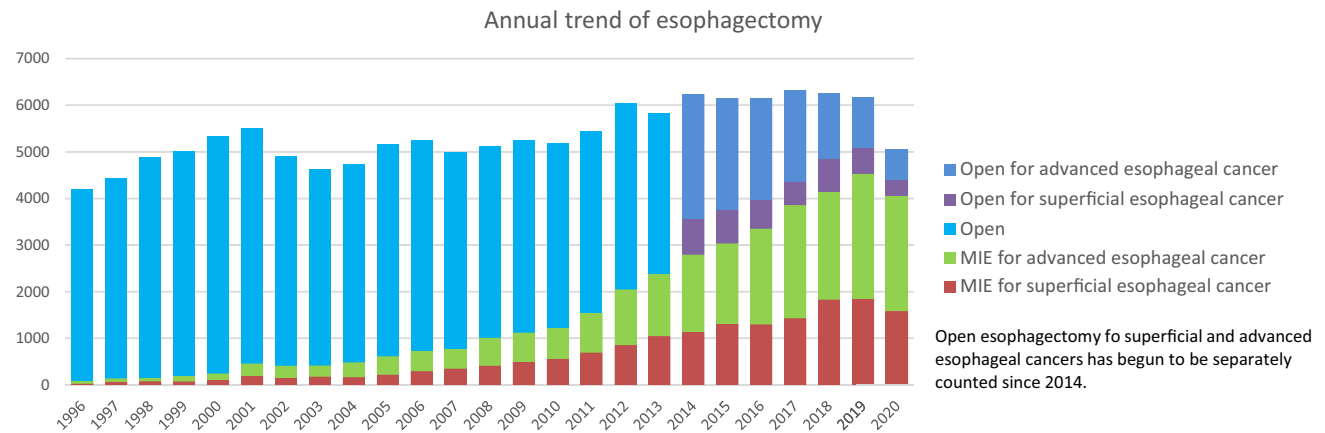


Fig. 4 Annual trend of esophagectomy

Table 35 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 | 300 | 0 | 2 (0.7) | 2 (0.7) | 188 | 4 (2.1) | 0 | 0 | 0 | 89 |

esophagectomy was slightly increased, and performed for 115 (6.0%) and 127 (4.1%) patients with superficial and advanced esophageal cancer, respectively. Robot-assisted esophagectomy has been remarkably increased since 2018 when the insurance approval was obtained in Japan, and performed for 355 (18.4%) and 479 (15.3%) patients with superficial and advanced esophageal cancer, respectively in 2020. Patients who underwent robot-assisted surgery are increasing for both superficial and advanced esophageal cancers compared to that in 2019 (12.3% and 9.9% in 2019, respectively). Hospital mortality rates within 30 days after thoracoscopic and/or laparoscopic esophagectomy were 0.6% and 0.4% for patients with superficial and advanced cancer, respectively (Table 34).

Detailed data collection regarding postoperative surgical and non-surgical complications was initiated in 2018. Overall, 1087 (21.5%) of 5049 patients developed grade III or higher complications based on the Clavien–Dindo classification in 2020 (Table 34). The incidence of grade III or higher complications was relatively higher in cervical esophageal cancer compared to thoracic or abdominal esophageal cancer. Among surgical complications, anastomotic leakage and recurrent nerve palsy occurred in 14.2% and 13.6% of the patients who underwent right transthoracic esophagectomy, in 11.0% and 14.1% of those who underwent robot-assisted esophagectomy, and in 18.2% and

24.4% of those who underwent mediastinoscopic esophagectomy, respectively. Among non-surgical postoperative complications, pneumonia occurred in 13.8% of the patients, 3.8% of whom underwent unplanned intubation. Postoperative pulmonary embolism occurred in 1.1% of the patients. These complication rates, including the others, were similar to those in 2019.

Salvage surgery following definitive (chemo)radiotherapy was safely performed in 300 patients in 2020, with hospital mortality rates of 0% within 30 days postoperatively. (Table 35).

We aim to continue our efforts in collecting comprehensive survey data through more active collaboration with the Japan Esophageal Society and other related institutions, with caution due to the impact of COVID-19 pandemic.

Acknowledgements On behalf of the Japanese Association for Thoracic Surgery, the authors thank the Heads of the Affiliate and Satellite Institutes of Thoracic Surgery for their cooperation and the Councilors of the Japan Esophageal Society. We also appreciate Mr. Hiroaki Miyata for his contribution as one of the founders of the JCVSD.

Data availability Based on the data use policy of JATS, data access is approved through assessment by the JATS: Committee for Scientific Affairs. Those interested in using the data should contact the JATS: Committee for Scientific Affairs (survey@jpts.org) to submit a proposal. The use of the data is granted for the approved study proposals.

Declarations

Conflict of interest Hiroyuki Yamamoto and Hiraku Kumamaru are affiliated with the Department of Healthcare Quality Assessment at the University of Tokyo. The department is a social collaboration department supported by grants from the National Clinical Database, Johnson & Johnson K.K., Nipro Corporation and Intuitive Surgical Sàrl.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Lotfi M, Hamblin MR, Rezaei N. COVID-19: transmission, prevention, and potential therapeutic opportunities. *Clin Chim Acta*. 2020;508:254–66.
- Aranda-Michel E, Sema-Gallegos D, Arnaoutakis G, et al. The effect of COVID-19 on cardiac surgical volume and its associates costs. *Semin Thorac Cardiovasc Surg*. 2023;35:508–15.
- Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery, Minatoya K, Sato Y, Toh Y, et al. Thoracic and cardiovascular surgery in Japan during 2019—Annual report by the Japanese Association for Thoracic Surgery. *Gen Thorac Cardiovasc Surg*. 2023;71:595–628.
- Kuwano H, Amano J, Yokomise H. Thoracic and cardiovascular surgery in Japan during 2010—annual report by the Japanese Association for Thoracic Surgery. *Gen Thorac Cardiovasc Surg*. 2012;60:680–708.
- Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery, Masuda M, Endo S, Natsugoe S, et al. Thoracic and cardiovascular surgery in Japan during 2015—annual report by the Japanese Association for Thoracic Surgery. *Gen Thorac Cardiovasc Surg*. 2018;66:581–615.
- Kazui T, Wada H, Fujita H, Japanese Association for Thoracic Surgery Committee of Science. Thoracic and cardiovascular surgery in Japan during 2003—annual report by the Japanese Association for Thoracic Surgery. *Jpn J Thorac Cardiovasc Surg*. 2005;53:517–36.
- Kazui T, Osada H, Fujita H, Japanese Association for Thoracic Surgery Committee of Science. Thoracic and cardiovascular surgery in Japan during 2004—annual report by the Japanese Association for Thoracic Surgery. *Jpn J Thorac Cardiovasc Surg*. 2006;54:363–85.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery¹ · Goro Matsumiya² · Yukio Sato³ · Hiroya Takeuchi⁴ · Tomonobu Abe⁵ · Shunsuke Endo⁶ · Yasutaka Hirata⁷ · Michiko Ishida⁸ · Hisashi Iwata⁹ · Takashi Kamei¹⁰ · Nobuyoshi Kawaharada¹¹ · Shunsuke Kawamoto¹² · Kohji Kohno¹³ · Hiraku Kumamaru¹⁴ · Kenji Minatoya¹⁵ · Noboru Motomura¹⁶ · Rie Nakahara¹⁷ · Morihito Okada¹⁸ · Hisashi Saji¹⁹ · Aya Saito²⁰ · Hideyuki Shimizu²¹ · Kenji Suzuki²² · Hirofumi Takemura²³ · Tsuyoshi Taketani²⁴ · Yasushi Toh²⁵ · Wataru Tatsuishi⁵ · Hiroyuki Yamamoto¹⁴ · Takushi Yasuda²⁶ · Masayuki Watanabe²⁷ · Naoki Yoshimura²⁸ · Masanori Tsuchida²⁹ · Yoshiki Sawa³⁰

✉ Goro Matsumiya
survey@jplats.org

¹ The Japanese Association for Thoracic Surgery, Committee for Scientific Affairs, Tokyo, Japan

² Department of Cardiovascular Surgery, Chiba University Graduate School of Medicine, Chiba, Japan

³ Department of Thoracic Surgery, University of Tsukuba, Tsukuba, Japan

⁴ Department of Surgery, Hamamatsu University School of Medicine, Shizuoka, Japan

⁵ Division of Cardiovascular Surgery, Department of General Surgical Science, Gunma University, Maebashi, Japan

⁶ Thoracic Surgery, Jichi Medical University Saitama Medical Center, Omiya, Japan

⁷ Department of Cardiac Surgery, The University of Tokyo Hospital, Tokyo, Japan

⁸ Cardiac Surgery, Handa City Hospita, Aichi, Japan

⁹ Department of General Thoracic Surgery, Gifu University Hospital, Gifu, Japan

¹⁰ Department of Surgery, Graduate School of Medicine, Tohoku University, Sendai, Japan

¹¹ Department of Cardiovascular Surgery, Sapporo Medical University School of Medicine, Sapporo, Japan

¹² Department of Cardiovascular Surgery, Tohoku Medical and Pharmaceutical University Hospital, Sendai, Japan

¹³ Department of Gastrointestinal Tract Surgery, Fukushima Medical University, Fukushima, Japan

¹⁴ Department of Healthcare Quality Assessment, Graduate School of Medicine, The University of Tokyo, Tokyo, Kagoshima, Japan

- ¹⁵ Department of Cardiovascular Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan
- ¹⁶ Department of Cardiovascular Surgery, Toho University Sakura Medical Center, Chiba, Japan
- ¹⁷ Division of Thoracic Surgery, Tochigi Cancer Center, Tochigi, Japan
- ¹⁸ Surgical Oncology, Hiroshima University, Hiroshima, Japan
- ¹⁹ Department of Chest Surgery, St. Marianna University School of Medicine, Kawasaki, Japan
- ²⁰ Department of Surgery, Yokohama City University, Graduate School of Medicine, Yokohama, Japan
- ²¹ Department of Cardiovascular Surgery, Keio University, Tokyo, Japan
- ²² Department of General Thoracic Surgery, Juntendo University School of Medicine, Tokyo, Japan
- ²³ Department of Cardiovascular Surgery, Kanazawa University, Kanazawa, Japan
- ²⁴ Department of Cardiovascular Surgery, Mitsui Memorial Hospital, Tokyo, Japan
- ²⁵ Department of Gastroenterological Surgery, National Hospital Organization Kyushu Cancer Center, Fukuoka, Japan
- ²⁶ Department of Surgery, Kindai University Faculty of Medicine, Osaka, Japan
- ²⁷ Department of Gastroenterological Surgery, Cancer Institute Hospital, Tokyo, Japan
- ²⁸ Department of Thoracic and Cardiovascular Surgery, University of Toyama, Graduate School of Medicine, Toyama, Japan
- ²⁹ Division of Thoracic and Cardiovascular Surgery, Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan
- ³⁰ Osaka University, Graduate School of Medicine, Osaka Police Hospital, Osaka, Japan