

# German Heart Surgery Report 2020: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

Andreas Beckmann<sup>1</sup> Renate Meyer<sup>2</sup> Jana Lewandowski<sup>1</sup> Andreas Markewitz<sup>1</sup> Jan Gummert<sup>3</sup>

<sup>1</sup>German Society for Thoracic and Cardiovascular Surgery, Langenbeck-Virchow-Haus, Berlin, Germany

<sup>2</sup>BQS Institute for Quality and Patient Safety, Hamburg, Germany

<sup>3</sup>Clinic for Thoracic and Cardiovascular Surgery, Heart and Diabetes Center NRW, Bad Oeynhausen, Germany

Address for correspondence Andreas Beckmann, MD, Deutsche Gesellschaft für Thorax-, Herz- und Gefäßchirurgie [DGTHG],

Langenbeck-Virchow-Haus, Luisenstr. 58-59, 10117 Berlin, Germany (e-mail: gf@dgthg.de).

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## Abstract

Based on a longtime voluntary registry, founded by the German Society for Thoracic and Cardiovascular Surgery (GSTCVS) in 1980, well-defined data of all cardiac, thoracic and vascular surgery procedures performed in 78 German heart surgery departments during the year 2020 are analyzed. Under the more than extraordinary conditions of the ongoing worldwide coronavirus disease 2019 pandemic, a total of 161,817 procedures were submitted to the registry. A total of 92,809 of these operations are summarized as heart surgery procedures in a classical sense. The unadjusted in-hospital survival rate for the 29,444 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 3.6:1) was 97.2%. For the 35,469 isolated heart valve procedures, (17,471 transcatheter interventions included), the survival rate was 96.7%. Concerning short- and long-term circulatory support, a total of 2,852 extracorporeal life support/extracorporeal membrane oxygenation implantations, respectively, 843 assist device implantations (left/right/biventricular assist device, total artificial device), were registered. In 2020, the number of isolated heart transplantations increased to 340, a rise of 2.1% compared with the previous year. The isolated lung transplantations amounted to 291, a decrease of 6.4%.

This annually updated registry of the GSTCVS represents voluntary public reporting by accumulating actual information for nearly all heart surgical procedures in Germany, constitutes advancements in heart medicine, and represents a basis for quality management for all participating institutions. In addition, the registry demonstrates that the provision of cardiac surgery in Germany is up to date, appropriate, and nationwide patient treatment is guaranteed all the time.

## Keywords

- ▶ heart valve surgery
- ▶ congenital heart disease
- ▶ coronary artery bypass grafting
- ▶ aortic surgery
- ▶ transplantations
- ▶ heart-lung
- ▶ COVID-19

## Introduction

Legitimate demands for a sophisticated quality management in medicine—by authorities, scientific organizations, health care companies, and patients all over the world—have stimulated a quality awareness. This resulted in the development of versatile quality assurance activities such as benchmark projects, public reporting, registries, and others to answer

those needs. More than 30 years ago the board of directors of the German Society for Thoracic and Cardiovascular Surgery (GSTCVS, [www.dgthg.de](http://www.dgthg.de)) decided to set up a periodic data collection of all cardiac surgical procedures in terms of a voluntary, unaudited registry.<sup>1,2</sup> Since 1989, the data are updated annually, summarized in the sense of a scientific registry, and published in the scientific society journal each year.<sup>3–7</sup> The prevalent aims are to detect developments and

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upcoming trends in cardiac surgery in Germany, to compile various results for nearly all cardiac surgical procedures, to provide each participant with a benchmark of the institutional results to the nationwide achievements, and to facilitate an evaluation on an international level for the GSTCVS.

For monitoring actual conditions as well as developments in cardiac medicine, the registry covers all relevant techniques and also innovative technologies including minimally invasive cardiac surgery as well as all kinds of heart valve procedures, including transcatheter heart valve interventions (e.g., TAVI). Thereby, important findings for current patient safety and the future of patient care are collected for evaluation under different aspects.

Data presented in this report comprehend the survey of the year 2020 whereby the more than special circumstances, caused by the coronavirus disease 2019 (COVID-19) pandemic, must necessarily be taken into account when interpreting the results.

## Materials and Methods

Since 2004 a standardized questionnaire gathers specific information for well-defined procedures, exactly described by an annually updated German adaption of the International Classification of Procedures in Medicine called “operation code” (OPS: Operationen- und Prozedurenschlüssel).

All participating institutions were requested to complete the structured questionnaire by January 25, 2021, entering all performed procedures and associated in-hospital mortality. The recommended path for data export is an electronic transmission of an encrypted file to the society office in Berlin. After transaction, the data were decrypted, evaluated for completeness and compiled for further analysis, thus ensuring anonymity for each participating institution. This compilation algorithm enables a high compliance for submission of complete datasets.

Inclusion criteria for the registry data 2020 were all cardiac surgical procedures performed on patients between January 1, 2020 and December 31, 2020, unrelated to the date of patients' admission or discharge as compared with other registries. Like in the earlier years, the number of procedures was counted rather than individual patients. For example, if a patient initially required isolated coronary artery bypass grafting (CABG), later followed by a mitral valve reconstruction due to an undesirable event, one count in the category “coronary surgery” and a second one in the category “mitral valve reconstruction” are enumerated. Thus, the registry contains more procedures than the real number of patients operated on.

Death of patients was defined as in-hospital mortality. Per definition, the observed mortality is always attributed to the first cardiac procedure, for example, the death of a patient requiring a replacement of the ascending aorta due to a complication after CABG would only be attributed to the coronary procedure.

The main reason for this structural setup of the registry—established over three decades—is to keep in accordance with the German data privacy act with its specific regulations for patients. Furthermore, it seemed to be relevant to get detailed information about all performed procedures and not only the number of treated patients. Last but not least the

process of data acquisition had to be standardized and feasible for all participating departments in Germany, thus enabling the submission of a complete dataset, regardless of the hard- and software used locally.

In 2020, a total of 78 institutions performed heart surgery. As in the years before, all departments answered the questionnaire and delivered a complete dataset for the year 2020, including in-hospital mortality rates. In addition, comparisons between the registry data and the external quality assurance in accordance with §§ 135a/136/137 SGB V, obligatory for licensed German hospitals (§ 108 SGB V), are feasible.

For descriptive statistical analyses categorized tables and a summary registry data file consolidate the transmitted information of all departments, providing the basis for this and further publications. Longitudinal data from earlier registry specifications are also included in the presentation. The period considered is restricted to the past 10 years.

Categorical data are displayed as absolute and/or relative frequencies. Due to lack of complete data for patients' risk adjustment, all mortality rates are unadjusted. Quantitative data are presented as absolute frequencies and arithmetic mean values. Where appropriate, the value range is presented additionally. Patient age, though originally a quantitative variable, is only available in age groups and therefore treated as a categorical variable. German population-based measures are calculated as frequencies per 100,000 inhabitants and are based on the latest published data of the Federal Office for Statistics (Destatis) dated December 31, 2019.

The questionnaires were compiled using Microsoft Visual Basic for Applications. Analyses were performed with IBM SPSS Statistics v22 and Microsoft Excel 2010, and charts and tables were created with Microsoft Excel 2010.

## Registry Data 2020

► **Table 1** shows the distribution of cardiac surgical procedures between the 16 German states, based on the population count of the Federal Office for Statistics as of December 31, 2019. The range of heart operations per 100,000 inhabitants again shows a minimum of 94.4 (Bavaria, population: 13,124,737) and a maximum of 167.0 (Sachsen-Anhalt, population: 2,194,782), while the nationwide mean-value by the end of 2020 was 110.9 (► **Table 1**). In addition, ► **Table 1** shows a state-by-state representation of confirmed COVID-19 cases/100,000 population with a median of 1,981 (range: 2,504), a minimum of 746 in Mecklenburg-Vorpommern and maximum of 3,250 in Sachsen. Analyzing quantified categories of heart operations by department dimension, categorizes more than 69% of institutions into two clusters with at least 541 up to 1,497 procedures, 22% into those with a minimum of 1,502 up to a maximum of 3,981 performed procedures (► **Table 2**). Summarizing the departments by various heart surgical procedures, it can be asserted that heart operations in patients for congenital heart disease (CHD) (<1 year, with extracorporeal circulation [ECC]) are conducted in 21, isolated heart transplantations in 19, and combined heart-lung transplantations in 1 institution (► **Table 3**).

The number of procedures using ECC in Germany from 2011 to 2020 is illustrated in ▶ **Table 4**. The comparison from 2019 to 2020 shows a decline by 8,039 procedures, presumably reflecting an enormous effect of the COVID-19 pandemic and only to a small extent the achievement of established innovations, especially minimally invasive heart surgical options.

Overall, 161,817 procedures were reported to the registry for the year 2020, a difference of 7.9% compared with 2019 (175,705 procedures). In 2020, a total of 92,809 heart surgical procedures in the narrower sense displays a COVID-19-related decrease of 7.6% ( $n = 7,637$ ) compared with 2019 (100,446 procedures) (▶ **Table 5**). Concerning gender distribution, the registry shows an overall male/female ratio of almost 2:1 with the greatest difference (4:1) in the patient group with coronary procedures (▶ **Table 6**). About 11.3% ( $n = 10,445$ ) of the operations were conducted as emergency procedures, and 7.9% ( $n = 7,330$ ) were reoperations (▶ **Table 7**). A total of 14,773 (41.7%) isolated heart valve procedures were performed as single, 2,836 as double (8.0%), and 289 (0.8%) as triple valve procedures (▶ **Table V1**). A total of 3,006 (36.7%) aortic valve and 3,342 (55.2%) mitral valve operations were performed via a minimally invasive access (▶ **Table V2**). In 7,194 (87.9%) isolated aortic valve operations using ECC, xenograft prostheses were implanted, while in 3,878 (64.1%) isolated mitral valve operations, a reconstruction with preservation of the native mitral valve could be achieved (▶ **Table V3**, ▶ **Figs. 5 and 7**). In a total of 2,594 combined mitral valve repair procedures, 1,115 (43.0%) simultaneous CABG procedures, 825 tricuspid valve repairs (31.8%), 447 (17.2%) aortic valve procedures, and 207 (8.0%) concomitant CABG and aortic valve replacement (AVR) were performed (▶ **Table V4**). The subgroup of 3,125 multiple heart valve procedures amounted to 2,613 (83.6%) operations, as a combination of mitral + tricuspid ( $n = 1,406$ ) or mitral + aortic ( $n = 1,207$ ) valve procedures (▶ **Table V5**). Regarding 15,621 transcatheter aortic valve implantations (TAVI), 14,275 (91.4%) procedures were performed by transvascular and 1,346 (8.6%) by transapical access. In TAVI procedures without ECC, the unadjusted mortality for those by transvascular access was 1.9% ( $n = 277$ ) and 5.2% ( $n = 70$ ), respectively, for the transapical approach. On the other hand, TAVI under use of ECC shows a remarkably high unadjusted mortality rate of 27.1% ( $n = 70$ ) resp. 30.0% ( $n = 10$ ) (▶ **Table V6**), probably related to complications during the initial procedure.

Concerning 37,979 CABG procedures, 77.5% were performed as isolated operations ( $n = 29,444$ ), 11.7% ( $n = 4,436$ ) combined with AVR and 5.1% ( $n = 1,930$ ) with simultaneous mitral valve procedures (▶ **Table C1**). ▶ **Table C2** provides an overview of the isolated CABG operations focused on the number of bypass grafts and indicates the corresponding unadjusted mortality rates for on/off pump surgery.

▶ **Tables Con1 and Con2** and **Mis1 to Mis5** demonstrate further compiled registry data under different aspects and for various categories.

Compared with the data of previous years some significant changes can be seen on one hand, while several developments remained almost unchanged in 2020 on the other hand. The number of CABG procedures, isolated or combined, shows a

remarkable decrease of 13.9% in 2020, while for isolated heart valve procedures, the difference is just 3.2% (▶ **Fig. 1**). However, unadjusted mortality rates for CABG, AVR, and mitral valve procedures vary just slight over the last decade (▶ **Fig. 2**). The age distribution of patients continues to evolve toward an elderly patient population (▶ **Fig. 3**). Presently, 32.2% of the cardiac procedures are performed in patients from 70 to 79 years of age, and 19.2% were in octo-/nonagenarians. The relative number of isolated off-pump CABG is steadily increasing, reaching 21.9% in 2020 (2019: 20.7%) (▶ **Fig. 4**).

With regard to prosthetic valve distribution in 89.7% ( $n = 7,194$ ) the sAVR was performed using a xenograft, while (▶ **Fig. 5**) in 10.3% ( $n = 830$ ) a mechanical prosthesis was implanted. The unchanged development of transcatheter heart valve procedures in Germany leads to a total of 17,354 procedures in 2020 (▶ **Table V6**). For the last year, 15,701 (66.1%) TAVI and 8,049 (33.9%) surgical aortic valve replacement (sAVR) procedures were reported to the registry (▶ **Fig. 6**). It must be emphasized that exclusively the German departments for cardiac surgery contribute these data. Therefore, the registry cannot reach completeness because procedures documented by cardiology departments are missed. On the basis of and in addition to the recommendations of international scientific guidelines, expert consensus on the management of valvular heart disease,<sup>8-11</sup> the German Federal Joint Committee (G-BA) implemented a quality assurance directive<sup>12</sup> for “minimally invasive heart valve interventions (TAVI, transcatheter mitral clip reconstruction)”, currently under evaluation. Further surveys for selected procedures, such as the legally compulsory quality assurance (§135a SGB V) or the voluntary nationwide German Aortic Valve Registry (GARY),<sup>13-23</sup> provide various important findings and thus also contribute to an exceptional patient benefit.

In 2020, the rate of isolated mitral valve reconstructions remains almost unchanged on a remarkable level of 64.1% (2019: 64.5%) (▶ **Fig. 7**). Based on the fact that each isolated mitral valve procedure is included, regardless of the underlying mitral valve disease concerning morphology or urgency of operation, it can be assumed that the relative rate of mitral valve reconstruction would certainly be even higher if patients without a possibility or indication for reconstruction would have been excluded (e.g., mitral valve stenosis, calcifications, or endocarditis). In other publications, for example, Gammie et al,<sup>24</sup> patients with mitral valve stenosis, endocarditis, and emergency procedures are usually excluded. Therefore, other published rates of mitral valve repair have to be interpreted with caution if compared with this registry.

In 2020, almost half (48.9%;  $n = 2,721$ ) of cardiac operations for CHD were performed in neonates/infants <1 year, 35.1% in children between 1 and 17 years, and 16.0% in patients at least 18 years of age (▶ **Fig. 8**). Concerning ventricular assist device (left/right/biventricular assist device, total artificial heart) implantations ( $n = 843$ ), a significant decrease of 11.5% compared with 2019 ( $n = 953$ ) (▶ **Fig. 9**) could be observed, while the heart transplantations increased to 340 (2019:  $n = 333$ ) (▶ **Fig. 10**). Nevertheless, the mechanical circulatory support therapy, in particular LVAD, is still of outstanding importance for patients with end-stage heart failure.

## Discussion

Even under the exceptional conditions of the COVID-19 pandemic, the registry of the GSTCVS enables a comprehensive overview of all heart surgical procedures performed in Germany in 2020. The accuracy of this registry remains high due to the implemented compilation algorithm using standardized operation coding as a relevant criterion for reimbursement purposes. This is supported by other authors who could demonstrate a high accuracy for major outcome parameters in unaudited registries.<sup>25</sup> As observed in recent years, heart surgery in Germany is performed on a high level with superior in-hospital patient survival compared with international surveys. In addition, the registry demonstrates that the provision of cardiac surgery in Germany could be guaranteed nationwide even under COVID-19 at all times (24/7/365). These aspects are especially important in the context of various activities in health care policy and considering the background of demographic trends of the German population, leading to patients at increased age combined with related comorbidities and an accordingly complex perioperative risk profile.

Compared with 2019, the number of cardiac surgery procedures showed a relevant decrease for isolated/combined CABG and sAVR, an ongoing trend in view of the German population characteristics and in the context of application of the scientific guidelines.<sup>26,27</sup> Despite this for the year 2020, it must be taken into account that the care of patients with heart disease was affected by the consequences of the severe acute respiratory syndrome coronavirus 2 pandemic with repeated shutdowns throughout Germany and various restrictions of elective/urgent heart surgical procedures due to limited intensive care resources in all German cardiac centers. Otherwise, the renewed increase in heart transplantations is a reason for hope that this positive development will continue.

Further improvements of the registry are recommended to enable more specified assessments and particularly risk-adjusted data analyses. However, if significant fundamental changes related to the modality of data collection were to be implemented, a modified structure would have to ensure further longitudinal data analysis.

Completeness, validity, and further progress depend on continued efforts and a close collaboration of the GSTCVS and

all cardiac surgical departments in our country. This will be of outstanding importance as a contribution for patient safety and to obtain evidence for the high quality of heart surgery in Germany.

### Conflict of Interest

None declared.

### Acknowledgments

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## Abbreviations

ASD	atrial septal defect
AVC	Atrioventricular canal
CABG	coronary artery bypass grafting
CHD	congenital heart disease
CIED	Cardiac Implantable Electronic Devices
DLTx	double lung transplantation
DORV	double outlet right ventricle
ECC	extracorporeal circulation
ECLS	extracorporeal life support
ECMO	extracorporeal membrane oxygenation
HLTx	heart-lung transplantation
HTx	heart transplantation
ICD	implantable cardioverter defibrillator
LTx	lung transplantation
PDA	patent ductus arteriosus
PTS	patients
SAVR	surgical aortic valve replacement
SLTx	single lung transplantation
TAH	total artificial heart
TAVI	transcatheter aortic valve implantation
TGA	transposition of great arteries
TMLR	transmyocardial laser revascularization
Tx	transplantation
VAD	ventricular assist device
VSD	ventricular septal defect

## Tables and Figures

**Table 1** German states/Heart operations/confirmed COVID-19 cases

Federal state	Population <sup>a</sup>	Quantity <sup>b</sup>	Heart procedures/ 100,000 inhabitants	Total number of COVID-19 cases <sup>c</sup>	COVID-19 cases/ 100,000 population <sup>c</sup>
Baden Württemberg	11,100,394	10,842	97.7	237,993	2,144
Bayern	13,124,737	12,384	94.4	324,937	2,476
Berlin	3,669,491	3,738	101.9	96,788	2,638
Brandenburg	2,521,893	3,291	130.5	41,241	1,635
Bremen	681,202	736	108.0	13,559	1,990
Hamburg	1,847,253	2,231	120.8	36,417	1,971
Hessen	6,288,080	6,554	104.2	136,577	2,172
Mecklenburg-Vorpommern	1,608,138	2,060	128.1	11,997	746
Niedersachsen	7,993,608	9,223	115.4	106,789	1,336
Nordrhein-Westfalen	17,947,221	20,363	113.5	393,185	2,191
Rheinland-Pfalz	4,093,903	4,656	113.7	71,993	1,759
Saarland	986,887	1,119	113.4	19,879	2,014
Sachsen	4,071,971	4,864	119.5	132,356	3,250
Sachsen-Anhalt	2,194,782	3,665	167.0	29,200	1,330
Schleswig-Holstein	2,903,773	3,730	128.5	24,792	854
Thüringen	2,133,378	2,814	131.9	42,034	1,970
Germany	83,166,711	92,270	110.9	1,719,737	2,068

<sup>a</sup>Federal Office for Statistics of German Population; due date Dec 31, 2019.

<sup>b</sup> $n = 539$ , foreign residences excluded.

<sup>c</sup>Robert Koch Institute: laboratory confirmed COVID-19 cases; due date Dec 31, 2020 12:00 AM.

**Table 2** Departments assorted by quantified categories ( $\Sigma^a [n = 92,809]$ )

Procedures (quantity)	<500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments	7	32	22	7	10
Average	343	784	1,215	1,700	2,671
Range	186–451	541–988	1,009–1,497	1,502–1,867	2,038–3,981

<sup>a</sup>CIED and extracardiac surgery without ECC are excluded.

**Table 3** Departments summarized by heart surgery procedures 2020

Category	<i>n</i>
Coronary artery bypass grafting	77
Heart valve surgery	77
Pacemaker/ICD procedures	75/72
Surgery for CHD (pat. <1 year with ECC)	21 <sup>a</sup>
Heart transplantation	19 <sup>b</sup>
Heart-lung transplantation	1

<sup>a</sup> $n = 2,061$ : thereof: 24–43 op. in 6, 59–89 op. in 5, 108–211 op. in 10 units.

<sup>b</sup> $n = 340$ : thereof: 2–4 transpl. in 5, 7–9 transpl. in 4, 11–20 transpl. in 4, 28–73 transpl. in 6 units.

**Table 4** Cardiac procedures using extracorporeal circulation (2011–2020)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Departments	78	79	79	78	78	78	78	78	78	78
Operations	84,402	84,388	84,040	83,787	81,527	79,082	76,696	72,331	71,759	63,720
Average	1,082	1,068	1,064	1,074	1,045	1,014	983	927	920	817

**Table 5** Frequency of cardiac procedures 2020

Category	With ECC	Without ECC	Total	Diff. 2019 (%)
CABG isolated	23,004 <sup>a</sup>	6,440 <sup>a</sup>	29,444	-14.0%
CABG combined	8,359	181	8,540	-13.5%
Heart valve procedures	18,137 <sup>a</sup>	17,332 <sup>a</sup>	35,469	-3.2%
Surgery of thoracic aorta	7,177 <sup>a</sup>	655 <sup>a</sup>	7,832	-5.0%
Surgery for CHD	4,714 <sup>a</sup>	855 <sup>a</sup>	5,569	-3.3%
Cardiac surgery, other	1,278 <sup>a</sup>	1,251 <sup>a</sup>	2,529	-5.9%
Assist device procedures	656 <sup>a</sup>	2,375 <sup>a</sup>	3,031	+ 15.2%
Extracardiac surgery	363 <sup>a</sup>	48,796	49,159	-9.5%
Pacemaker and ICD procedures	32 <sup>a</sup>	20,212	20,244	-5.0%
<b>Total</b>	<b>63,720</b>	<b>98,097</b>	<b>161,817</b>	<b>-7.9%</b>

<sup>a</sup>Sum: n = 92,809 (heart surgery procedures).

**Table 6** Gender distribution

Distribution	Female		Male	
	n	%	n	%
Heart valve procedures	15,302	43	20,167	57
Coronary procedures	7,786	20	30,198	80
CHD procedures	2,481	45	3,088	55
Surgery of thoracic aorta	2,642	34	5,190	66
Cardiac surgery, other	1,457	58	1,072	42
Assist device	773	26	2,258	74
Pacemaker and ICD	7,672	38	12,572	62
Extracardiac surgery	16,274	33	32,885	67
<b>Total</b>	<b>54,387</b>	<b>34</b>	<b>107,430</b>	<b>66</b>

**Table V1** Isolated heart valve procedures

Procedure	n	†	%
Single valve	14,773	479	3.2
Double valve	2,836	237	8.4
Triple valve	289	34	11.8
Transcatheter access (single valve)	17,443	400	2.3
Transcatheter access (double valve)	28	3	10.7
Unspecified	100	12	12.0
<b>Total</b>	<b>35,469</b>	<b>1,165</b>	<b>3.3</b>

Notes: Transcatheter heart valve procedures: 15,701 aortic valve implantation; 161 mitral valve implantation; 1,325 mitral valve repair; 6 tricuspid valve implantation; 250 tricuspidal valve repair; 28 double aortic and mitral valve procedure; no pulmonary valve implantation.

**Table V4** Isolated/combined mitral valve procedures—implantation/replacement versus repair

Mitral valve procedures	Repair			Implantation/replacement			Total		
	n	†	%	n	†	%	n	†	%
Isolated	3,878	45	1.2	2,172	174	8.0	6,050	219	3.6
+ CABG	1,115	71	6.4	815	131	16.1	1,930	202	10.5
+ Tricuspid valve repair <sup>a</sup>	825	25	3.0	534	57	10.7	1,359	82	6.0
+ Aortic valve	447	23	5.1	760	104	13.7	1,207	127	10.5
+ CABG + aortic valve replacement	207	20	9.7	274	53	19.3	481	73	15.2
<b>Total</b>	<b>6,472</b>	<b>184</b>	<b>2.8</b>	<b>4,555</b>	<b>519</b>	<b>11.4</b>	<b>11,027</b>	<b>703</b>	<b>6.4</b>

<sup>a</sup>Forty-seven procedures (not specified mitral valve + tricuspid valve surgery) excluded, Mortality: 15% (7/47).

**Table 7** Additional data 2020 versus 2019

Procedures with ECC	2020		2019	
	n	%	n	%
Emergency	10,445	11.3%	10,861	10.8%
Redo	7,330	7.9%	8,481	8.4%

**Table V2** Single heart valve procedures

Access path	n	†	%
<b>Aortic valve</b>			
Sternotomy	5,180	189	3.6
Partial sternotomy	3,006	31	1.0
Transvascular	14,345	296	2.1
Transapical	1,356	73	5.4
<b>Mitral valve</b>			
Sternotomy	2,708	174	6.4
Minimal invasive	3,342	45	1.3
Transcatheter	1,486	26	1.7
<b>Tricuspidal valve</b>			
Sternotomy	340	35	10.3
Minimal invasive	138	5	3.6
Transcatheter	256	5	2.0
<b>Pulmonary valve</b>			
Sternotomy	57	0	0.0
Minimal invasive	0	0	–
Transcatheter	0	0	–
<b>Total</b>	<b>32,214</b>	<b>879</b>	<b>2.7</b>

Apical aortic conduits procedures (n = 2) are not included.

**Table V3** Isolated aortic/mitral valve operations

Prosthesis/native heart valve	Aortic			Mitral		
	n	†	%	n	†	%
Xenograft	7,194	205	2.8	1,769	156	8.8
Mechanical prosthesis	830	10	1.2	398	17	4.3
Repair	137	2	1.5	3,878	45	1.2
Homograft	25	3	12.0	5	1	20.0
<b>Total</b>	<b>8,186</b>	<b>220</b>	<b>2.7</b>	<b>6,050</b>	<b>219</b>	<b>3.6</b>

Note: Transcatheter procedures and apical aortic conduits procedures (n = 2) excluded.

**Table V5** Multiple heart valve procedures

Combination	n	†	%
Mitral + tricuspid	1,406	89	6.3
Aortic + mitral	1,207	127	10.5
Aortic + mitral + tricuspid	287	34	11.8
Aortic + tricuspid	155	18	11.6
Aortic + pulmonary <sup>a</sup>	58	1	1.7
Tricuspid + pulmonary	10	2	20.0
Aortic + mitral + pulmonary	2	0	0.0
<b>Total</b>	<b>3,125</b>	<b>271</b>	<b>8.7</b>

Notes: Transcatheter procedures are excluded.

<sup>a</sup>Including Ross procedures.

**Table V6** Transcatheter heart valve procedures

	Without ECC		With ECC		Total		
	n	†	n	†	n	†	%
Aortic valve implantation	15,621	347	80	22	15,701	369	2.4
Transvascular	14,275	277	70	19	14,345	296	2.1
Transapical	1,346	70	10	3	1,356	73	5.4
Mitral valve	1,428	24	58	2	1,486	26	1.7
Repair	1,279	14	46	0	1,325	14	1.1
Implantation	149	10	12	2	161	12	7.5
Tricuspid valve repair	256	5	0	0	256	5	2.0
Repair	250	4	0	0	250	4	1.6
Implantation	6	1	0	0	6	1	16.7
Aortic + mitral valve implantation	27	3	1	0	28	3	10.7
Aortic valve implantation <sup>a</sup> + CABG	21	1	16	8	37	9	24.3
Mitral valve implantation <sup>b</sup> + CABG	1	0	4	1	5	1	20.0
Aortic + mitral valve + CABG	0	0	0	0	0	0	-
<b>Total</b>	<b>17,354</b>	<b>380</b>	<b>159</b>	<b>33</b>	<b>17,513</b>	<b>413</b>	<b>2.4</b>

Notes: Pulmonary valve implantation for CHD excluded; 9% of TAVI by transapical access and less than 1% of TAVI under ECC conditions.

<sup>a</sup>Femoral, subclavian, or transaortic access.

<sup>b</sup>Transvascular and transapical access.

**Table C1** Isolated CABG and combined procedures with ECC

	n	†	%
Isolated CABG	29,444	830	2.8
+ Aortic valve replacement	4,436	198	4.5
+ Other	1,582	96	6.1
+ Mitral valve repair	1,115	71	6.4
+ Mitral valve replacement	815	131	16.1
+ Aortic valve replacement + mitral valve repair	207	20	9.7
+ Aortic + mitral valve replacement	274	53	19.3
+ Aneurysm resection	69	3	4.3
+ Transcatheter aortic valve implantation	37	9	24.3
+ Transcatheter mitral valve procedure	5	1	20.0
<b>Total</b>	<b>37,984</b>	<b>1,412</b>	<b>3.7</b>

**Table C2** Isolated CABG on-/off-pump surgery

Grafts	On-pump			Off-pump			Total		
	n	†	%	n	†	%	n	†	%
Single	748	42	5.6	1,225	24	2.0	1,973	66	3.3
Double	4,491	166	3.7	1,682	39	2.3	6,173	205	3.3
Triple	9,850	280	2.8	2,443	43	1.8	12,293	323	2.6
Quadruple	5,740	146	2.5	869	18	2.1	6,609	164	2.5
Quintuple + more	2,175	69	3.2	221	3	1.4	2,396	72	3.0
<b>Total</b>	<b>23,004</b>	<b>703</b>	<b>3.1</b>	<b>6,440</b>	<b>127</b>	<b>2.0</b>	<b>29,444</b>	<b>830</b>	<b>2.8</b>

**Table Con1** Congenital heart surgery with/without ECC

Age (y)	n		†		%	
	With ECC	Without ECC	With ECC	Without ECC	With ECC	Without ECC
< 1	2,084	660	78	17	3.7	2.6
1–17	1,832	167	21	1	1.1	0.6
≥ 18	866	28	28	0	3.2	0.0
<b>Total</b>	<b>4,782</b>	<b>855</b>	<b>127</b>	<b>18</b>	<b>2.7</b>	<b>2.1</b>

**Table Con2** Procedures for congenital heart disease with and without ECC

Lesion/Procedure	Age < 1 year			Age 1 to 17 years			Age ≥ 18 years		
	n	†	%	n	†	%	n	†	%
ASD	34	0	0.0	245	0	0.0	208	7	3.4
Complete AV-canal	217	5	2.3	93	3	3.2	6	0	0.0
VSD	335	2	0.6	91	1	1.1	17	2	11.8
Fallot's tetralogy	182	1	0.5	41	0	0.0	1	0	0.0
DORV	55	2	3.6	21	1	4.8	1	0	0.0
TGA	144	3	2.1	9	0	0.0	0	–	–
TGA + VSD	61	2	3.3	5	0	0.0	0	–	–
Truncus arteriosus	31	2	6.5	6	0	0.0	0	–	–
Fontan circulation	0	–	–	250	0	0.0	4	0	0.0
Norwood	142	23	16.2	3	0	0.0	0	–	–
Pulmonary valve	60	1	1.7	217	3	1.4	57	1	1.8
Transcatheter pulmonary valve implantation	0	–	–	0	–	–	10	0	0.0
Aortic valve	59	1	1.7	214	3	1.4	333	7	2.1
Ross procedure	8	2	25.0	27	0	0.0	19	0	0.0
Mitral valve	44	1	2.3	123	0	0.0	84	4	4.8
Tricuspid valve	141	1	0.7	83	2	2.4	49	5	10.2
PDA	133	2	1.5	20	0	0.0	1	0	0.0
Coarctation	239	4	1.7	33	0	0.0	3	0	0.0
Others	857	43	5.0	483	7	1.4	101	2	2.0
HTx	1	0	0.0	24	2	8.3	0	–	–
HLTx	0	–	–	0	–	–	0	–	–
LTx	1	0	0.0	11	0	0.0	0	–	–
<b>Total</b>	<b>2,744</b>	<b>95</b>	<b>3.5</b>	<b>1,999</b>	<b>22</b>	<b>1.1</b>	<b>894</b>	<b>28</b>	<b>3.1</b>



**Table Mis1** Ross procedures (autologous AV and PVR)

Age (y)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
< 18	40	36	33	37	28	38	38	29	32	35
≥ 18	134	117	107	90	64	72	52	61	104	70
<b>Total</b>	<b>174</b>	<b>153</b>	<b>140</b>	<b>127</b>	<b>92</b>	<b>110</b>	<b>90</b>	<b>90</b>	<b>136</b>	<b>105</b>

**Table Mis2** Heart and lung transplantation

Transplant	With ECC			Without ECC		
	n	†	%	n	†	%
HTx	340	30	8.8			
HLTx	1	0	0.0			
LTx	40	3	7.5	251	18	7.2

Notes: All pediatric transplantations (demonstrated in Table Con2) are included in this table.

Eurotransplant (ET) report 2020: 327 HTx, 10 HTx + kidneyTx, 1 HTx + liverTx, 1 HLTx, 315 DLTx, 25 SLTx, 1 LTx + kidneyTx and 2 LTx + liverTx.

**Table Mis3** Aortic surgery

Replacement <sup>a</sup>	With ECC			Without ECC		
	n	†	%	n	†	%
Supracoronary replacement of ascending aorta	1,166	106	9.1			
Supracoronary ascending + aortic valve replacement	1,205	50	4.1			
Infracoronary replacement of ascending aorta						
Mechanical aortic valve conduits	327	20	6.1			
Biological aortic conduits	1,046	102	9.8			
David procedure	517	9	1.7			
Yacoub procedure	101	3	3.0			
Other	274	28	10.2			
Aortic arch replacement <sup>b</sup>	2,396	345	14.4			
Replacement of descending aorta	60	6	10.0	4	0	0.0
Thoraco-abdominal aortic replacement	82	15	18.3	18	1	5.6
Endostent descending aorta	3	1	33.3	633	27	4.3
<b>Total</b>	<b>7,177</b>	<b>685</b>	<b>9.5</b>	<b>655</b>	<b>28</b>	<b>4.3</b>

Notes: All procedures involving aortic surgery are included in this table, Isolated aortic surgery as well as all possible combined procedures (e.g., additional CABG) are summarized in this category.

<sup>a</sup>Procedures for abdominal aortic diseases excluded: 463, abdominal procedures and 21 endovascular abdominal stents.

<sup>b</sup>All possible combined procedures included; the only common denominator is aortic arch surgery.

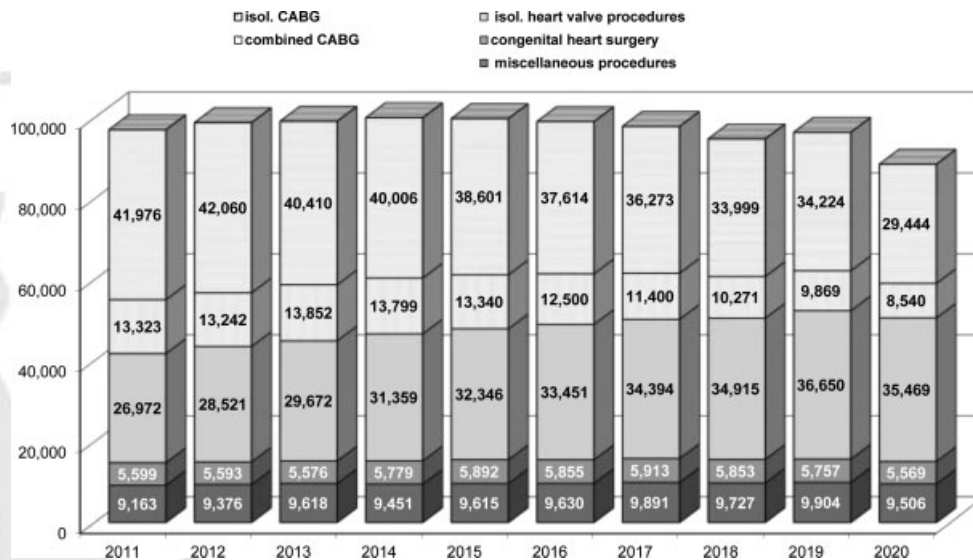
**Table Mis4** Pacemaker and ICD procedures

Device/Category				With ECC		Without ECC	
	n	†	%	n	†	n	†
<b>Pacemaker</b>	12,698	85	0.7	14	2	12,684	83
Implantation	8,510	58	0.7	2	0	8,508	58
Battery exchange	1,662	2	0.1	0	0	1,662	2
Revision procedures	2,526	25	1.0	12	2	2,514	23
<b>ICD</b>	6,489	58	0.9	16	4	6,473	54
Implantation	2,741	7	0.3	0	0	2,741	7
Battery exchange	1,427	1	0.1	0	0	1,427	1
Revision procedures	2,321	50	2.2	16	4	2,305	46
<b>Miscellaneous</b>	1,057	4	0.4	2	0	1,055	4
<b>Total</b>	<b>20,244</b>	<b>147</b>	<b>0.7</b>	<b>32</b>	<b>6</b>	<b>20,212</b>	<b>141</b>

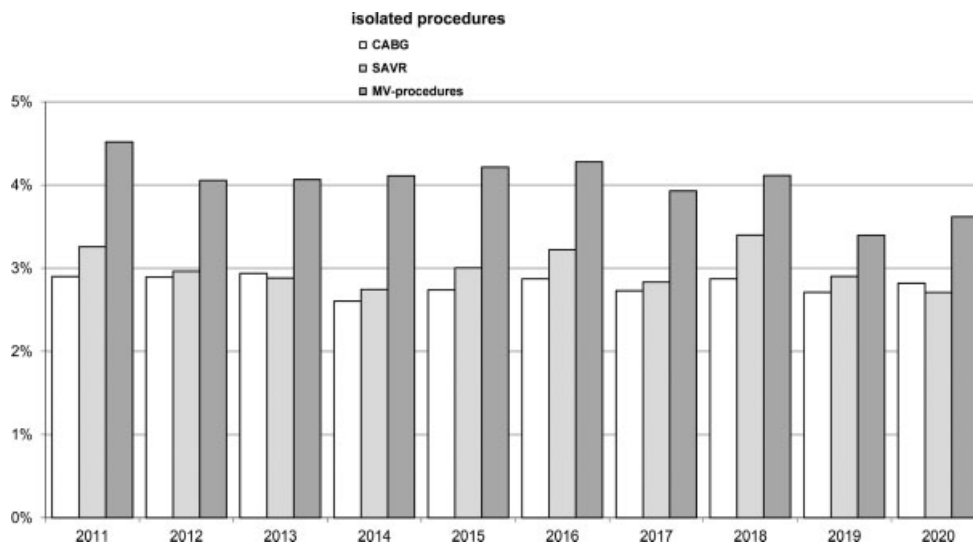
**Table Mis5** Surgical procedures for tachyarrhythmia

Energy source	Endocardiac	Epicardiac	n
	n	n	
Unipolar radio frequency	116	191	307
Unipolar cooled radio frequency	41	123	164
Bipolar radiofrequency	164	1,626	1,790
Cryotherapy	1,424	351	1,775
Microwave	1	7	8
Focused ultrasound	1	93	94
Laser	1	0	1
Other	7	4	11
<b>Total</b>	<b>1,755</b>	<b>2,395</b>	<b>4,150</b>

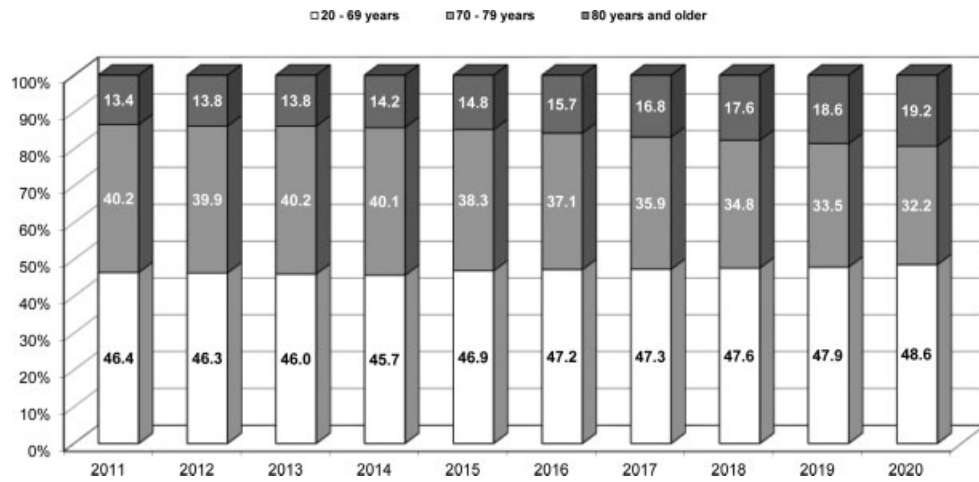
Note: 202 procedures are unspecified with regard to endocardiac/epicardiac ablation.



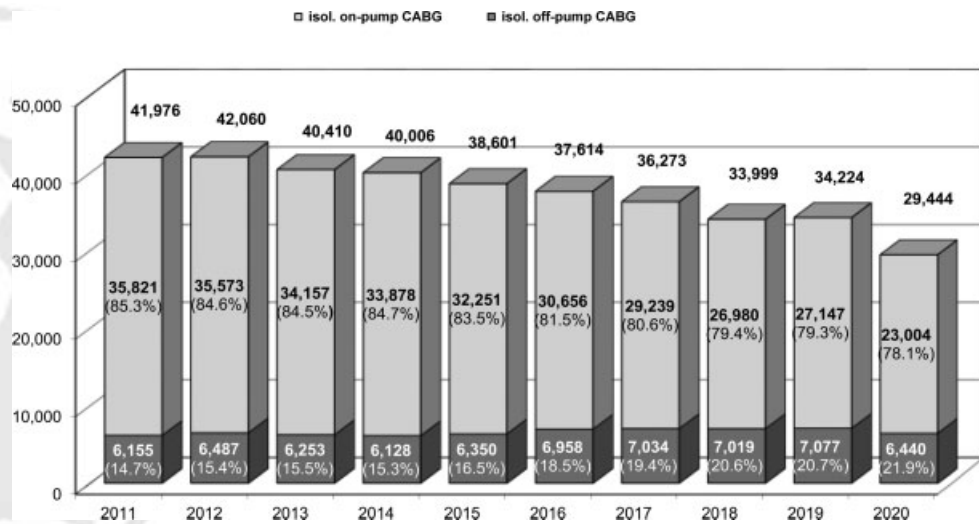
**Fig. 1** Selected heart surgical categories (2011–2020). Notes: Congenital heart surgery: Atrial septal defect repairs in adults or in combination with coronary artery bypass grafting (CABG) or heart valve procedures are summarized in the CABG or heart valve procedure groups; miscellaneous procedures: all other types of procedures with extracorporeal circulation.



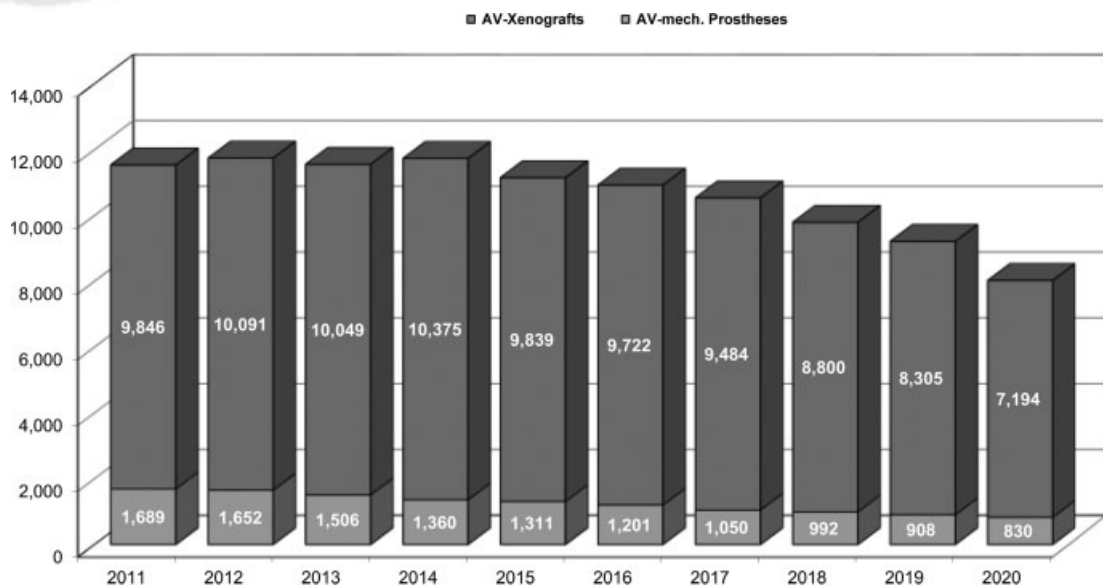
**Fig. 2** Unadjusted mortality for selected procedures (2011–2020).



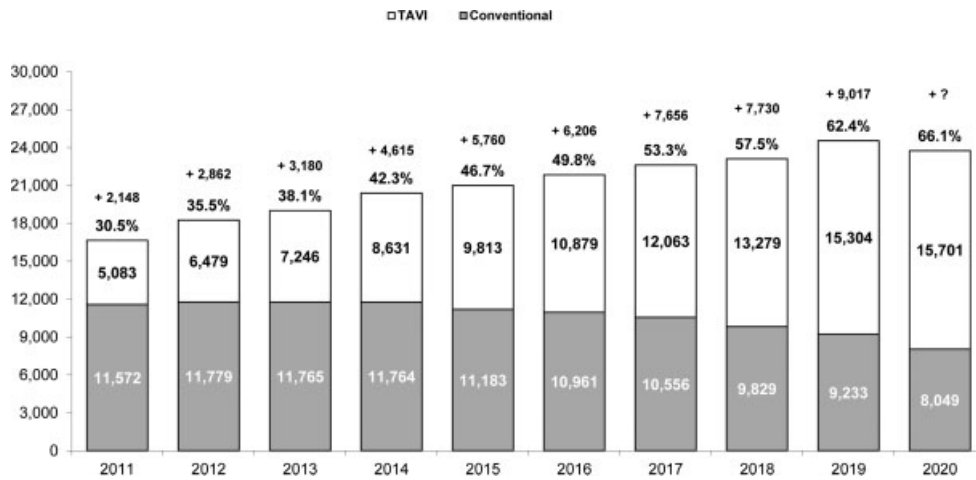
**Fig. 3** Age distribution of cardiac procedures (2011–2020). Notes: Patients < 20 years and CIED procedures excluded.



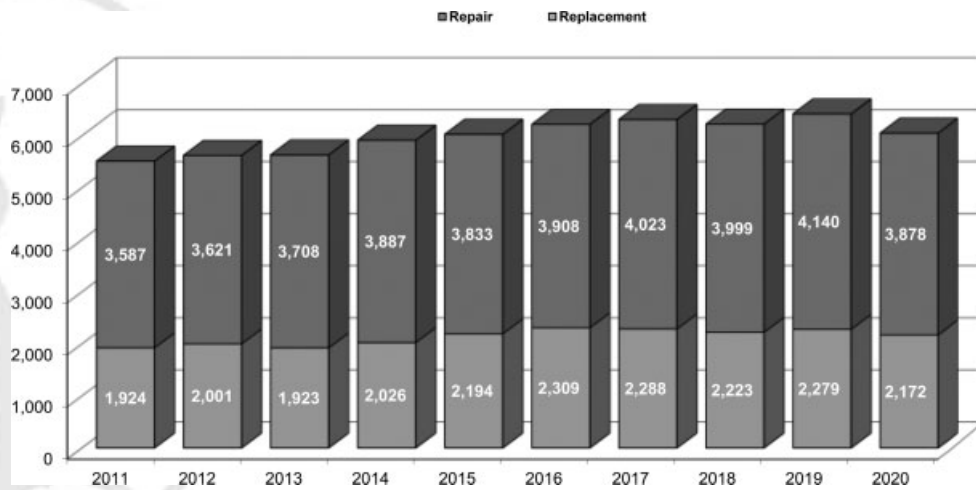
**Fig. 4** Isolated coronary artery bypass grafting (CABG) (2011–2020).



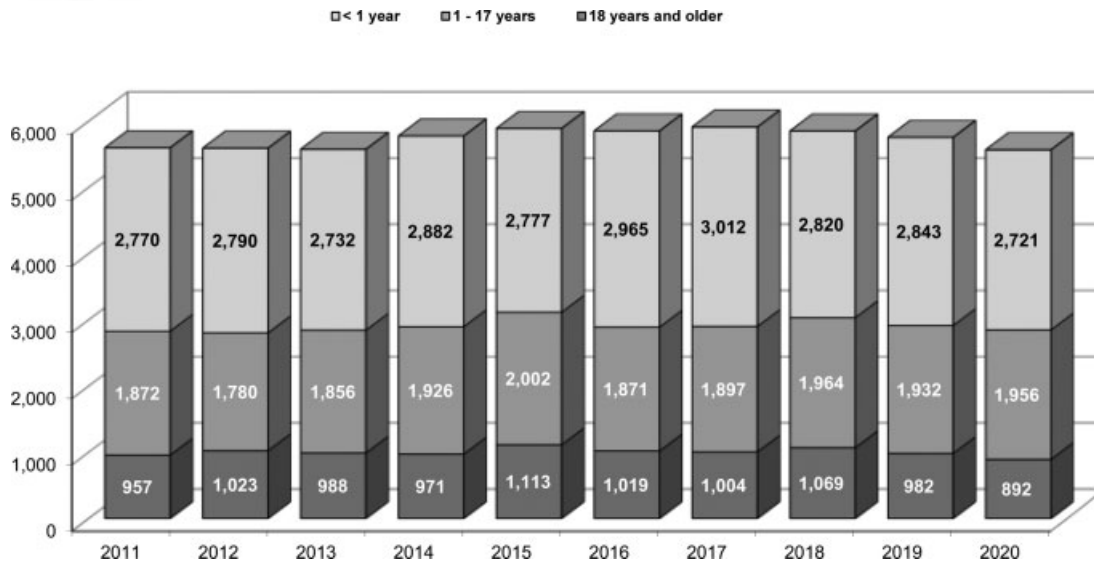
**Fig. 5** Isolated aortic valve (AV) replacement (2011–2020). Notes: Ross procedures, homograft implantations, and transcatheter heart valve interventions excluded.



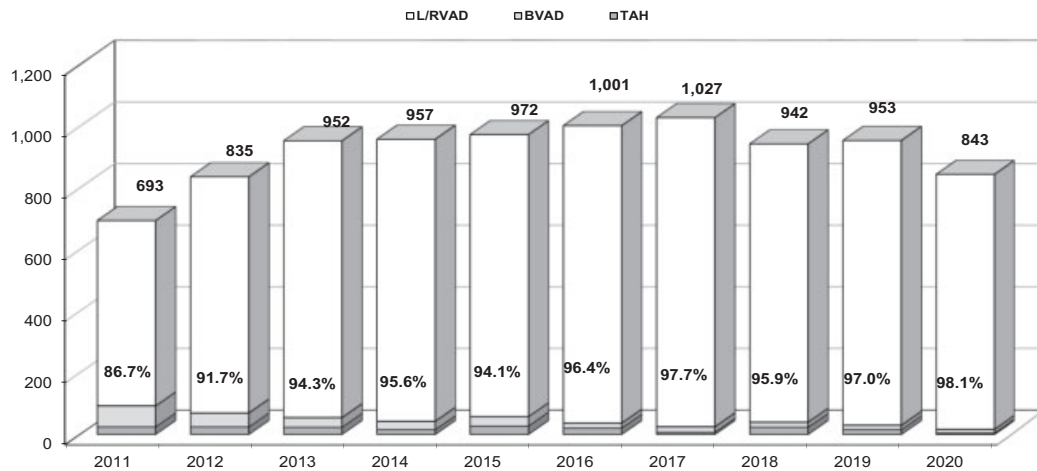
**Fig. 6** Isolated aortic valve replacement and transcatheter aortic valve implantation (TAVI). +Additional TAVI procedures calculated from the German legal quality assurance program, §§ 135a/ 136/ 137 SGB V.



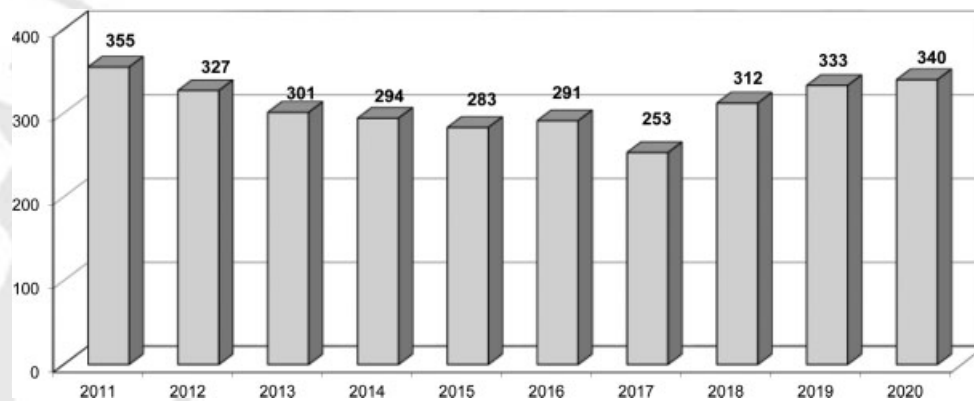
**Fig. 7** Isolated mitral valve surgery (2011–2020).



**Fig. 8** Age distribution for congenital heart disease (CHD) (2011–2020). Notes: Bias possible due to the fact that not all relevant procedures can be allocated exactly to CHD-category in patients > 18 years (e.g., aortic valve disease).



**Fig. 9** Mechanical circulatory support devices (2011–2020).



**Fig. 10** Heart transplantation (2011–2020).

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