

# German Heart Surgery Report 2018: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

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## Abstract

### Keyword

- ▶ heart valve procedures
- ▶ heart surgery
- ▶ mortality
- ▶ congenital heart disease
- ▶ coronary heart disease
- ▶ aorta surgery
- ▶ coronary artery bypass grafting
- ▶ heart and lung transplantation

Based on a longtime voluntary registry, founded by the German Society for Thoracic and Cardiovascular Surgery (GSTCVS), well-defined data of all cardiac, thoracic, and vascular surgery procedures performed in 78 German heart surgery departments during the year 2018 are analyzed. For this period, a total of 174,902 procedures were submitted to the registry, 98,707 summarized as heart surgery procedures in the classical meaning. The unadjusted in-hospital survival rate for 33,999 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 3.8:1) was 97.1% and for 34,915 isolated heart valve procedures, 14,396 transcatheter interventions included, it was 96.0%. Concerning short- and long-term circulatory supports, a total of 2,871 extracorporeal life support (ECLS)/extracorporeal membrane oxygenation (ECMO) implants, respectively, 942 assist device implantations (L-/R-/BVAD, TAH) were registered. In 2018, the number of isolated heart transplantations increased to 312, a growth of 23% compared with the previous year. The isolated lung transplantations reached 340, a rise of nearly 19%. This annual 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 is a basis for quality management for all participating institutions. In addition, the registry demonstrates that the provision of cardiac surgery in Germany is appropriate and nationwide patient treatment is guaranteed all the time.

## 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, resulting in the development of versatile quality assurance activities such as benchmark projects, public reporting, registries, and others to answer those needs. Thirty 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 sense of a registry, and published in the scientific society journal each year.<sup>3–7</sup> The prevalent aims are: to detect developments and upcoming trends in cardiac surgery in Germany; to compile various results for nearly all cardiac surgical procedures; to

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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 German society.

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 and all kinds of heart valve procedures, including transcatheter aortic valve implantation (TAVI). Thereby, important findings for current patient safety and the future of patient care are collected for evaluation under different aspects.

Data and results presented in this report comprehend assorted findings of the year 2018.

## 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 (Operationen- und Prozedurenschlüssel).

All participating institutions were requested to complete the structured questionnaire by January 21, 2019, 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 2018 were all cardiac surgical procedures performed on patients between January 1, 2018, and December 31, 2018, 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 count 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 locally existing hard- and software used.

In 2018, a total of 78 institutions performed heart surgery. As always, all departments answered the questionnaire and delivered a complete dataset for the year 2018 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 statistical analyses, categorized tables and a summary registry data file consolidate all transmitted information of the 78 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 the 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) from November 30, 2018.

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 2018

► **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 November 30, 2018. The range of heart operations per 100,000 inhabitants again shows a minimum of 102.1 (Baden Württemberg, population: 11,076,352) and a maximum of 165.3 (Sachsen-Anhalt, population: 2,209,938), while the nationwide mean value was 117.9 (2017: 122.0). Analyzing quantified categories of heart operations by department dimension, nearly 67% of institutions are in two clusters with at least 518 up to 1,480 procedures, and 26% in those with a minimum of 1,569 up to a maximum of 3,872 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 (< 1 year, with extracorporeal circulation [ECC]) are conducted in 22, isolated heart transplantations in 20, and combined heart-lung transplantations in 2 institutions (► **Table 3**). The number of procedures using ECC in Germany from 2009 to 2018 is illustrated in ► **Table 4**. Over the past decade, the number of heart operations using ECC shows a decline by 14,585 procedures, presumably reflecting an achievement of

established innovations such as catheter-based procedures in cardiac medicine and minimally invasive therapeutic options in heart surgery.

Overall, 174,902 procedures were reported to the registry for the year 2018, a decrease of 2.5% (2017: 179,337 procedures). In 2018, a total of 98,707 heart surgical procedures in the narrower sense display a decline of 3.0% ( $n = 3,021$ ) compared with 2017 (101,728 procedures) (► **Table 5**). Concerning gender distribution, the registry shows an overall male:female ratio of 1.9:1 with the greatest distinction (3.3:1) in the patient group of coronary procedures (► **Table 6**); 11.3% ( $n = 11,147$ ) of the operations were conducted as emergency procedures, and 8.8% ( $n = 8,642$ ) were reoperations (► **Table 7**). A total of 16,840 (48.2%) isolated heart valve procedures were performed as single, 3,233 as double (9.3%), and 353 (1.0%) as triple valve procedures (► **Table V1**); 7,021 (41.7%) single heart valve operations were performed via a minimally invasive access (► **Table V2**). In 8,800 (87.8%) isolated aortic valve operations under ECC conditions, xenograft prostheses were implanted, while in 3,999 (64.3%) isolated mitral valve operations, a reconstruction with preservation of the native valve could be achieved (► **Table V3**, ► **Figs. 5 and 7**). The subdivision of 3,586 multiple heart valve procedures led to 3,014 (84.0%) operations, as a combination of mitral + tricuspid ( $n = 1,607$ ) or mitral + aortic ( $n = 1,407$ ) valve procedures (► **Tables V4 and V5**).

► **Tables V6, C1, C2, Con1, Con2, and Mis1 to Mis5** as well as ► **Figs. 1–4, 6, 8–10** demonstrate further compiled registry data under different aspects and for various categories.

Compared with the data of previous years, several important developments remained almost unchanged in 2018. The age distribution of patients (► **Fig. 3**) shows a continuous shift toward an elderly patient population, with presently 34.8% of the cardiac procedures being performed in patients from 70 to 79 years of age, and 17.6% in octo-/nonagenarians. However, unadjusted mortality rates remain on the same low level over the past decade (► **Fig. 2**). The number of CABG procedures, isolated or combined, decreased over the past decade, while the relative count for isolated off-pump CABG has now reached a level of 20.6% (2017: 19.4%) (► **Figs. 1 and 4**).

There is still a continuous increase of transcatheter heart valve procedures in Germany (► **Table V6**). In 2018, a total of 13,279 (57.5%) TAVI procedures and 9,829 (42.5%) surgical aortic valve replacements were reported to the registry (► **Fig. 6**). It must be emphasized that exclusively the German departments for cardiac surgery contribute their data and therefore the registry cannot reach completeness by the way of exception. On the basis of and in addition to the recommendations of international scientific guidelines resp. expert consensus on the management of valvular heart disease,<sup>8–11</sup> in July 2015, the German Federal Joint Committee (G-BA) implemented a quality assurance directive for “minimally invasive heart valve interventions (TAVI, transcatheter mitral clip reconstruction),” in which obligatory structures, defined processes, and qualified

personnel are precisely specified.<sup>12</sup> Further surveys for selected procedures, such as the legally compulsory quality assurance (§135a SGB V) or the voluntary nationwide German Aortic Valve Registry,<sup>13–18</sup> provide various important findings and thus contribute to an exceptional patient benefit.

In 2018, the rate of mitral valve reconstructions shows a slight increase to 64.3% (2017: 63.7%) (► **Fig. 7**). Based on the fact that each isolated mitral valve procedure is included, regardless of the underlying 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>19</sup> patients with mitral valve stenosis, endocarditis, and emergency procedures are usually excluded. Therefore, the published rates of mitral valve repair have to be interpreted with caution if compared with this registry.

In 2018, the ventricular assist device (L-/R-/BVAD, TAH) implantations ( $n = 942$ ) showed a decrease of 8.2% compared with 2017 ( $n = 1,027$ ) (► **Fig. 9**), while the heart transplantations ( $n = 312$ ) reached the highest level for the past 5 years (► **Fig. 10**). Nevertheless, the mechanical circulatory support therapy, in particular LVAD, is still of outstanding importance for patients with end-stage heart failure.

## Discussion

The registry of the GSTCVS enables a comprehensive overview of all heart surgical procedures performed in Germany in 2018. The accuracy of this registry is considered to be 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>20</sup> As observed in recent years, heart surgery in Germany is continuously 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 is appropriate, and that patient care is guaranteed nationwide 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 preoperative risk profile.

Compared with 2017, the number of cardiac surgery procedures showed a disproportionate decrease for coronary artery bypass procedures, a curious trend in view of the German population characteristics and in the context of application of the scientific guidelines.<sup>21,22</sup> Otherwise, the remarkable 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 are conducted, it has to be considered that data compatibility will still allow 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 Germany. 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.

#### Acknowledgments

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## Abbreviations

ASD	atrial septal defect
AVC	Atrioventricular canal
CABG	coronary artery bypass grafting
CHD	congenital heart disease
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
VADs	ventricular assist devices
VSD	ventricular septal defect

## Tables and Figures

**Table 1** Heart operations/German states

Federal state	Quantity <sup>a</sup>	Population <sup>b</sup>	Heart procedures/100,000 inhabitants
Baden Württemberg	11,306	11,076,352	102.1
Bayern	13,690	13,082,541	104.6
Berlin	3,923	3,644,998	107.6
Brandenburg	3,414	2,511,943	135.9
Bremen	799	682,947	117.0
Hamburg	2,232	1,841,484	121.2
Hessen	7,395	6,268,099	118.0
Mecklenburg-Vorpommern	2,266	1,610,280	140.7
Niedersachsen	10,235	7,984,849	128.2
Nordrhein-Westfalen	20,610	17,932,567	114.9
Rheinland-Pfalz	5,119	4,085,831	125.3
Saarland	1,313	991,116	132.5
Sachsen	5,107	4,079,703	125.2
Sachsen-Anhalt	3,653	2,209,938	165.3
Schleswig-Holstein	4,005	2,897,035	138.2
Thüringen	2,876	2,144,446	134.1
<b>Germany</b>	<b>97,943</b>	<b>83,044,129</b>	<b>117.9</b>

<sup>a</sup>n = 764 foreign residents excluded.

<sup>b</sup>Federal Office for Statistics of German: Population; due date November 30, 2018.

**Table 2** Departments assorted by quantified categories ( $\sum^a [n = 98,707]$ )

Procedures (quantity)	<500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments	6	25	27	10	10
Average	367	789	1,190	1,750	2,716
Range	225–475	518–991	1,004–1,480	1,569–1,941	2,023–3,872

<sup>a</sup>Pacemaker/implantable cardioverter–defibrillator and extracardiac surgery without extracorporeal circulation are excluded.

**Table 3** Departments summarized by heart surgery procedures 2018

Category	N
Coronary artery bypass grafting	77
Heart valve surgery	77
Surgery for CHD in pat. <1 y with ECC	22 <sup>a</sup>
Heart transplantation	20 <sup>b</sup>
Heart–lung transplantation	2

<sup>a</sup>N = 2,086: thereof: 6 to 16 operations in 2 units, 25 to 49 operations in 6 units, 58 to 97 operations in 4 units, and 109 to 234 operations in 10 units.

<sup>b</sup>N = 312: thereof: 1 to 4 transplants in six units, 6 to 9 transplants in three units, 10 to 19 transplants in six units, and 21 to 81 transplants in five units.

**Table 4** Cardiac procedures using extracorporeal circulation (2009–2018)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Departments	80	79	78	79	79	78	78	78	78	78
Operations	86,916	84,686	84,402	84,388	84,040	83,787	81,527	79,082	76,696	72,331
Average	1,086	1,072	1,082	1,068	1,064	1,074	1,045	1,014	983	927

**Table 5** Frequency of cardiac procedures 2018

Category	With ECC	Without ECC	Total	Difference 2017 (%)
Coronary artery bypass grafting	37,051 <sup>a</sup>	7,219 <sup>a</sup>	44,270	–7.1
Heart valve procedures	20,671 <sup>a</sup>	14,244 <sup>a</sup>	34,915	+1.5
Surgery of thoracic aorta	7,562 <sup>a</sup>	607 <sup>a</sup>	8,169	–0.6
Surgery for CHD	4,882 <sup>a</sup>	971 <sup>a</sup>	5,853	–1.0
Cardiac surgery, other	1,119 <sup>a</sup>	1,229 <sup>a</sup>	2,348	+6.7
Assist device procedures	656 <sup>a</sup>	2,106 <sup>a</sup>	2,762	–5.1
Extracardiac surgery	355 <sup>a</sup>	53,788	54,143	–1.2
Pacemaker and ICD procedures	35 <sup>a</sup>	22,407	22,442	–3.3
<b>Total</b>	<b>72,331</b>	<b>102,571</b>	<b>174,902</b>	<b>–2.5</b>

<sup>a</sup>Sum: n = 98,707 (heart surgery procedures).

**Table 6** Gender distribution 2018

Distribution	Female		Male	
	N	%	N	%
Heart valve procedures	15,132	43	19,783	57
Coronary procedures	10,220	23	34,050	77
CHD procedures	2,624	45	3,229	55
Surgery of thoracic aorta	2,828	35	5,341	65
Cardiac surgery, other	1,323	56	1,025	44
Assist device	749	27	2,013	73
Pacemaker and ICD	8,451	38	13,991	62
Extracardiac surgery	18,949	35	35,194	65
<b>Total</b>	<b>60,276</b>	<b>34</b>	<b>114,626</b>	<b>66</b>

**Table 7** Additional data 2018 versus 2017

Procedures with ECC	2018		2017	
Emergency	11,147	11.3%	12,032	11.8%
Redo	8,642	8.8%	9,049	8.9%

**Table V1** Isolated heart valve procedures

Procedure	N	†	%
Single valve	16,840	658	3.9
Double valve	3,233	285	8.8
Triple valve	353	48	13.6
Transcatheter access (single valve)	14,375	386	2.7
Transcatheter access (double valve)	21	2	9.5
Unspecified	93	10	10.8
<b>Total</b>	<b>34,915</b>	<b>1,389</b>	<b>4.0</b>

Notes: Transcatheter heart valve procedures: 13,279 aortic valve implantation; 156 mitral valve implantation; 831 mitral valve repair; 3 tricuspid valve implantation; 102 tricuspid valve repair; 4 pulmonary valve implantation; and 21 combined aortic and mitral valves procedure.

**Table V2** Single heart valve procedures

Access path	N	†	%
<b>Aortic valve</b>			
Sternotomy	6,534	270	4.1
Partial sternotomy	3,488	64	1.8
Transvascular	11,654	272	2.3
Transapical	1,625	86	5.3
<b>Mitral valve</b>			
Sternotomy	2,819	208	7.4
Minimal invasive	3,403	48	1.4
Transcatheter	987	26	2.6
<b>Tricuspid valve</b>			
Sternotomy	413	53	12.8
Minimal invasive	129	11	8.5
Transcatheter	105	2	1.9
<b>Pulmonary valve</b>			
Sternotomy	50	2	4.0
Minimal invasive	1	0	0.0
Transcatheter	4	0	0.0
<b>Total</b>	<b>31,212</b>	<b>1,042</b>	<b>3.3</b>

Notes: A total of 3,488 (35%) by partial sternotomy. A total of 3,403 (55%) mitral valve procedures by minimally invasive access. Apical aortic conduit procedures ( $n = 3$ ) not included.

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

Prosthesis/native heart valve	Aortic			Mitral		
	N	†	%	N	†	%
Xenograft	8,800	312	3.5	1,813	184	10.1
Mechanical prosthesis	992	21	2.1	400	22	5.5
Repair	193	0	0.0	3,999	49	1.2
Homograft	37	1	2.7	10	1	10.0
<b>Total</b>	<b>10,022</b>	<b>334</b>	<b>3.3</b>	<b>6,222</b>	<b>256</b>	<b>4.1</b>

Note: Transcatheter procedures and apical aortic conduit procedures ( $n = 3$ ) not included.

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

Mitral valve procedures	Repair			Implantation/replacement			Total			
	N	†	%	N	†	%	N	%	†	%
Isolated	3,999	49	1.2	2,223	207	9.3	6,222	64.3	256	4.1
CABG	1,302	86	6.6	903	139	15.4	2,205	59.0	225	10.2
Tricuspid valve repair <sup>a</sup>	918	27	2.9	632	71	11.2	1,550	59.2	98	6.3
Aortic valve	558	33	5.9	849	130	15.3	1,407	39.7	163	11.6
CABG + aortic valve replacement	241	25	10.4	256	47	18.4	497	48.5	72	14.5
<b>Total</b>	<b>7,018</b>	<b>220</b>	<b>3.1</b>	<b>4,863</b>	<b>594</b>	<b>12.2</b>	<b>11,881</b>	<b>59.1</b>	<b>814</b>	<b>6.9</b>

<sup>a</sup>57 procedures (not specified mitral valve + tricuspid valve surgery) excluded. Mortality: 9% (5/57).

**Table V5** Multiple heart valve procedures

Combinations	N	†	%
Mitral + tricuspid	1,607	103	6.4
Aortic + mitral	1,407	163	11.6
Aortic + mitral + tricuspid	352	47	13.4
Aortic + tricuspid	168	19	11.3
Aortic + pulmonary <sup>a</sup>	37	0	0.0
Tricuspid + pulmonary	14	0	0.0
Aortic + mitral + pulmonary	1	1	100.0
<b>Total</b>	<b>3,586</b>	<b>333</b>	<b>9.3</b>

Note: 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	13,190	336	89	22	13,279	358	3
Transvascular	11,582	254	72	18	11,654	272	2
Transapical	1,608	82	17	4	1,625	86	5
Mitral valve	925	25	62	1	987	26	3
Repair	777	13	54	0	831	13	2
Implantation	148	12	8	1	156	13	8
Tricuspid valve repair	105	2	0	0	105	2	2
Repair	102	2	0	0	102	2	2
Implantation	3	0	0	0	3	0	0
Aortic + mitral valve implantation	20	2	1	0	21	2	10
Aortic valve implantation <sup>a</sup> + CABG	23	3	7	2	30	5	17
Mitral valve implantation <sup>b</sup> + CABG	0	0	7	2	7	2	29
Aortic + mitral valve + CABG	0	0	0	0	0	0	–
<b>Total</b>	<b>14,263</b>	<b>368</b>	<b>166</b>	<b>27</b>	<b>14,429</b>	<b>395</b>	<b>3</b>

Notes: Pulmonary valve implantation for congenital heart disease excluded; 12% of transcatheter aortic valve implantation (TAVI) by transapical access and less than 1% of TAVI under the use of ECC.

<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	33,999	976	2.9
Aortic valve replacement	5,668	273	4.8
Other	1,749	106	6.1
Mitral valve repair	1,302	86	6.6
Mitral valve replacement	903	139	15.4
Aortic valve replacement + mitral valve repair	241	25	10.4
Aortic valve + mitral valve replacement	256	47	18.4
Aneurysm resection	115	10	8.7
Transcatheter aortic valve implantation	30	5	16.7
<b>Total</b>	<b>44,263</b>	<b>1,667</b>	<b>3.8</b>

**Table C2** Isolated CABG with/without ECC

Grafts	With ECC			Without ECC			Total		
	N	†	%	N	†	%	N	†	%
Single	881	59	6.7	1,327	34	2.6	2,208	93	4.2
Double	5,576	213	3.8	1,973	37	1.9	7,549	250	3.3
Triple	11,672	328	2.8	2,627	41	1.6	14,299	369	2.6
Quadruple	6,405	166	2.6	886	13	1.5	7,291	179	2.5
Quintuple + more	2,446	81	3.3	206	4	1.9	2,652	85	3.2
<b>Total</b>	<b>26,980</b>	<b>847</b>	<b>3.1</b>	<b>7,019</b>	<b>129</b>	<b>1.8</b>	<b>33,999</b>	<b>976</b>	<b>2.9</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	2,109	734	76	12	3.6	1.6
1–17	1,800	210	14	0	0.8	0.0
≥ 18	1,048	27	32	0	3.1	0.0
<b>Total</b>	<b>4,957</b>	<b>971</b>	<b>122</b>	<b>12</b>	<b>2.5</b>	<b>1.2</b>

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

Lesion/procedure	Age < 1 y			Age 1–17 y			Age ≥ 18 y		
	N	†	%	N	†	%	N	†	%
ASD	36	0	0.0	288	0	0.0	254	4	1.6
Complete AV canal	206	4	1.9	91	0	0.0	10	0	0.0
VSD	358	1	0.3	122	0	0.0	9	1	11.1
Fallot's tetralogy	182	5	2.7	37	1	2.7	3	0	0.0
DORV	49	3	6.1	19	0	0.0	0	0	–
TGA	166	5	3.0	8	0	0.0	1	1	100.0
TGA + VSD	72	2	2.8	6	0	0.0	0	0	–
Truncus arteriosus	34	2	5.9	5	1	20.0	1	0	0.0
Fontan circulation	1	0	0.0	216	0	0.0	3	0	0.0
Norwood	164	23	14.0	1	0	0.0	0	0	–
Pulmonary valve	47	0	0.0	213	5	2.3	56	1	1.8
Transcatheter pulmonary valve implantation	0	–	–	5	0	0.0	11	0	0.0
AV	49	0	0.0	183	1	0.5	418	10	2.4
Ross procedure	6	0	0.0	23	0	0.0	30	2	6.7
Mitral valve	47	2	4.3	118	2	1.7	107	5	4.7
Tricuspid valve	93	5	5.4	63	1	1.6	52	5	9.6
PDA	188	3	1.6	15	0	0.0	0	0	–
Coarctation	200	0	0.0	20	0	0.0	4	0	0.0
Others	937	33	3.5	531	2	0.4	116	3	2.6
HTx	6	0	0.0	34	1	2.9	0	0	–
HLTx	0	–	–	0	0	–	0	0	–
LTx	2	0	0.0	12	0	0.0	0	0	–
<b>Total</b>	<b>2,843</b>	<b>88</b>	<b>3.1</b>	<b>2,010</b>	<b>14</b>	<b>0.7</b>	<b>1,075</b>	<b>32</b>	<b>3.0</b>

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

Age (y)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
< 18	54	43	40	36	33	37	28	38	38	29
≥ 18	175	184	134	117	107	90	64	72	52	61
<b>Total</b>	<b>229</b>	<b>227</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>

**Table Mis2** Heart and lung transplantation

Transplant	With ECC			Without ECC		
	N	†	%	N	†	%
HTx	312	33	10.6			
HLTx	2	0	0.0			
LTx	45	4	8.9	295	10	3.4

Notes: All pediatric transplantations (demonstrated in ► **Table Con2**) are included in this table. Eurotransplant (ET) report 2018: 312 HTx, 4 HTx + kidney Tx, 0 HTx + liver Tx, 2 HLTx, 317 DLTx, 54 SLTx, 0 LTx + kidney Tx, and 2 LTx + liver Tx.

**Table Mis3** Aortic surgery

Replacement <sup>a</sup>	With ECC			Without ECC		
	N	†	%	N	†	%
Supracoronary replacement of ascending aorta	1,308	111	8.5			
Supracoronary ascending + aortic valve replacement	1,308	68	5.2			
Infracoronary ascending						
Mechanical aortic valve conduits	400	22	5.5			
Biological aortic conduits	1,062	113	10.6			
David procedure	474	4	0.8			
Yacoub procedure	127	0	0.0			
Other	259	17	6.6			
Aortic arch replacement <sup>b</sup>	2,497	319	12.8			
Replacement of descending aorta	44	6	13.6	4	0	0.0
Thoracoabdominal aortic replacement	81	7	8.6	16	3	18.8
Endostent descending aorta	2	0	0.0	587	32	5.5
<b>Total</b>	<b>7,562</b>	<b>667</b>	<b>8.8</b>	<b>607</b>	<b>35</b>	<b>5.8</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 coronary artery bypass grafting) are summarized in this category.

<sup>a</sup>Procedures for abdominal aortic diseases excluded: 438, abdominal procedures and 18, endovascular abdominal stents.

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

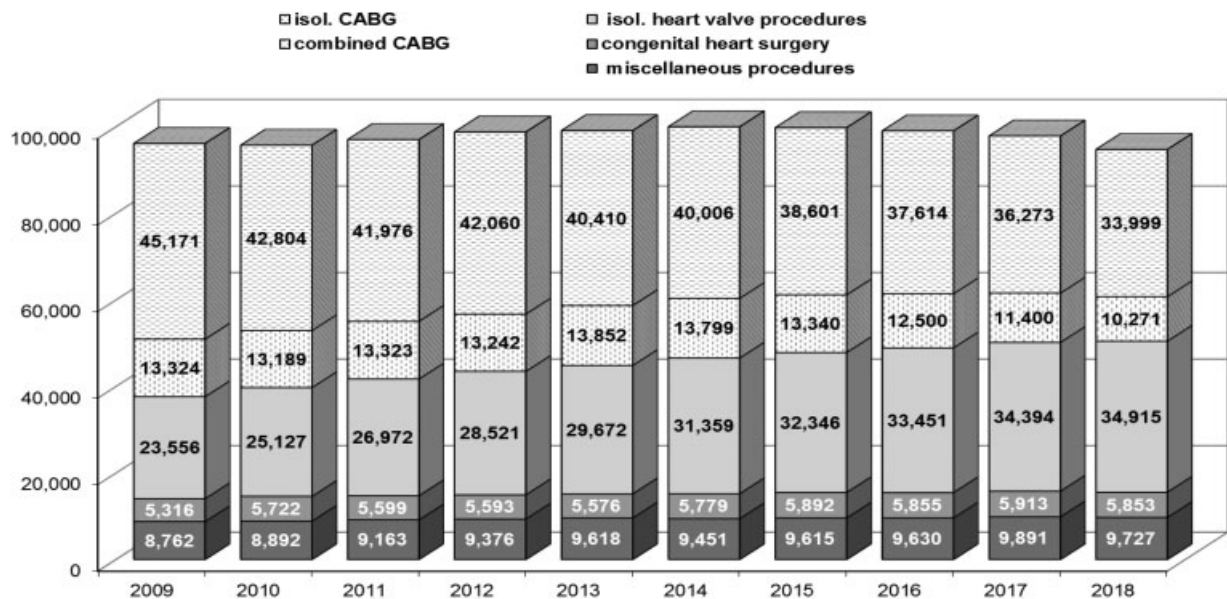
**Table Mis4** Pacemaker and ICD procedures

Device/category				With ECC		Without ECC	
	N	†	%	N	†	N	†
Pacemaker	13,433	101	0.8	19	1	13,414	100
Implantation	8,983	61	0.7	4	0	8,979	61
Battery exchange	1,734	4	0.2	0	0	1,734	4
Revision procedures	2,716	36	1.3	15	1	2,701	35
ICD	7,382	73	1.0	15	3	7,367	70
Implantation	3,194	11	0.3	0	0	3,194	11
Battery exchange	1,671	4	0.2	0	0	1,671	4
Revision procedures	2,517	58	2.3	15	3	2,502	55
Miscellaneous	1,627	14	0.9	1	1	1,626	13
<b>Total</b>	<b>22,442</b>	<b>188</b>	<b>0.8</b>	<b>35</b>	<b>5</b>	<b>22,407</b>	<b>183</b>

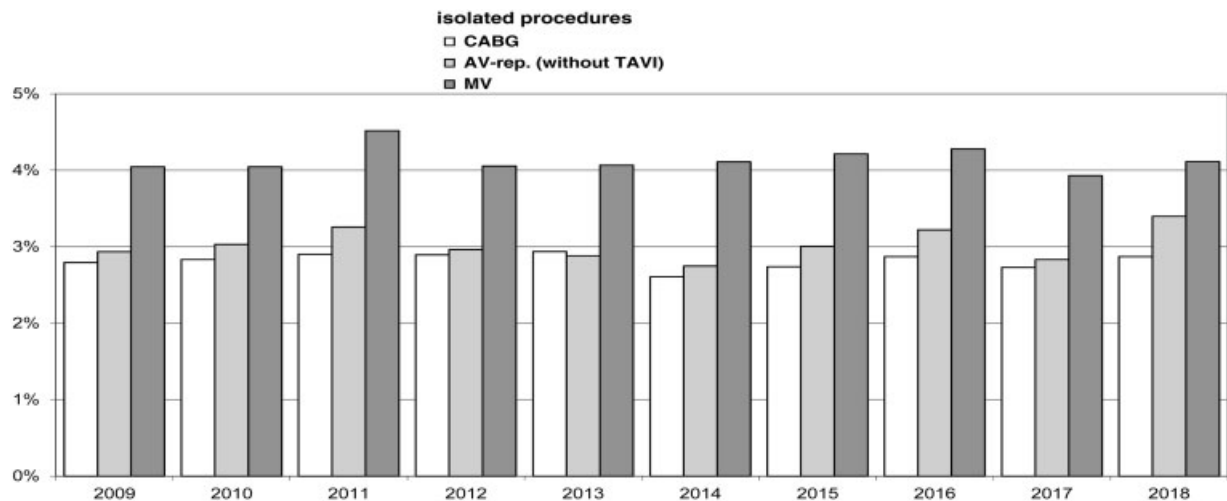
**Table Mis5** Surgical procedures for tachyarrhythmia

Energy source	Endocardiac	Epicardiac	Total
	N	N	
Unipolar radiofrequency	95	182	277
Unipolar cryoradiofrequency	84	118	202
Bipolar radiofrequency	231	2,035	2,266
Cryotherapy	1,343	380	1,723
Microwave	4	17	21
Focused ultrasound	9	113	122
Laser	0	0	0
Other	13	11	24
<b>Total</b>	<b>1,779</b>	<b>2,856</b>	<b>4,635</b>

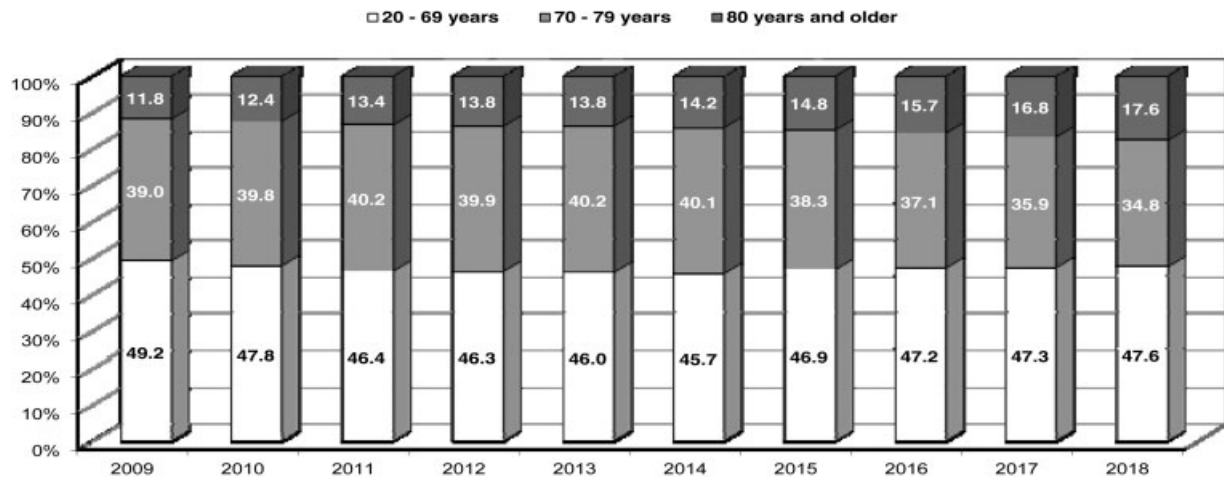
Note: A total of 279 procedures are unspecified with regard to endocardiac/epicardiac ablation.



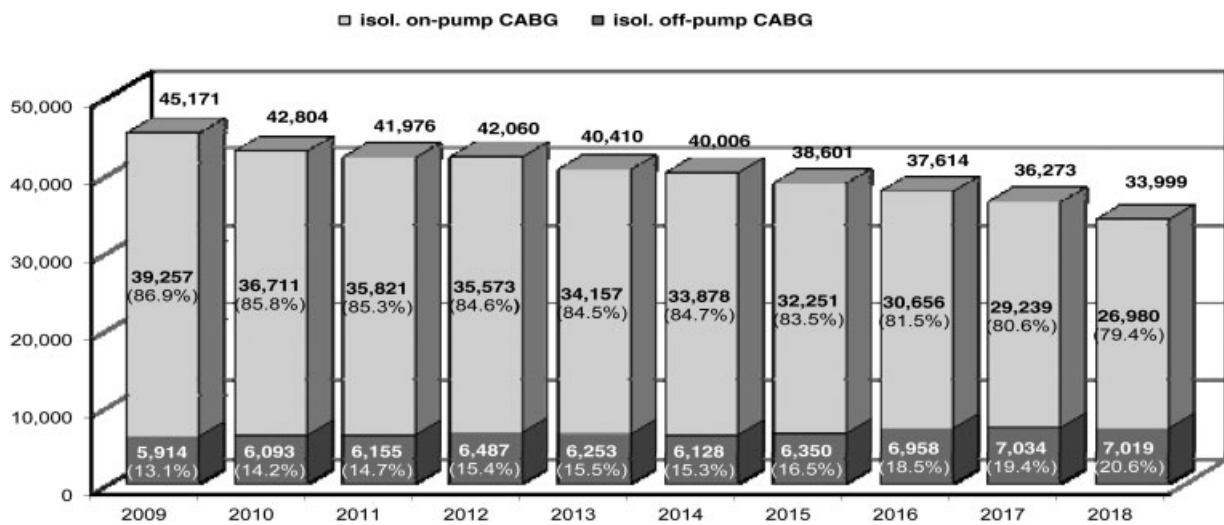
**Fig. 1** Selected heart surgical categories (2009–2018). Notes: Congenital heart surgery: ASD repairs in adults or in combination with CABG or heart valve procedures are summarized in the CABG or heart valve procedure groups; miscellaneous procedures: all other types of procedures with ECC.



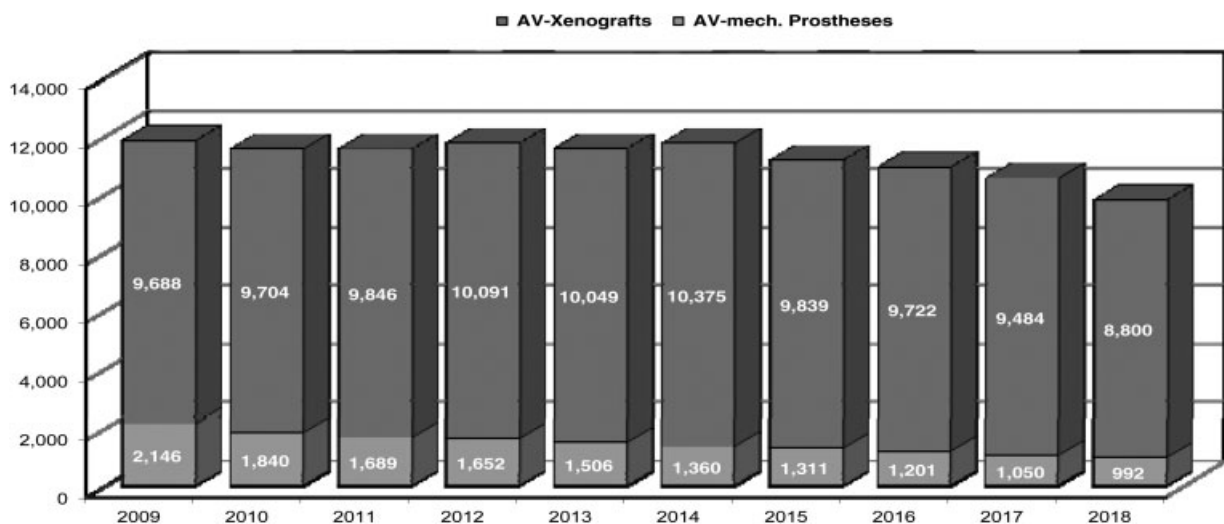
**Fig. 2** Unadjusted mortality for selected procedures (2009–2018).



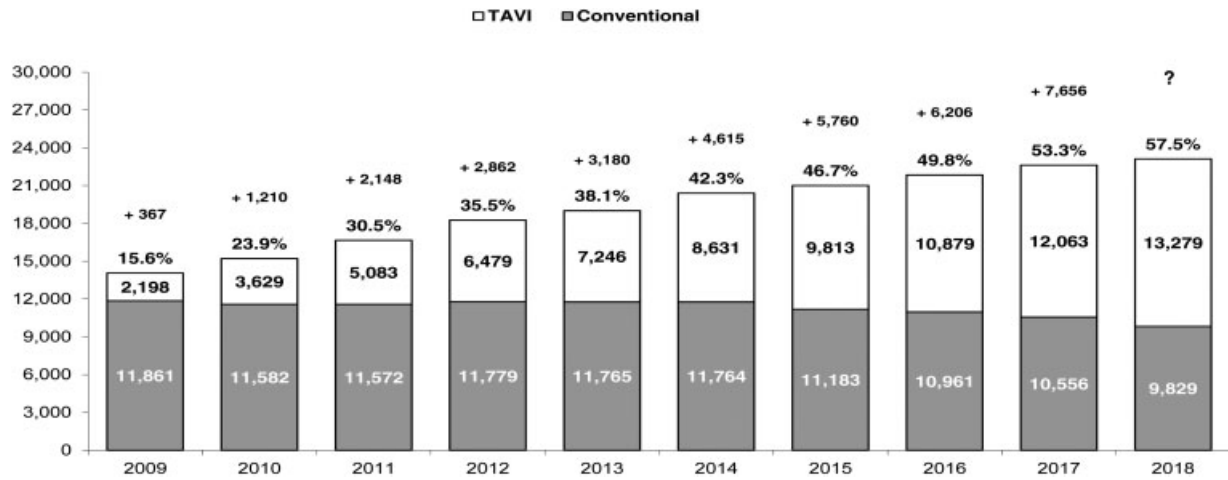
**Fig. 3** Age distribution of cardiac procedures (2009–2018). Notes: patients <20 years and pacemaker/implantable cardioverter–defibrillator procedures were excluded.



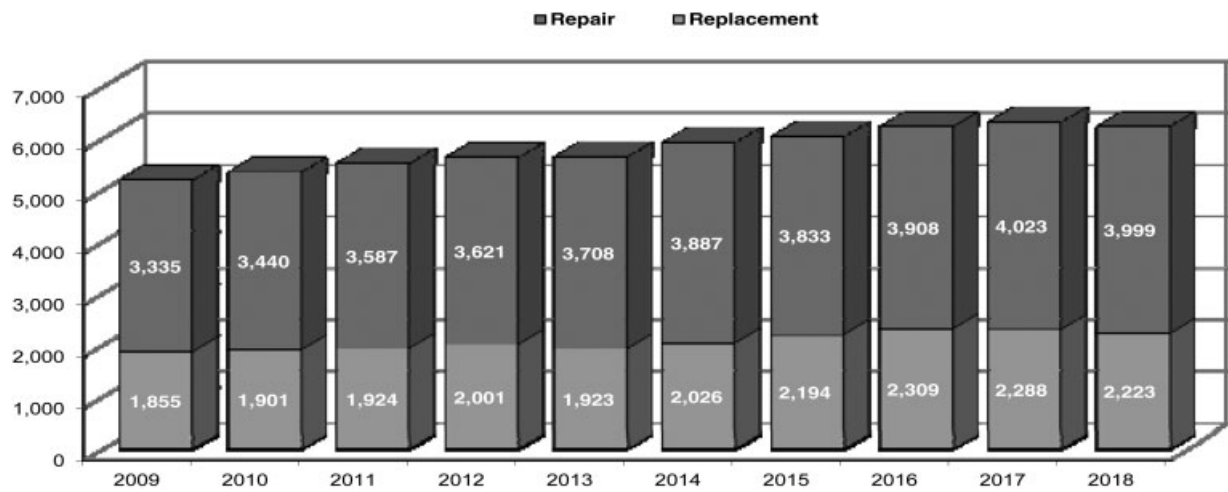
**Fig. 4** Isolated coronary artery bypass grafting (CABG) (2009–2018).



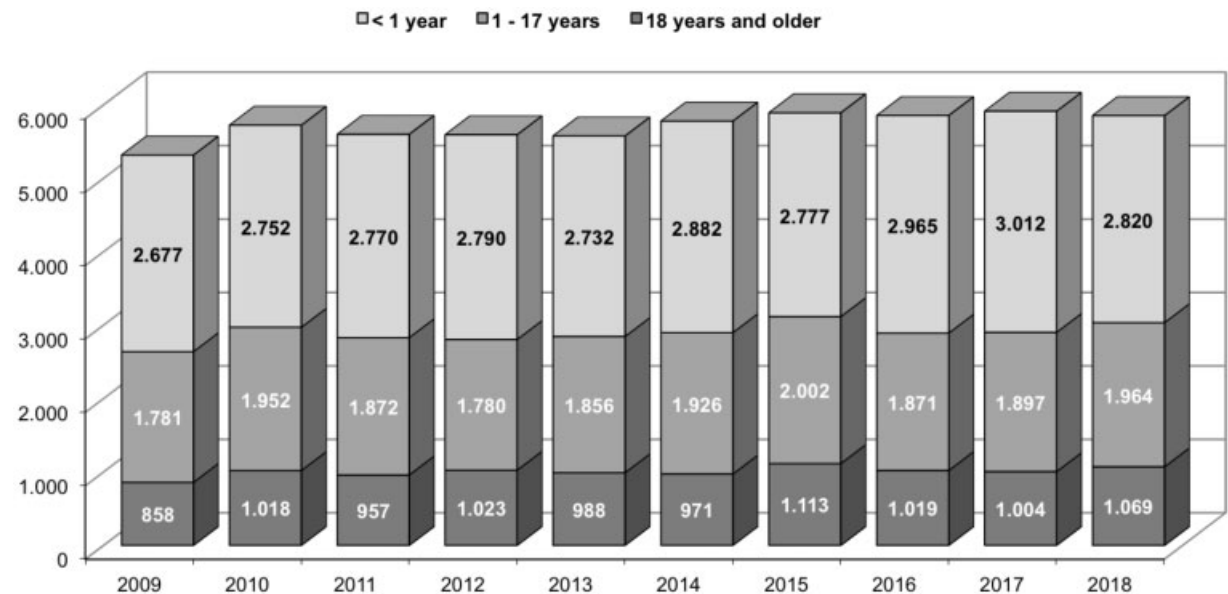
**Fig. 5** Isolated aortic valve replacement (2009–2018). Notes: Ross procedures, homograft implantations, and transcatheter heart valve intervention excluded.



**Fig. 6** Isolated aortic valve replacement and transcatheter aortic valve implantation (TAVI). The annual count of TAVI submitted to the voluntary registry of German Society for Thoracic and Cardiovascular Surgery does not represent all TAVI procedures performed in Germany in 2018. +Additional TAVI procedures calculated from the German legal quality assurance program, §§ 135a/ 136/ 137 SGB V.



**Fig. 7** Isolated mitral valve surgery (2009–2018).



**Fig. 8** Age distribution for CHD (2009–2018). 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).

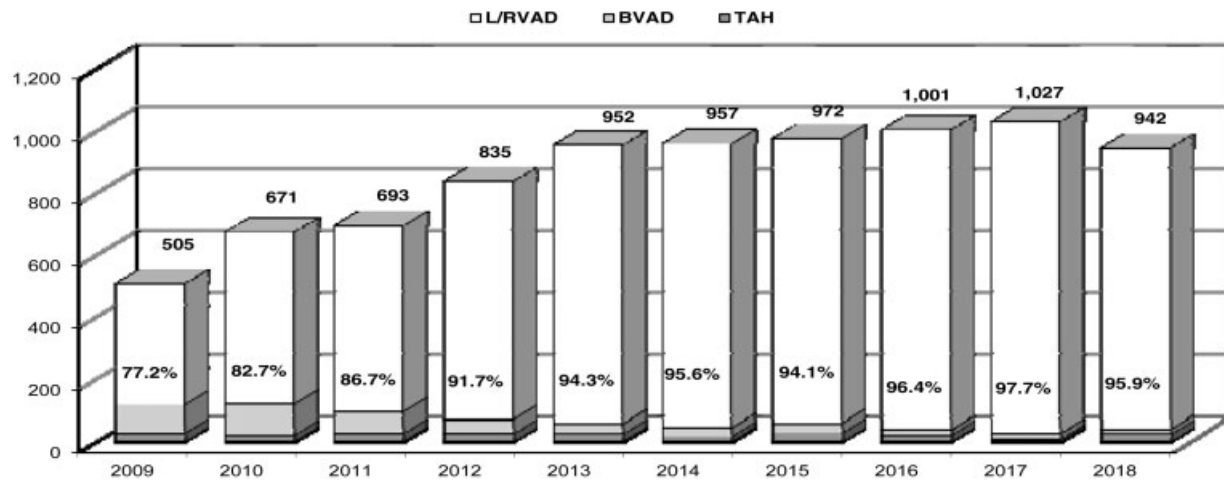


Fig. 9 Development of mechanical circulatory support (2009–2018).

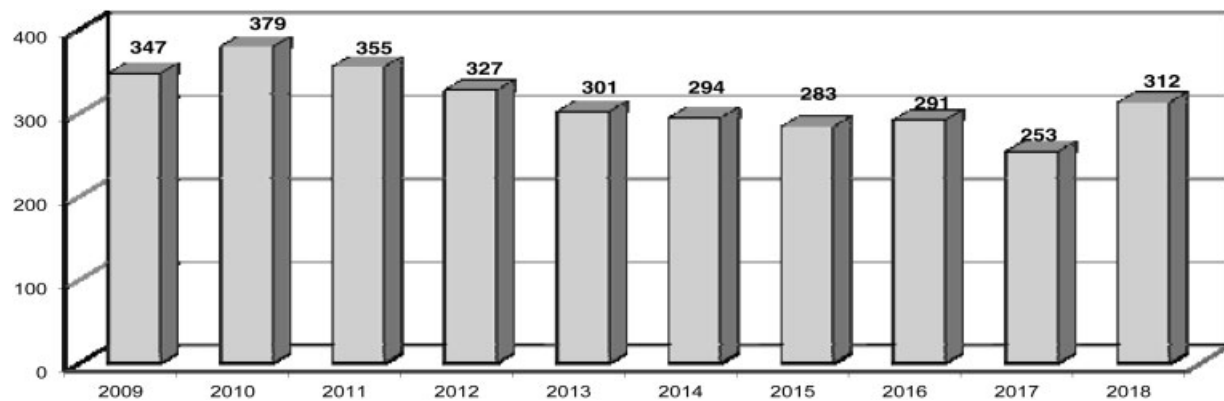


Fig. 10 Heart transplantation (2009–2018).

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