

# German Heart Surgery Report 2017: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

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## Abstract

### Keywords

- heart valve surgery
- outcomes
- congenital heart disease
- CHD
- aorta
- coronary artery bypass grafting
- CABG
- arrhythmia therapy

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 2017 are analyzed. In 2017, a total of 179,337 procedures were submitted to the registry, and 101,728 were summarized as heart surgery procedures in the narrower sense. About 16.8% of these patients were at least 80 years old, resulting in an increase of 1.1% compared with the data of 2016. The 36,273 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 4.2:1) were associated with an unadjusted in-hospital survival rate of 97.3%. Concerning the 34,394 isolated heart valve procedures (including 12,965 transcatheter interventions), the unadjusted in-hospital survival rate was 96.0%. This annual updated registry of the GSTCVS represents voluntary public reporting by accumulating actual information for nearly all heart surgical procedures in Germany, describes advancements in heart medicine, and is a basis for in- and external quality assurance 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 at any 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. In 1978, 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 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 registry and published in the scientific journal of the GSTCVS each year.<sup>3–7</sup> The prevalent aims of this registry are to gather developments and upcoming

trends in cardiac surgery in Germany; to compile various results for nearly all cardiac surgical procedures, to provide each participating institution with a benchmark of the reached 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 heart valve interventions (e.g., TAVI). Thereby, important findings for current patient safety and the future of patient care are collected and can be evaluated under different aspects.

Data and results presented in this report comprehend assorted findings of the year 2017.

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## 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 26, 2018, 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 office of the GSTCVS 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 2017 were all cardiac surgical procedures performed on patients between January 1, 2017 and December 31, 2017, unrelated to the date of admission or discharge of the patients 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 several 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 for data acquisition.

In 2017, a total of 78 institutions performed heart surgery. As always, all departments answered the questionnaire and delivered a complete dataset for the year 2017 including in-hospital mortality rates. In addition, comparisons between the registry data and the external quality assurance in accordance with §§ 136/137 SGB V, obligatory for licensed German hospitals (§ 108 SGB V), are feasible.

For statistical analyses, categorized tables and a summarizing registry data file amalgamate 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. All described mortality rates are unadjusted. Quan-

titative data are presented as absolute frequencies and arithmetic mean values. Where appropriate, the value range is presented additionally. Patients age, though originally a quantitative variable, is only available in age groups and therefore treated as a categorical variable. Population-based measures are calculated as frequencies per 100,000 inhabitants and are based on the German population by December 31st of the previous year.

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 2017

► **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 31st, 2016. The range of heart operations per 100,000 inhabitants again shows a minimum of 100.8 (Baden Württemberg, population: 10,951,893) and a maximum of 172.8 (Sachsen-Anhalt, population: 2,236,252), resulting in a nationwide mean-value of 122.0 (2016:125.7). Analyzing quantified categories of heart operations by department dimension, nearly 62% of institutions are in two clusters in which at least 529 and at most 1,462 procedures were performed (► **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]) were conducted in 22 and heart transplantations in just 20 institutions (► **Table 3**), a slight shift compared with the previous year. ► **Table 4** illustrates the count of procedures using ECC in Germany from 2008 to 2017. Over the past decade, the count of heart operations using ECC shows a decline by 13,077 procedures, certainly an achievement of established innovations and minimally invasive therapeutic options in heart surgery.

Overall, 179,337 procedures were reported to the registry for the year 2017, a decrease of 3.0% (2016: 184,789 procedures). A total of 101,728 heart surgical procedures (excluded: implantable cardioverter defibrillator, pacemakers and miscellaneous procedures without ECC) in 2017 display a decline with a difference of 1.4% ( $n = 1,400$ ) compared with 2016 (103,128 procedures) (► **Table 5**). About 11.8% of the operations were conducted as emergency procedures, and 8.9% as a reoperation (► **Table 6**). Concerning gender distribution, the registry shows an overall male/female ratio of 2:1 with major distinctions in specified categories (► **Table 7**). 17,582 (51.1%) heart valve operations were performed as a single-valve procedure, and 6,763 (38.5%) of these through a minimal invasive access (► **Tables V1, V2**). In 9,484 (88.6%) isolated aortic valve operations under ECC conditions, xenograft prostheses were implanted (► **Table V3, Fig. 4**). In 4,023 (63.7%) isolated mitral valve procedures, a reconstruction under preservation of the native heart valve was performed (► **Table V4, V5**). The subdivision of 3,731 multiple heart valve procedures leads to 3,039 (81.5%) operations: a combination of mitral + tricuspid ( $n = 1,656$ ) or mitral + aortic ( $n = 1,383$ ) valve procedures (► **Table V6**). ► **Tables V7, C1, C2, Con1, Con2, Mis1, Mis2, Mis3, Mis4, Mis5** and ► **Figs. 1–9** demonstrate further compiled registry data under different aspects and for various categories.

Compared with the data of previous years, several important developments continued almost unchanged in 2017. The age distribution of patients (►Fig. 6) shows a continuous shift to an elderly patient population with presently 35.9% of the cardiac procedures performed in patients from 70 to 79 years of age and 16.8% in octo-/nonagenarians. However, unadjusted mortality rates remain on the same low level over the last decade (►Fig. 2). The rate of CABG procedures decreased over the past decade, while the relative count for off-pump CABG has now reached a level of 19.4% (2016: 18.5%) (►Figs. 1, 3).

There is still a continuous increase of TAVI in Germany (►Fig. 5, ►Table V7), while the count of isolated aortic valve procedures shows a slight decrease of 3.7%. In 2017, a total of 12,063 (53.3%) TAVI procedures were reported to the registry. It must be emphasized that the 78 participating departments which contribute their data to the registry do not represent all departments performing TAVI in Germany. In context to the recommendations of international guidelines<sup>8–10</sup> on the management of valvular heart disease, the German Federal Joint Committee implemented a quality assurance directive for “minimally invasive heart valve interventions (TAVI, transcatheter mitral clip reconstruction)” in July 2015, in which obligatory structures, defined processes, and qualified personnel are precisely specified. In addition, the annual analyses for selected procedures of the legally compulsory quality assurance (§136, 137 SGB V) as well as the results of the voluntary German Aortic Valve Registry<sup>11–22</sup> contribute to public and scientific reporting.

In 2017, the rate of mitral valve reconstructions shows a slight increase up to 63.7% (2016: 62.9%) (►Fig. 8). 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 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>23</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.

The continued increase in left/right ventricular assist device implantations emphasizes the importance of mechanical circulatory support therapies ( $n = 1,027$ ), while biventricular and total artificial heart implantations are of subordinate importance with only 2.3% in 2017 (►Fig. 10).

## Discussion

The registry of the GSTCVS enables a comprehensive overview of all heart surgical procedures performed in Germany in 2017. 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>24</sup> As observed in recent years, heart surgery in Germany is continuously performed on a high level with superior in-hospital patient survival rates compared with

international surveys. In addition, the registry demonstrates that the provision of heart surgery in Germany is appropriate and patient care is guaranteed nationwide at any time (24/7/365). These aspects are especially important in the context of various activities in health care politics and the demographic trends of the German population leading to patients at increased age combined with related comorbidities and a complex preoperative risk profile, respectively.

Compared with 2016, the count of cardiac surgery procedures remains on a comparable level, predominantly induced by the continuous increase in catheter-based heart valve procedures.

Further developments and improvements in 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 still allows 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 in the sense of a contribution for patient safety and to obtain evidence for the high quality of heart surgery in Germany.

## 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
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

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## 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	11,039	10,951,893	100.8
Bayern	14,128	12,930,751	109.3
Berlin	3,754	3,574,830	105.0
Brandenburg	3,413	2,494,648	136.8
Bremen	895	6,78,753	131.9
Hamburg	2,374	1,810,438	131.1
Hessen	7,506	6,213,088	120.8
Mecklenburg- Vorpommern	1,962	1,610,674	121.8
Niedersachsen	10,738	7,945,685	135.1
Nordrhein- Westfalen	22,339	17,890,100	124.9
Rheinland-Pfalz	5,257	4,066,053	129.3
Saarland	1,351	9,96,651	135.6
Sachsen	5,138	4,081,783	125.9
Sachsen-Anhalt	3,865	2,236,252	172.8
Schleswig- Holstein	4,002	2,881,926	138.9
Thüringen	2,930	2,158,128	135.8
<b>Germany</b>	<b>100,691</b>	<b>82,521,653</b>	<b>122.0</b>

<sup>a</sup>n = 1013, foreign residences excluded.

<sup>b</sup>Federal Office for Statistics of German: Population; due date December 31, 2016.

**Table 2** Departments assorted by quantified categories ( $\sum^a [n = 101,728]$ )

Procedures (quantity)	<500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments	6	26	22	13	11
Average	382	795	1,200	1,742	2,704
Range	258–476	529–983	1,001–1,462	1,510–1,974	2,039–3,958

Abbreviations: ECC, extracorporeal circulation; ICD, implantable cardioverter defibrillator.

<sup>a</sup>Pacemaker/ICD and extracardiac surgery without ECC excluded.

**Table 3** Departments summarized by heart surgery procedures 2017

Category	n
Coronary artery bypass grafting	77
Heart valve surgery	77
CHD-procedures with ECC in patients < year	22 <sup>a</sup>
HTx	20 <sup>b</sup>
HLTx	5

Abbreviations: CHD, congenital heart disease; ECC, extracorporeal circulation.

<sup>a</sup>n = 2168: thereof: 1 operation in 1 unit, 26 to 41 operations in 5 units, 50 to 98 operations in 7 units, 128 to 241 operations in 9 units.

<sup>b</sup>n = 253: thereof: 1 to 3 transplants in 4 units, 5 to 9 transplants in 7 units, 11 to 20 transplants in 7 units, 21 to 71 transplants in 2 units.

**Table 4** Cardiac procedures using extracorporeal circulation (2008–2017)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Departments	79	80	79	78	79	79	78	78	78	78
Procedures	89,773	86,916	84,686	84,402	84,388	84,040	83,787	81,527	79,082	76,696
<b>Average</b>	<b>1,136</b>	<b>1,086</b>	<b>1,072</b>	<b>1,082</b>	<b>1,068</b>	<b>1,064</b>	<b>1,074</b>	<b>1,045</b>	<b>1,014</b>	<b>983</b>

**Table 5** Frequency of cardiac procedures 2017

Category	With ECC	Without ECC	Total	Difference 2016 (%)
Coronary artery bypass grafting	40,418 <sup>a</sup>	7,255 <sup>a</sup>	47,673	– 4.9
Heart valve procedures	21,535 <sup>a</sup>	12,859 <sup>a</sup>	34,394	+ 2.8
Surgery of thoracic aorta	7,580 <sup>a</sup>	636 <sup>a</sup>	8,216	+ 1.2
Surgery for CHD	4,852 <sup>a</sup>	1,061 <sup>a</sup>	5,913	+ 1.0
Cardiac surgery, other	1,124 <sup>a</sup>	1,076 <sup>a</sup>	2,200	– 2.4
Assist device procedures	764 <sup>a</sup>	2,145 <sup>a</sup>	2,909	– 0.9
Extracardiac surgery	388 <sup>a</sup>	54,440	54,828	– 4.4
Pacemaker-/ICD-procedures	35 <sup>a</sup>	23,169	23,204	– 6.0
<b>Total</b>	<b>76,696</b>	<b>102,641</b>	<b>179,337</b>	<b>- 3.0</b>

Abbreviations: CHD, congenital heart disease; ECC, extracorporeal circulation; ECLS, extracorporeal life support; ECMO, extracorporeal membrane oxygenation; ICD, implantable cardioverter defibrillator; TAH, total artificial heart; VAD, ventricular assist device.

<sup>a</sup>Sum:  $n = 101,728$  (heart surgery procedures).

**Table 6** Additional data 2017 versus 2016

Procedures with ECC	2017		2016	
Emergency	12,032	11.8%	12,745	12.4%
Redo	9,049	8.9%	9,186	8.9%

**Table 7** Gender distribution

Distribution	Female (%)	Male (%)
Heart valve procedures	44	56
Coronary artery procedures	22	78
CHD procedures	45	55
Surgery of thoracic aorta	34	66
Cardiac surgery, other	57	43
Assist device	28	72
Pacemaker and ICD	35	65
Extracardiac surgery	35	65
<b>Total</b>	<b>34</b>	<b>66</b>

**Table V1** Isolated heart valve procedures

Procedure	<i>n</i>	†	%
Single valve	17,582	607	3.5
Double valve	3,321	312	9.4
Triple valve	410	51	12.4
Transcatheter access (single valve)	12,934	395	3.1
Transcatheter access (double valve)	31	7	22.6
Unspecified	116	9	7.8
<b>Total</b>	<b>34,394</b>	<b>1,381</b>	<b>4.0</b>

Transcatheter heart valve procedures: 12,063 aortic valve implantation; 130 mitral valve implantation; 696 mitral valve repair.

Three tricuspid valve implantation; 42 tricuspidal valve repair; 31 double aortic and mitral valve procedure; 0 pulmonary valve implantation.

**Table V2** Single heart valve procedures

Access path	n	†	%
<b>Aortic valve</b>			
Sternotomy	7,243	258	3.6
Partial sternotomy	3,467	44	1.3
Transvascular	10,233	257	2.5
Transapical	1,830	108	5.9
<b>Mitral valve</b>			
Sternotomy	3,131	213	6.8
Minimal invasive	3,180	35	1.1
Transcatheter	826	28	3.4
<b>Tricuspidal valve</b>			
Sternotomy	390	44	11.3
Minimal invasive	115	12	10.4
Transcatheter	45	2	4.4
<b>Pulmonary valve</b>			
Sternotomy	55	1	1.8
Minimal invasive	1	0	0.0
Transcatheter	0	0	—
<b>Total</b>	<b>30,516</b>	<b>1,002</b>	<b>3.3</b>

**Table V3** Isolated aortic valve procedures

Prosthesis/native aortic valve	n	†	%
Xenograft	9,484	271	2.9
Mechanical prosthesis	1,050	22	2.1
Repair	154	3	1.9
Homograft	22	6	27.3
<b>Total</b>	<b>10,710</b>	<b>302</b>	<b>2.8</b>

Notes: A total of 3,467 (32%) were performed by partial sternotomy. Transcatheter procedures and apical aortic conduits procedures (n = 0) excluded.

**Table V4** Isolated mitral valve procedures

Prosthesis/native mitral valve	n	†	%
Repair	4,023	44	1.1
Xenograft	1,885	182	9.7
Mechanical prosthesis	394	22	5.6
Homograft	9	0	0.0
<b>Total</b>	<b>6,311</b>	<b>248</b>	<b>3.9</b>

Notes: 3,180 (50%) procedures performed via minimally invasive access. Transcatheter procedures excluded.

**Table V6** Multiple heart valve procedures

Combination	n	†	%
Mitral + tricuspid	1,656	113	6.8
Aortic + mitral	1,383	171	12.4
Aortic + mitral + tricuspid	409	51	12.5
Aortic + tricuspid	232	27	11.6
Aortic + pulmonary <sup>a</sup>	35	0	0.0
Tricuspid + pulmonary	15	1	6.7
Aortic + mitral + pulmonary	1	0	0.0
<b>Total</b>	<b>3,731</b>	<b>363</b>	<b>9.7</b>

Notes: Transcatheter procedures excluded.

<sup>a</sup>Including Ross procedures

**Table V5** Isolated/combined mitral valve procedures—implantation/replacement versus repair

Mitral valve procedures	Repair			Implantation/replacement			Total			
	n	†	%	n	†	%	n	% repair	†	%
Isolated	4,023	44	1.1	2,288	204	8.9	6,311	63.7	248	3.9
+ Aortic valve	516	30	5.8	867	141	16.3	1,383	37.3	171	12.4
+ Tricuspid valve repair <sup>a</sup>	972	43	4.4	621	56	9.0	1,593	61.0	99	6.2
+ CABG	1,522	96	6.3	919	143	15.6	2,441	62.4	239	9.8
+ CABG + Aortic valve replacement	291	41	14.1	288	63	21.9	579	50.3	104	18.0
<b>Total</b>	<b>7,324</b>	<b>254</b>	<b>3.5</b>	<b>4,983</b>	<b>607</b>	<b>12.2</b>	<b>12,307</b>	<b>59.5</b>	<b>861</b>	<b>7.0</b>

<sup>a</sup>Sixty-three procedures (unspecified mitral + tricuspid valve surgery) excluded. Unadjusted mortality: 22% (14/63).



**Table V7** Transcatheter heart valve procedures

	Without ECC		With ECC		Total		
	<i>n</i>	†	<i>n</i>	†	<i>n</i>	†	%
Aortic valve implantation	11,971	336	92	29	12,063	365	3
Transvascular	10,155	233	78	24	10,233	257	3
Transapical	1,816	103	14	5	1,830	108	6
Mitral valve	814	26	12	2	826	28	3
Repair	688	18	8	1	696	19	3
Implantation	126	8	4	1	130	9	7
Tricuspid valve repair	44	2	1	0	45	2	4
Repair	41	2	1	0	42	2	5
Implantation	3	0	0	0	3	0	0
Aortic + mitral valve implantation	30	7	1	0	31	7	23
Aortic valve implantation <sup>a</sup> + CABG	25	3	5	3	30	6	20
Mitral valve implantation <sup>b</sup> + CABG	1	0	0	0	1	0	0
Aortic + mitral valve + CABG	0	0	0	0	0	0	–
<b>Total</b>	<b>12,885</b>	<b>374</b>	<b>111</b>	<b>34</b>	<b>12,996</b>	<b>408</b>	<b>3</b>

Notes: Pulmonary valve implantation for CHD excluded.

Fifteen percent of transcatheter aortic valve implantation (TAVI) by transapical access and less than 1% of TAVI under 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

	<i>n</i>	†	%
Isolated CABG	36,273	990	2.7
+ Aortic valve replacement	6,290	303	4.8
+ Other	1,950	113	5.8
+ Mitral valve repair	1,522	96	6.3
+ Mitral valve replacement	919	143	15.6
+ Aortic valve replacement + mitral valve repair	291	41	14.1
+ Aortic + mitral valve replacement	288	63	21.9
+ Aneurysm resection	109	8	7.3
+ Transcatheter aortic valve implantation	30	6	20.0
<b>Total</b>	<b>47,672</b>	<b>1,763</b>	<b>3.7</b>

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

Grafts	With ECC			Without ECC			Total		
	<i>n</i>	†	%	<i>n</i>	†	%	<i>n</i>	†	%
Single	1,024	50	4.9	1,358	25	1.8	2,382	75	3.1
Double	6,030	197	3.3	1,922	30	1.6	7,952	227	2.9
Triple	12,676	392	3.1	2,570	35	1.4	15,246	427	2.8
Quadruple	7,032	175	2.5	975	16	1.6	8,007	191	2.4
Quintuple + more	2,477	70	2.8	209	0	0.0	2,686	70	2.6
<b>Total</b>	<b>29,239</b>	<b>884</b>	<b>3.0</b>	<b>7,034</b>	<b>106</b>	<b>1.5</b>	<b>36,273</b>	<b>990</b>	<b>2.7</b>

**Table Con 1** Congenital heart surgery with/without ECC

Age (years)	n		†		%	
	With ECC	Without ECC	With ECC	Without ECC	With ECC	Without ECC
< 1	2,190	844	76	19	3.5	2.3
1–17	1,754	180	21	4	1.2	2.2
≥ 18	974	37	30	2	3.1	5.4
<b>Total</b>	<b>2,728</b>	<b>217</b>	<b>51</b>	<b>6</b>	<b>1.9</b>	<b>2.8</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	43	3	7.0	257	0	0.0	229	6	2.6
Complete AV canal	199	3	1.5	68	1	1.5	15	0	0.0
VSD	321	2	0.6	116	0	0.0	16	2	12.5
Fallot's tetralogy	205	1	0.5	54	0	0.0	2	0	0.0
DORV	47	2	4.3	27	0	0.0	2	0	0.0
TGA	171	5	2.9	6	1	16.7	0	0	–
TGA + VSD	69	5	7.2	7	2	28.6	0	0	–
Truncus arteriosus	30	2	6.7	6	0	0.0	0	0	–
Fontan circulation	3	0	0.0	260	4	1.5	7	0	0.0
Norwood	159	24	15.1	2	1	50.0	1	1	100.0
Pulmonary valve	64	1	1.6	211	1	0.5	78	3	3.8
Transcatheter pulmonary valve implantation	0	–	–	2	0	0.0	14	1	7.1
Aortic valve	45	1	2.2	196	1	0.5	379	9	2.4
Ross procedure	11	2	18.2	27	1	3.7	21	0	0.0
Mitral valve	51	1	2.0	111	4	3.6	91	4	4.4
Tricuspid valve	84	0	0.0	50	1	2.0	39	4	10.3
PDA	235	3	1.3	32	0	0.0	3	0	0.0
Coarctation	233	2	0.9	28	0	0.0	2	0	0.0
Others	1,063	38	3.6	432	4	0.9	112	2	1.8
HTx	1	0	0.0	32	2	6.3	0	0	–
HLTx	0	0	–	0	0	–	0	0	–
LTx	0	0	–	10	2	20.0	0	0	–
<b>Total</b>	<b>3,034</b>	<b>95</b>	<b>3.1</b>	<b>1,934</b>	<b>25</b>	<b>1.3</b>	<b>1,011</b>	<b>32</b>	<b>3.2</b>

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

Age (years)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
< 18	42	54	43	40	36	33	37	28	38	38
≥ 18	207	175	184	134	117	107	90	64	72	52
<b>Total</b>	<b>249</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>



**Table Mis2** Heart and lung transplantation

Transplant	With ECC			Without ECC		
	n	†	%	n	†	%
HTx	253	27	10.7			
HLTx	5	1	20.0			
LTx	36	9	25.0	250	12	4.8

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

Eurotransplant (ET) report 2017: 248 HTx, 2 HTx + kidneyTx, 2 HTx + liverTx, 5 HLTx, 272 DLTx, 31 SLTx, 0 LTx + kidneyTx and 1 LTx + liverTx.

**Table Mis3** Aortic surgery

Replacement <sup>a</sup>	With ECC			Without ECC		
	n	†	%	n	†	%
Supracoronary replacement of ascending aorta	1,357	108	8.0			
Supracoronary ascending + aortic valve replacement	1,348	73	5.4			
Infracoronary ascending						
Mechanical aortic valve conduits	406	31	7.6			
Biological aortic valve conduits	984	113	11.5			
David procedure	487	11	2.3			
Yacoub procedure	122	4	3.3			
Other	284	23	8.1			
Aortic arch replacement <sup>b</sup>	2,432	345	14.2			
Replacement of descending aorta	58	4	6.9	6	1	16.7
Thoracoabdominal aortic replacement	99	23	23.2	19	1	5.3
Endostent descending aorta	3	0	0.0	611	37	6.1
<b>Total</b>	<b>7,580</b>	<b>735</b>	<b>9.7</b>	<b>636</b>	<b>39</b>	<b>6.1</b>

Abbreviation: ECC, extracorporeal circulation.

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: 386 abdominal procedures and 19 endovascular abdominal stents.

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

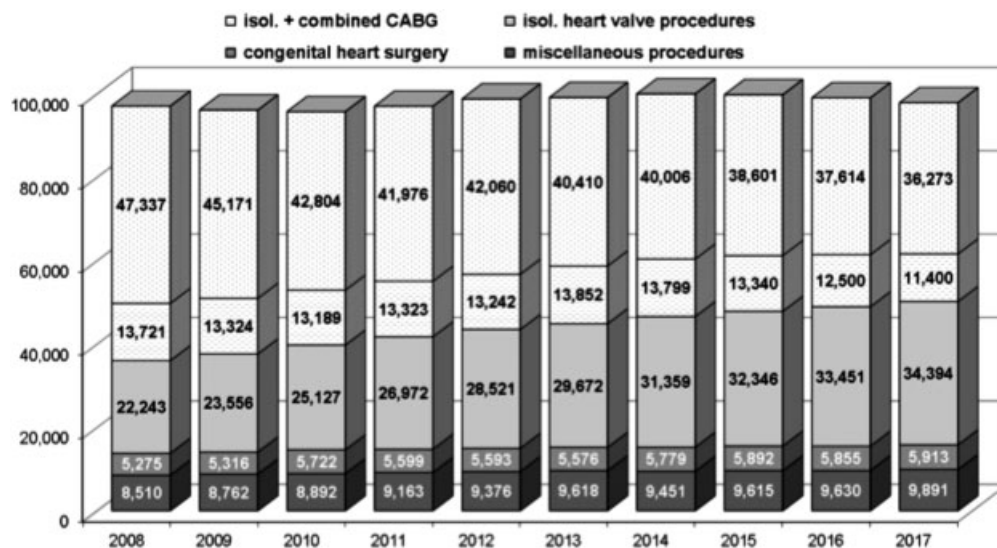
**Table Mis4** Pacemaker and ICD procedures

Device/category				With ECC		Without ECC	
	n	†	%	n	†	n	†
Pacemaker	13,560	120	0.9	14	2	13,546	118
Implantation	8,963	79	0.9	3	2	8,960	77
Battery exchange	1,814	3	0.2	1	0	1,813	3
Revision	2,783	38	1.4	10	0	2,773	38
ICD	8,296	91	1.1	21	4	8,275	87
Implantation	3,537	15	0.4	0	0	3,537	15
Battery exchange	1,812	6	0.3	0	0	1,812	6
Revision	2,947	70	2.4	21	4	2,926	66
Miscellaneous	1,348	6	0.4	0	0	1,348	6
<b>Total</b>	<b>23,204</b>	<b>217</b>	<b>0.9</b>	<b>35</b>	<b>6</b>	<b>23,169</b>	<b>211</b>

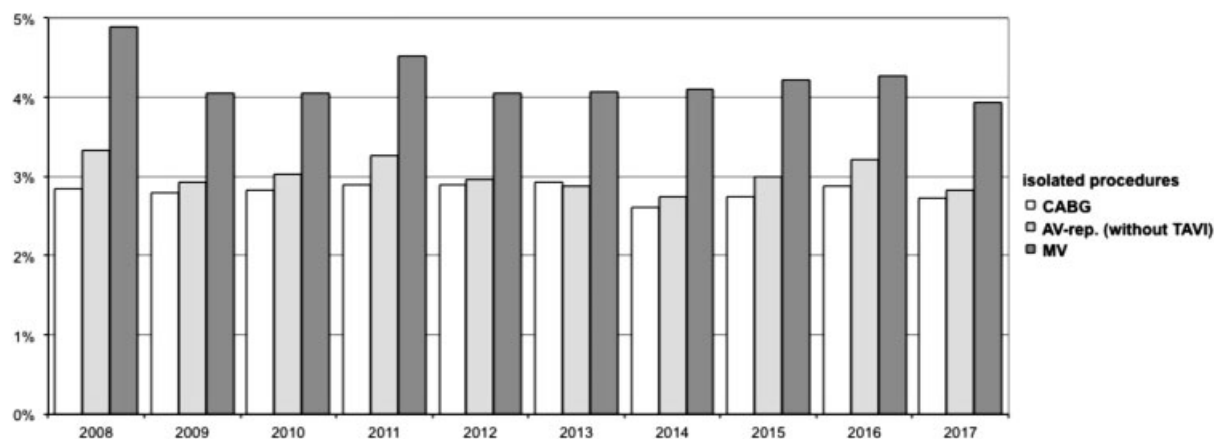
**Table Mis5** Surgical procedures for tachyarrhythmia

Energy source	Endocardiac	Epicardiac	Total
	<i>n</i>	<i>n</i>	
Unipolar radiofrequency	100	165	265
Unipolar cryoradiofrequency	88	137	225
Bipolar radiofrequency	224	1,991	2,215
Cryotherapy	1,306	253	1,559
Microwave	0	8	8
Focused ultrasound	29	108	137
Laser	0	0	0
Other	3	6	9
<b>Total</b>	<b>1,750</b>	<b>2,668</b>	<b>4,418</b>

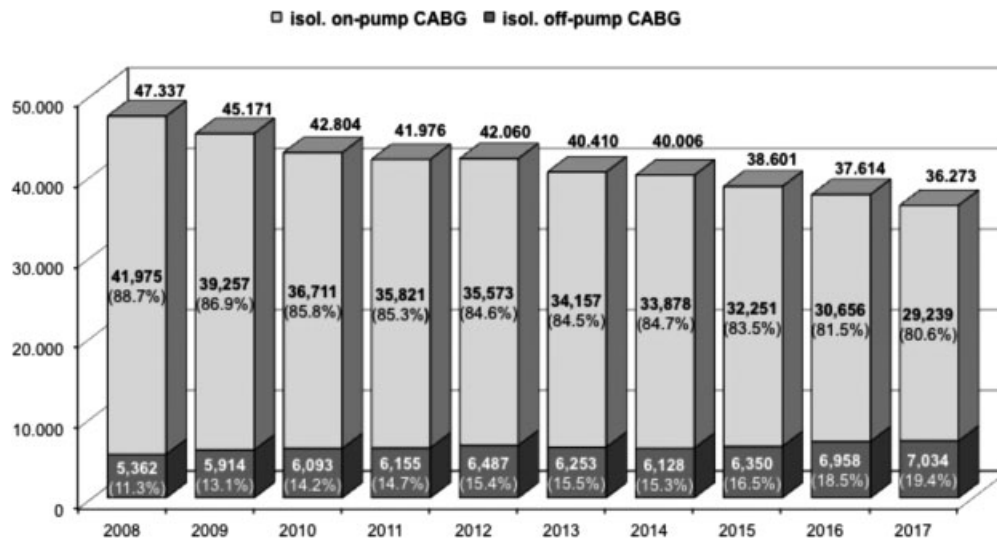
Note: 391 procedures are not unspecified with regard to endocardiac/epicardiac ablation.



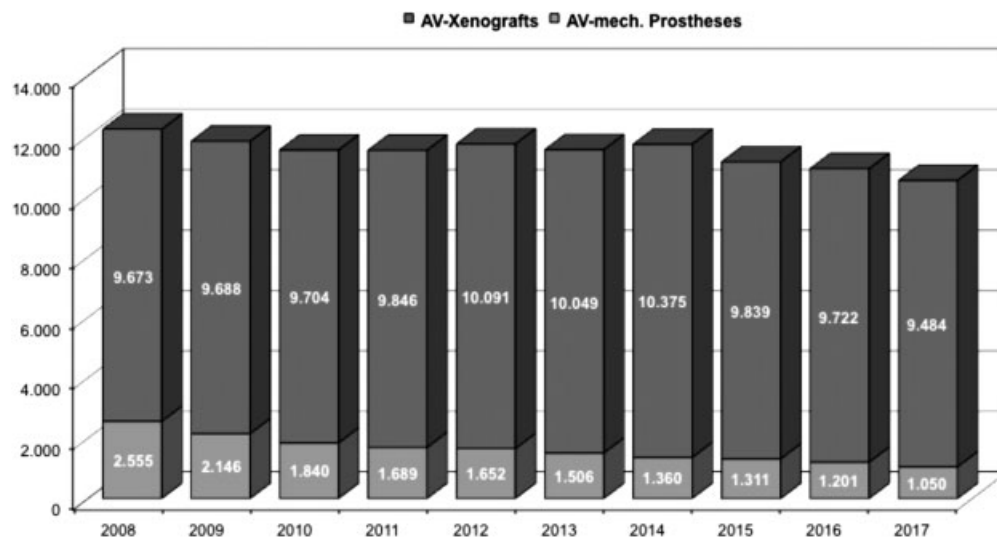
**Fig. 1** Selected heart surgical categories (2008–2017). 1. Isolated and combined CABG: all types 2. Isolated heart valve procedures: combination with aortic surgery summarized in miscellaneous procedures. 3. Congenital heart surgery: ASD repairs in adults or in combination with CABG or heart valve procedures are summarized in the CABG or heart valve procedure groups. 4. Miscellaneous procedures: all other types of procedures with ECC.



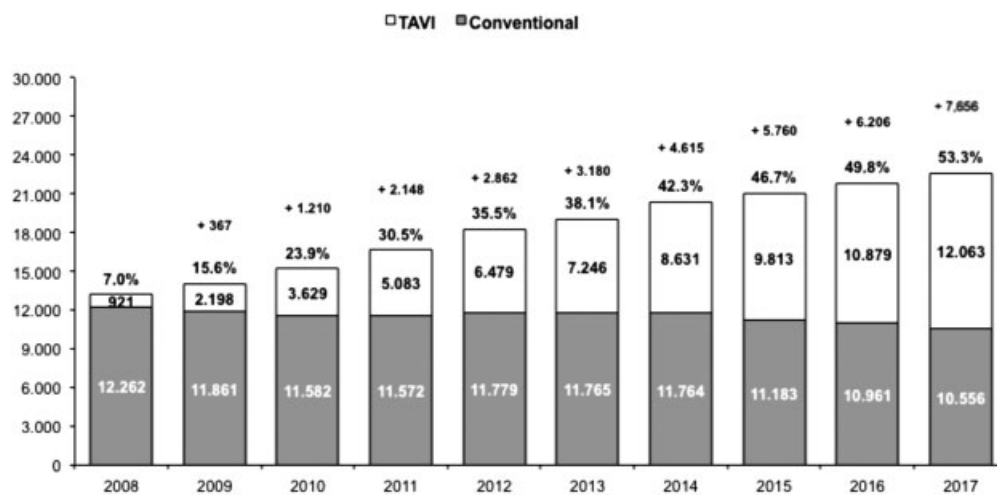
**Fig. 2** Unadjusted mortality for selected procedures (2008–2017).



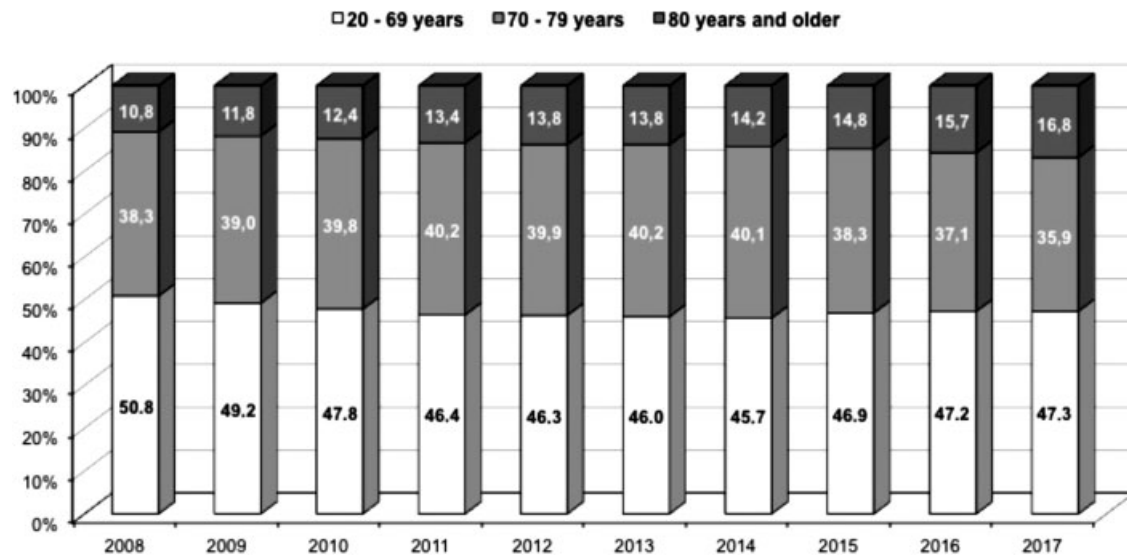
**Fig. 3** Isolated coronary artery bypass grafting (2008–2017).



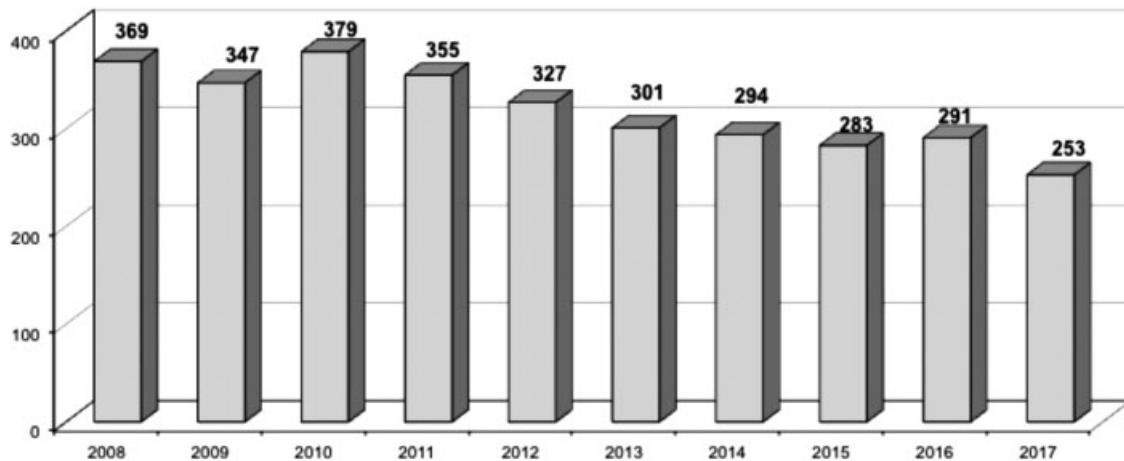
**Fig. 4** Isolated aortic valve replacement (2008–2017). Notes: Ross procedures, homograft implantations, and transcatheter heart valve intervention excluded.



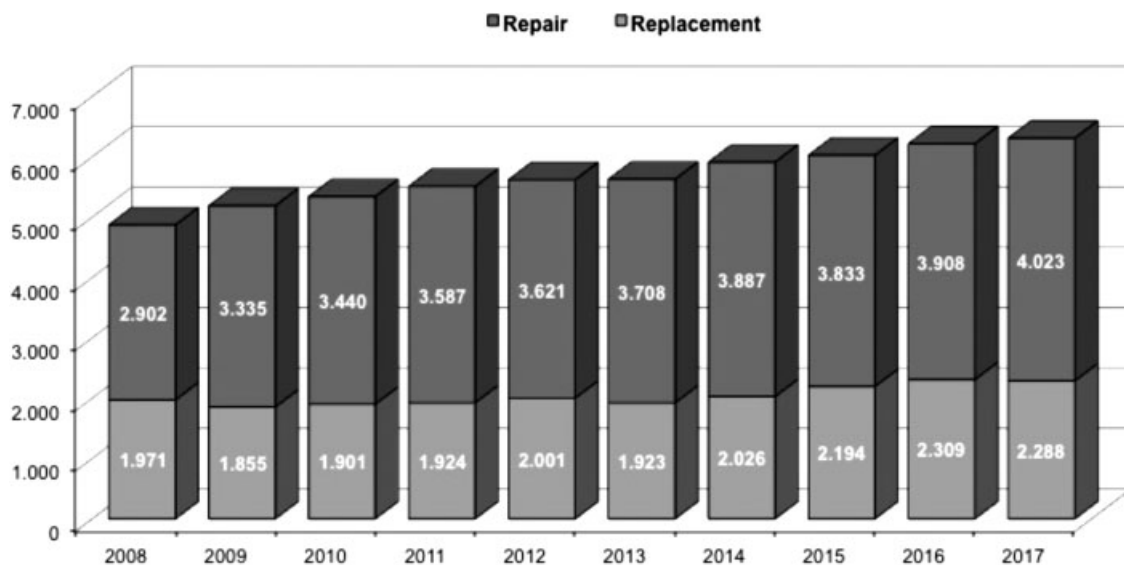
**Fig. 5** Isolated aortic valve replacement and transcatheter aortic valve implantation (TAVI). The annual count of TAVI submitted to the voluntary registry of German Society for Thoracic and Cardiovascular Surgery does not represent all TAVI procedures performed in Germany in 2017. +Additional TAVI procedures calculated from the German legal quality assurance program, § 136ff, § 137a SGB V.



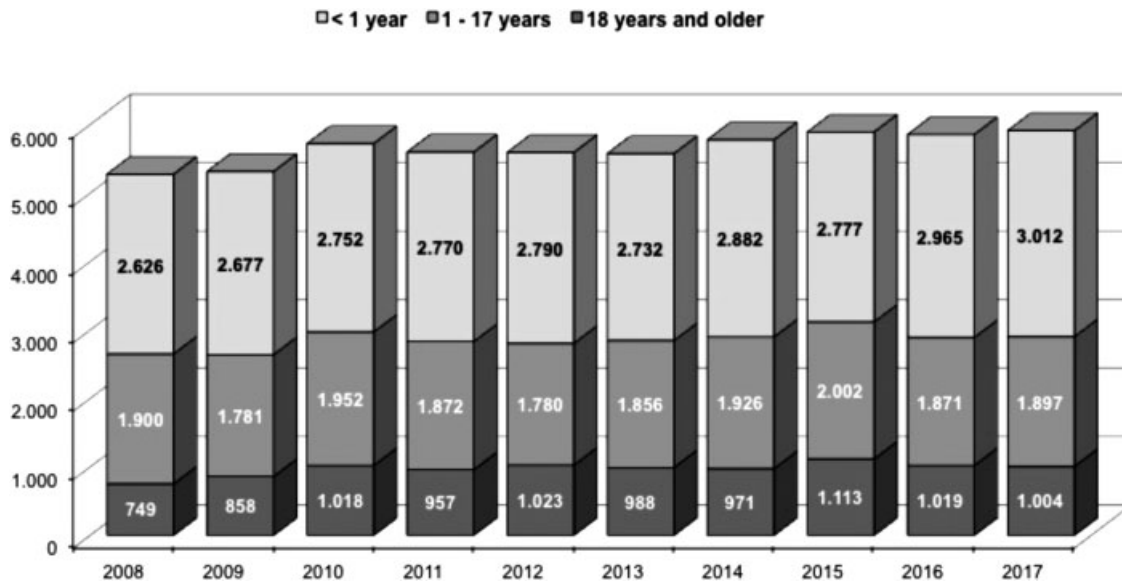
**Fig. 6** Age distribution of cardiac procedures (2008–2017). Notes: Patients < 20 years and pacemaker/implantable cardioverter defibrillator procedures were excluded.



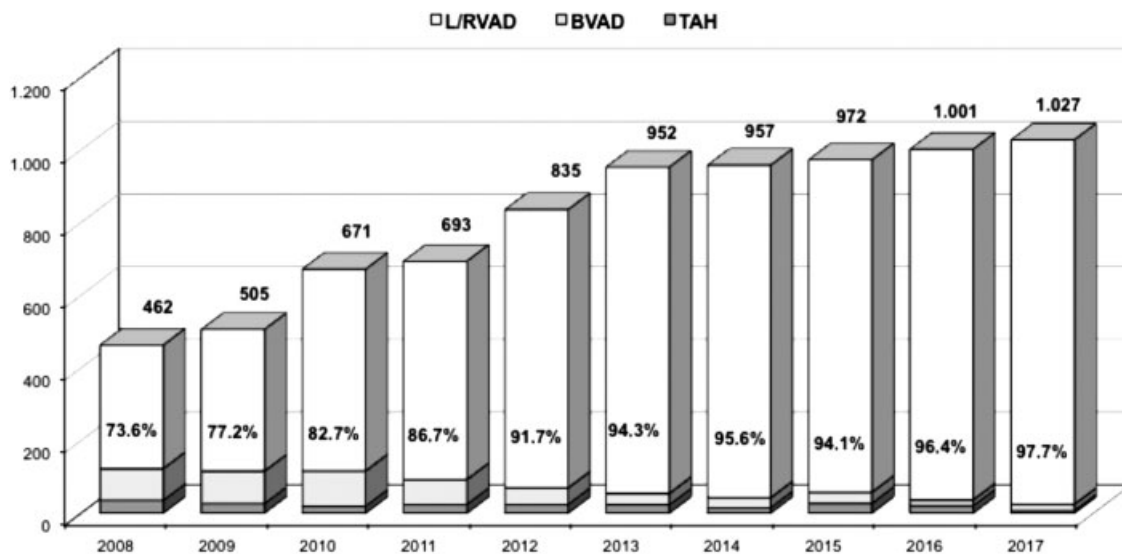
**Fig. 7** Heart transplantation (2008–2017).



**Fig. 8** Isolated mitral valve surgery (2008–2017).



**Fig. 9** Age distribution for CHD (2008–2017). 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). Abbreviation: CHD, congenital heart disease.



**Fig. 10** Development of mechanical circulatory support (2008–2017).

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