German Heart Surgery Report 2019: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

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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 2019 are analyzed. For this period, a total of 175,705 procedures were submitted to the registry, 100,446 summarized as heart surgery procedures in a classical sense. The unadjusted in-hospital survival rate for the 34,224 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 3.8:1) was 97.3%. For the 36,650 isolated heart valve procedures (16,625 transcatheter interventions included), it was 96.4%. Concerning short- and long-term circulatory support, a total of 2,716 extracorporeal life support/extracorporeal membrane oxygenation implantations, resp. 953 assist device implantations (L-/ R-/ BVAD, TAH) were registered. In 2019, the number of isolated heart transplantations increased to 333, a rise of 6.7% compared to the previous year. The isolated lung transplantations amounted to 311, a decrease of 8.5%. 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
- outcomes
- congenital heart disease
- coronary artery bypass grafting
- aortic surgery
- heart/lung transplantation

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. Thirty years ago the board of directors of the German Society for Thoracic and Cardiovascular Surgery (GSTCVS, www.dgthg.de) decided to set up a periodic data collection of all cardiac surgical procedures in terms of a voluntary, unaudited registry.[1,2] Since 1989, the data are updated annually, summarized in the sense of a registry, and published in the scientific society journal each year.[3–7] 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 provide

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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 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 and results presented in this report comprehend the survey of the year 2019.

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 (ICPM) called "operation code" (OPS - Operationen- und Prozedurenschlüssel).

All participating institutions were requested to complete the structured questionnaire by January 20, 2020, 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 2019 were all cardiac surgical procedures performed on patients between January 1, 2019 and December 31, 2019, unrelated to the date of patients' admission or discharge as compared to 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 the 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 data set, regardless of the hard- and software used locally.

In 2019, a total of 78 institutions performed heart surgery. As in the years before, all departments answered the questionnaire and delivered a complete data set for the year 2019, 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 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 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, 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 2019

►**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, 2018. The range of heart operations per 100,000 inhabitants again shows a minimum of 104.2 (Bavaria, population: 13,076,721) and a maximum of 168.7 (Sachsen-Anhalt, population: 2,208,321), while the nationwide mean-value by the end of 2018 was 120.0. Analyzing quantified categories of heart operations by department dimension categorizes nearly 62% of institutions into two clusters with at least 577 up to 1,483 procedures, 29% into those with a minimum of 1,517 up to a maximum of 4,099 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 21, and combined heart-lung transplantations in 4 institutions (►**Table 3**).

The number of procedures using ECC in Germany from 2010 to 2019 is illustrated in ►**Table 4**. Over the past decade, the number of heart operations using ECC shows a decline by 12,927 procedures, presumably reflecting an achievement of established innovations like catheter-based procedures in cardiac medicine and minimally invasive therapeutic options in heart surgery, such as off-pump CABG.

Overall, 175,705 procedures were reported to the registry for the year 2019, a difference of <0.5% compared to 2018 (174,902 procedures). In 2019, a total of 100,446 heart surgical procedures in the narrower sense displays an increase of 1.8% ($n = 1{,}739$) compared to 2018 (98,707 procedures) (►**Table 5**). Concerning gender distribution, the registry shows an overall male/female ratio of 2.0:1 with the greatest difference (3.7:1) in the patient group with coronary procedures (►**Table 6**). About 10.8% ($n = 10{,}861$) of the operations were conducted as emergency procedures, and 8.4% ($n = 8{,}481$) were reoperations (►**Table 7**). Sixteen thousand three hundred sixty (44.6%) isolated heart valve procedures were performed as single, 3,206 as double (8.7%), and 355 (1.0%) as triple heart valve procedures (►**Table V1**). Three thousand two hundred ninety-three (35.1%) aortic valve and 3,438 (53.6%) mitral valve operations were performed via a minimally invasive access (►**Table V2**). In 8,305 (88.4%) isolated aortic valve operations using ECC, xenograft prostheses were implanted, while in 4,140 (64.5%) isolated mitral valve operations a reconstruction with preservation of the native mitral valve could be achieved (►**Table V3**, ►**Figs. 1** and **2**). In a total of 3,004 combined mitral valve repair procedures, 1,321 (44.0%) simultaneous CABG procedures, 927 tricuspid valve repairs (30.9%), and 505 (16.8%) aortic valve procedures were performed (►**Table V4**). The subgroup of 3,561 multiple heart valve procedures amounted to 2,958 (83.1%) operations, as a combination of mitral + tricuspid ($n = 1{,}600$) or mitral + aortic ($n = 1{,}358$) valve procedures (►**Table V5**). Regarding 15,304 transcatheter aortic valve implantations (TAVI), 13,886 (90.7%) procedures were performed by transvascular and 1,418 (9.3%) by transapical access. In TAVI procedures with the need of ECC, a remarkably high unadjusted mortality rate of 25.9% ($n = 81$) resp. 23.5% ($n = 17$) could be observed (►**Table V6**), probably related to complications during the initial procedure.

►**Tables C1**+**C2**, **Con1**+**2**, **Mis1**–**5** as well as ►**Figs. 1**–**9** to **10** demonstrate further compiled registry data under different aspects and for various categories.

Compared to the data of previous years, several important developments remained almost unchanged in 2019. The age distribution of patients (►**Fig. 5**) shows a continuous shift towards an elderly patient population. Presently, 33.5% of the cardiac procedures are performed in patients from 70 to 79 years of age, and 18.6% in octo-/nonagenarians. However, unadjusted mortality rates just show a discrete change over the last decade (►**Fig. 4**). The number of CABG procedures, isolated or combined, decreased over the past decade, while the relative number of isolated off-pump CABG remains on a nearly unchanged level of 20.7% compared to the previous year (2018: 20.6%) (►**Figs. 3**, **6**).

There is still a continuous increase in transcatheter heart valve procedures in Germany with a total of 16,469 procedures in 2019 (►**Table V6**). For the last year 15,304 (62.4%) TAVI and 9,233 (37.6%) surgical aortic valve replacement procedures were reported to the registry (►**Fig. 7**). 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 resp. expert consensus on the management of valvular heart disease,[8–11] the German Federal Joint Committee (G-BA) implemented a quality assurance directive for "minimally invasive heart valve interventions (TAVI, transcatheter mitral clip reconstruction)" in July 2015. In this obligatory structures, defined processes, and qualified personnel are precisely specified.[12] Further surveys for selected procedures, such as the legally compulsory quality assurance (§135a SGB V) or the voluntary nationwide German Aortic Valve Registry (GARY),[13–20] provide various important findings and thus also contribute to an exceptional patient benefit.

In 2019, the rate of isolated mitral valve reconstructions remains almost unchanged on a remarkable level of 64.5% (2018: 64.3%) (►**Fig. 2**). 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,[21] 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 to this registry.

In 2019, the ventricular assist device (L-/ R-/ BVAD, TAH) implantations ($n = 953$) showed a slight increase of 1.2% compared to 2018 ($n = 942$) (►**Fig. 9**), while the heart transplantations ($n = 333$) reached a new height for the past 5 years (►**Fig. 10**). Nevertheless, the mechanical circulatory support therapy, in particular left ventricular assist device, 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 2019. 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.[22] As observed in recent years, heart surgery in Germany is continuously performed on a high level with superior in-hospital patient survival compared to 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 perioperative risk profile.

Compared to 2018, the number of cardiac surgery procedures showed a slight decrease for isolated + combined

coronary artery bypass procedures, an ongoing trend in view of the German population characteristics and in the context of application of the scientific guidelines.[23,24] Otherwise, the renewed increase in heart transplantations is a reason for hope that this positive development will continue.

Further 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 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 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 declared.

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Abbreviation

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	extracorporal life support
ECMO	extracorporal 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[a]	Population[b]	Heart procedures/100,000 inhabitants
Baden Württemberg	11,680	11,069,533	105.5
Bayern	13,626	13,076,721	104.2
Berlin	3,973	3,644,826	109.0
Brandenburg	3,576	2,511,917	142.4
Bremen	745	682,986	109.1
Hamburg	2,375	1,841,179	129.0
Hessen	6,899	6,265,809	110.1
Mecklenburg-Vorpommern	2,114	1,609,675	131.3
Niedersachsen	10,238	7,982,448	128.3
Nordrhein-Westfalen	21,820	17,932,651	121.7
Rheinland-Pfalz	5,181	4,084,844	126.8
Saarland	1,318	990,509	133.1
Sachsen	5,279	4,077,937	129.5
Sachsen-Anhalt	3,725	2,208,321	168.7
Schleswig-Holstein	4,088	2,896,712	141.1
Thüringen	2,975	2,143,145	138.8
Germany	**99,612**	**83,019,213**	**120.0**

[a] $n = 834$ foreign residences excluded.
[b] Federal Office for Statistics of German Population due date December 31, 2018.

Table 2 Departments assorted by quantified categories ($\sum^a$ [$n = 100,446$])

Procedures (quantity)	<500	500–999	1,000–1,499	1,500–1,999	2,000-5,000
Departments	7	24	24	12	11
Average	372	797	1,186	1,685	2,728
Range	237–499	577–992	1,008–1,483	1,517–1,905	2,076–4,099

[a]CIED and extracardiac surgery without ECC are excluded.

Table 3 Departments summarized by heart surgery procedures 2019

Category	*n*
Coronary artery bypass grafting	77
Heart valve surgery	77
Pacemaker/ICD procedures	76/73
Surgery for CHD in patient <1 year with ECC	22[a]
Heart transplantation	21[b]
Heart-lung transplantation	4

[a]$n = 2099$; thereof: 18 operations in 1 unit, 22 to 45 operations in 5 units, 57 to 95 operations in 7 units, 110 to 240 operations in 9 units.
[b]$n = 333$: thereof: 1 to 4 transplants in 8 units, 5 transplants in 3 units, 10 to 18 transplants in 3 units, 21 to 89 transplants in 7 units.

Table 4 Cardiac procedures using extracorporeal circulation (2010–2019)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Departments	79	78	79	79	78	78	78	78	78	78
Procedures	84,686	84,402	84,388	84,040	83,787	81,527	79,082	76,696	72,331	71,759
Average	**1,072**	**1,082**	**1,068**	**1,064**	**1,074**	**1,045**	**1,014**	**983**	**927**	**920**

Table 5 Frequency of cardiac procedures 2019

Category	With ECC	Without ECC	Total	Diff. 2018 (%)
CABG isolated	27,147[a]	7,077[a]	44,093	+ 0.6%
CABG combined	9,692[a]	177[a]	44,093	− 4.1%
Heart valve procedures	20,197[a]	16,453[a]	36,650	+ 5.0%
Surgery of thoracic aorta	7,591[a]	655[a]	8,246	+ 0.9%
Surgery for CHD	4,819[a]	938[a]	5,757	− 1.6%
Cardiac surgery, other	1,207[a]	1,480[a]	2,687	+ 14.4%
Assist device procedures	723[a]	1,907[a]	2,630	− 4.8%
Extracardiac surgery	352[a]	53,970	54,322	+ 0.3%
Pacemaker and ICD procedures	31[a]	21,289	21,320	− 5.0%
Total	**71,759**	**103,946**	**175,705**	**+ 0.5%**

[a]Sum: $n = 100,446$ (heart surgery procedures).

Table 6 Gender distribution 2019

	Female		Male	
Distribution	***n***	**%**	***n***	**%**
Heart valve procedures	15,656	43	20,994	57
Coronary procedures	9,292	21	34,801	79
CHD procedures	2570	45	3,187	55
Surgery of thoracic aorta	2,804	34	5,442	66
Cardiac surgery, other	1,633	61	1,054	39
Assist device	705	27	1,925	73
Pacemaker and ICD	8,135	38	13,185	62
Extracardiac surgery	18,764	35	35,558	65
Total	**59,559**	**38**	**116,146**	**62**

Table 7 Additional data 2019 versus 2018

Procedures with ECC	2019		2018	
Emergency	10,861	10.8%	11,147	11.3 %
Redo	8,481	8.4%	8,642	8.8%

Table V1 Isolated heart valve procedures

Procedure	*n*	†	%
Single valve	16,360	534	3.3
Double valve	3,206	318	9.9
Triple valve	355	58	16.3
Transcatheter access (single valve)	16,595	400	2.4
Transcatheter access (double valve)	30	4	13.3
Unspecified	104	11	10.6
Total	**36,650**	**1,325**	**3.6**

Transcatheter heart valve procedures: 15,304 aortic valve implantations; 152 mitral valve implantations; 988 mitral valve repairs. Seven tricuspid valve implantations; 142 tricuspidal valve repairs; 30 double aortic and mitral valve procedures; 2 pulmonary valve implantations.

Table V2 Single heart valve procedures

Access path	*n*	†	%
Aortic valve			
Sternotomy	6,098	215	3.5
Partial sternotomy	3,293	55	1.7
Transvascular	13,886	289	2.1
Transapical	1,418	77	5.4
Mitral valve			
Sternotomy	2,981	186	6.2
Minimal invasive	3,438	32	0.9
Transcatheter	1,140	33	2.9
Tricuspidal valve			
Sternotomy	365	37	10.1
Minimal invasive	125	7	5.6
Transcatheter	149	1	0.7
Pulmonary valve			
Sternotomy	55	2	3.6
Minimal invasive	0	0	–
Transcatheter	2	0	0.0
Total	**32,950**	**934**	**2.8**

Apical aortic conduits procedures ($n = 5$) are not included.

Table V3 Isolated aortic/mitral valve operations

Prosthesis/ native heart valve	Aortic			Mitral		
	n	†	%	*n*	†	%
Xenograft	8,305	245	3.0	1,891	170	9.0
Mechanical prosthesis	908	22	2.4	385	16	4.2
Repair	158	2	1.3	4,140	32	0.8
Homograft	20	1	5.0	3	0	0.0
Total	**9,391**	**270**	**2.9**	**6,419**	**218**	**3.4**

Transcatheter procedures and apical aortic conduits procedures ($n = 5$) are not included.

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

Mitral valve procedures	Repair			Implantation/ replacement			Total			
	n	†	%	*n*	†	%	*n*	% repair	†	%
Isolated	4,140	32	0.8	2,279	186	8.2	6,419	64.5	218	3.4
+ CABG	1,321	82	6.2	840	133	15.8	2,161	61.1	215	9.9
+ Tricuspid valve repair[a]	927	33	3.6	603	74	12.3	1,530	60.6	107	7.0
+ Aortic valve	505	31	6.1	853	136	15.9	1,358	37.2	167	12.3
+ CABG + Aortic valve replacement	251	36	14.3	274	48	17.5	525	47.8	84	16.0
Total	**7,144**	**214**	**3.0**	**4,849**	**577**	**11.9**	**11,993**	**59.6**	**791**	**6.6**

[a]Seventy procedures (not specified mitral valve + tricuspid valve surgery) excluded. Mortality: 19% (13/70).

Table V5 Multiple heart valve procedures

Combination	*n*	†	%
Mitral + tricuspid	1,600	120	7.5
Aortic + mitral	1,358	167	12.3
Aortic + mitral + tricuspid	354	58	16.4
Aortic + tricuspid	175	27	15.4
Aortic + pulmonary[a]	56	1	1.8
Tricuspid + pulmonary	17	3	17.6
Aortic + mitral + pulmonary	1	0	0.0
Total	**3,561**	**376**	**10.6**

Notes: Transcatheter procedures are excluded.
[a]Including Ross procedures.

Table V6 Transcatheter heart valve procedures

	Without ECC		With ECC		Total		
	n	†	*n*	†	*n*	†	%
Aortic valve implantation	15,206	341	98	25	15,304	366	2.4
Transvascular	13,805	268	81	21	13,886	289	2.1
Transapical	1,401	73	17	4	1,418	77	5.4
Mitral valve	1,069	25	71	8	1,140	33	2.9
Repair	925	14	63	5	988	19	1.9
Implantation	144	11	8	3	152	14	9.2
Tricuspid valve repair	148	1	1	0	149	1	0.7
Repair	141	1	1	0	142	1	0,7
Implantation	7	0	0	0	7	0	0
Aortic + mitral valve implantation	28	3	2	1	30	4	13.3
Aortic valve implantation[a] + CABG	18	1	12	4	30	5	16.7
Mitral valve implantation[b] + CABG	0	0	2	0	2	0	0
Aortic + mitral valve + CABG	0	0	0	0	0	0	–
Total	**16,469**	**371**	**186**	**38**	**16,655**	**409**	**2.5**

Notes: Pulmonary valve implantation for CHD excluded.
9% of TAVI by transapical access and less than 1% of TAVI under ECC conditions.
[a]Femoral, subclavian, or transaortic access.
[b]Transvascular and transapical access.

Table C1 Isolated CABG and combined procedures with ECC

	n	†	%
Isolated CABG	34,224	928	2.7
+ Aortic valve replacement	5,289	226	4.3
+ Other	1,752	124	7.1
+ Mitral valve repair	1,321	82	6.2
+ Mitral valve replacement	840	133	15.8
+ Aortic valve replacement + mitral valve repair	251	36	14.3
+ Aortic + mitral valve replacement	274	48	17.5
+ Aneurysm resection	110	4	3.6
+ Transcatheter aortic valve implantation	30	5	16.7
Total	**44,091**	**1,586**	**3.6**

Table C2 Isolated CABG with/without ECC

Grafts	With ECC			Without ECC			Total		
	n	†	%	*n*	†	%	*n*	†	%
Single	955	55	5.8	1,332	22	1.7	2,287	77	3.4
Double	5,609	185	3.3	1,879	32	1.7	7,488	217	2.9
Triple	11,740	338	2.9	2,677	39	1.5	14,417	377	2.6
Quadruple	6,370	161	2.5	968	15	1.5	7,338	176	2.4
Quintuple + more	2,473	81	3.3	221	0	0.0	2,694	81	3.0
Total	**27,147**	**820**	**3.0**	**7,077**	**108**	**1.5**	**34,224**	**928**	**2.7**

Table Con1 Congenital heart surgery with/without ECC

Age (years)	*n*		†		%	
	With ECC	Without ECC	With ECC	Without ECC	With ECC	Without ECC
< 1	2,121	744	81	25	3.8	3.4
1–17	1,806	179	15	1	0.8	0.6
≥ 18	969	15	34	1	3.5	6.7
Total	**4,896**	**938**	**130**	**27**	**2.7**	**2.9**

Table Con2 Procedures for congenital heart disease with and without ECC

Lesion/Procedure	Age < 1 year			Age 1–17 years			Age ≥ 18 year		
	n	†	%	*n*	†	%	*n*	†	%
ASD	47	0	0.0	291	0	0.0	244	6	2.5
Complete AV canal	200	4	2.0	89	4	4.5	10	0	0.0
VSD	331	2	0.6	133	0	0.0	15	0	0.0
Fallot's tetralogy	180	0	0.0	42	0	0.0	2	0	0.0
DORV	68	3	4.4	14	2	14.3	0	–	–
TGA	157	5	3.2	3	0	0.0	0	–	–
TGA + VSD	62	0	0.0	9	0	0.0	0	–	–
Truncus arteriosus	29	3	10.3	5	0	0.0	0	–	–
Fontan circulation	0	–	–	231	1	0.4	4	0	0.0
Norwood	153	26	17.0	1	0	0.0	0	–	–
Pulmonary valve	62	1	1.6	210	0	0.0	67	2	3.0
Transcatheter pulmonary valve implantation	0	–	–	0	–	–	2	0	0.0
Aortic valve	50	2	4.0	224	3	1.3	370	12	3.2
Ross procedure	8	4	50.0	24	0	0.0	52	0	0.0
Mitral valve	39	1	2.6	93	0	0.0	92	7	7.6
Tricuspid valve	81	6	7.4	56	2	3.6	40	4	10.0
PDA	191	6	3.1	26	0	0.0	1	0	0.0
Coarctation	199	2	1.0	30	0	0.0	0	–	–
Others	1,001	41	4.1	461	4	0.9	85	4	4.7
HTx	7	0	0.0	37	0	0.0	0	–	–
HLTx	0	–	–	0	–	–	0	–	–
LTx	0	–	–	6	0	0.0	0	–	–
Total	**2,865**	**106**	**3.7**	**1,985**	**16**	**0.8**	**984**	**35**	**3.6**

Table Mis1 Ross procedures (autologous AV- and PVR)

Age (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
< 18	43	40	36	33	37	28	38	38	29	32
≥ 18	184	134	117	107	90	64	72	52	61	104
Total	**227**	**174**	**153**	**140**	**127**	**92**	**110**	**90**	**90**	**136**

Table Mis2 Heart and lung transplantation

Transplant	With ECC			Without ECC		
	n	†	%	*n*	†	%
HTx	333	33	9.9			
HLTx	6	2	33.3			
LTx	42	4	9.5	269	11	4.1

Notes: All pediatric transplantations (demonstrated in table Con2) are included.
Eurotransplant (ET) report 2019: 333 HTx, 4 HTx + kidneyTx, 1 HTx + liverTx, 6 HLTx, 327 DLTx, 26 SLTx, 0 LTx + kidneyTx and 2 LTx + liverTx.

Table Mis3 Aortic surgery

Replacement [a]	With ECC			Without ECC		
	n	†	%	*n*	†	%
Supracoronary replacement of ascending aorta	1,377	116	8.4			
Supracoronary ascending + aortic valve replacement	1,372	58	4.2			
Infracoronary replacement of ascending aorta			–			
Mechanical aortic valve conduits	349	16	4.6			
Biological aortic conduits	1,034	120	11.6			
David procedure	479	9	1.9			
Yacoub procedure	111	5	4.5			
Other	345	31	9.0			
Aortic arch replacement[b]	2,398	316	13.2			
Replacement of descending aorta	51	6	11.8	3	1	33.3
Thoracoabdominal aortic replacement	75	14	18.7	11	1	9.1
Endostent descending aorta	0	0	–	641	32	5.0
Total	**7,591**	**691**	**9.1**	**655**	**34**	**5.2**

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.
[a]Procedures for abdominal aortic diseases excluded: 424, abdominal procedures and 27 endovascular abdominal stents.
[b]All possible combined procedures included; the only common denominator is aortic arch surgery.

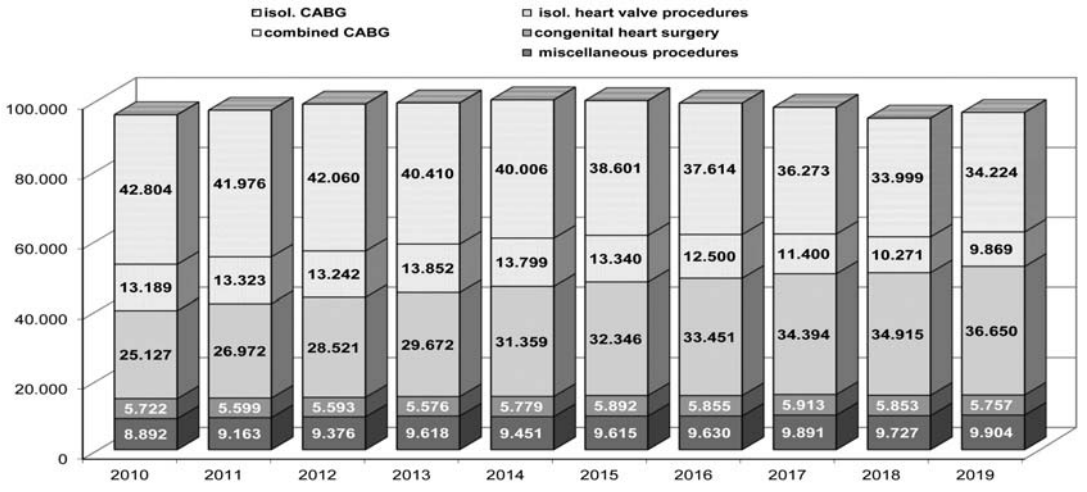
Table Mis4 Pacemaker and ICD procedures

Device/Category				With ECC		Without ECC	
	n	†	%	*n*	†	*n*	†
Pacemaker	**12,952**	**101**	**0.8**	**11**	**3**	**12,941**	**98**
Implantation	8,722	60	0.7	1	0	8,721	60
Battery exchange	1,682	1	0.1	1	0	1,681	1
Revision procedures	2,548	40	1.6	9	3	2,539	37
ICD	**6,864**	**71**	**1.0**	**18**	**2**	**6,846**	**69**
Implantation	2,933	16	0.5	4	0	2,929	16
Battery exchange	1,569	2	0.1	0	0	1,569	2
Revision procedures	2,362	53	2.2	14	2	2,348	51
Miscellaneous	**1,504**	**19**	**1.3**	**2**	**0**	**1,502**	**19**
Total	**21,320**	**191**	**0.9**	**31**	**5**	**21,289**	**186**

Table Mis5 Surgical procedures for treatment of tachyarrhythmias

Energy source	Endocardiac	Epicardiac	Total
	n	*n*	
Unipolar radio frequency	97	181	278
Unipolar cooled radio frequency	73	141	214
Bipolar radio frequency	262	1,857	2,119
Cryothermy	1,388	401	1,789
Microwave	0	15	15
Focused ultrasound	6	118	124
Laser	0	0	0
Other	10	0	10
Total	**1,836**	**2,713**	**4,549**

Note: 361 procedures are unspecified with regard to endocardiac/epicardiac ablation.



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. 1 Selected heart surgical categories (2010–2019). ASD, atrial septal defect; CABG, coronary artery bypass grafting; ECC, extracorporeal circulation.

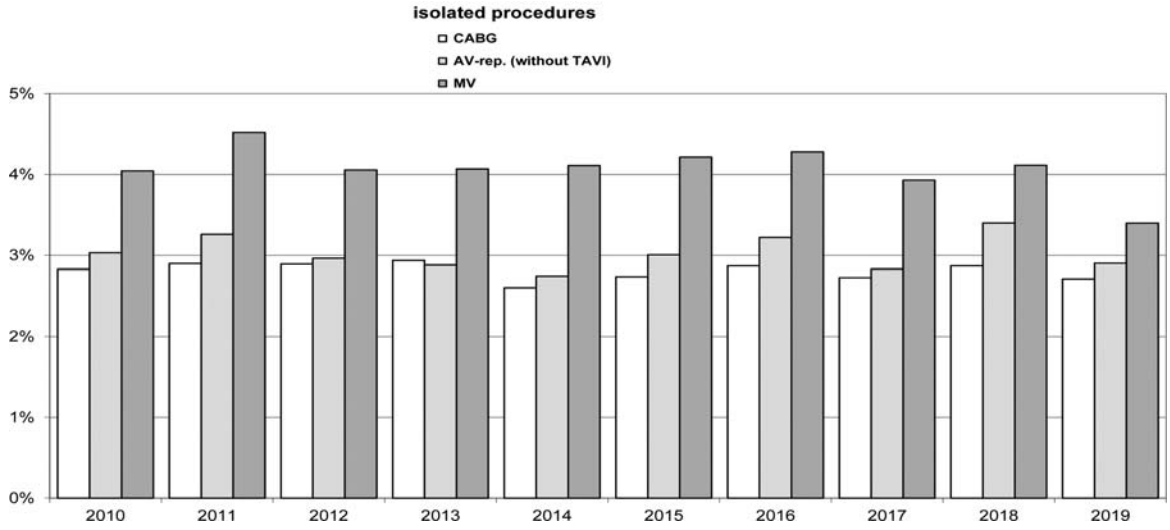


Fig. 2 Unadjusted mortality for selected procedures (2010–2019). AV, aortic valve; CABG, coronary artery bypass grafting; MV, mitral valve; TAVI, transcatheter aortic valve implantation.

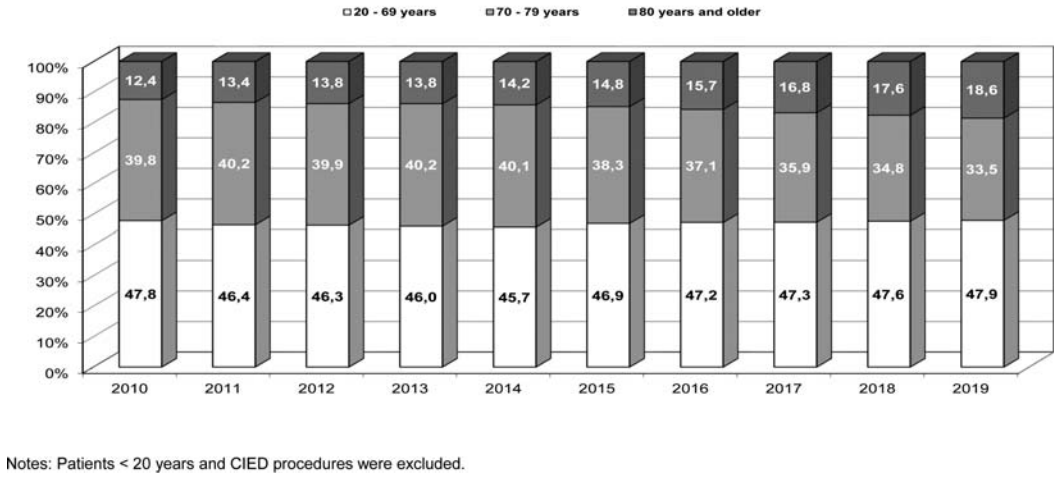


Fig. 3 Age distribution of cardiac procedures (2010–2019). Notes: Patients < 20 years and cardiac implantable electronic device procedures were excluded.

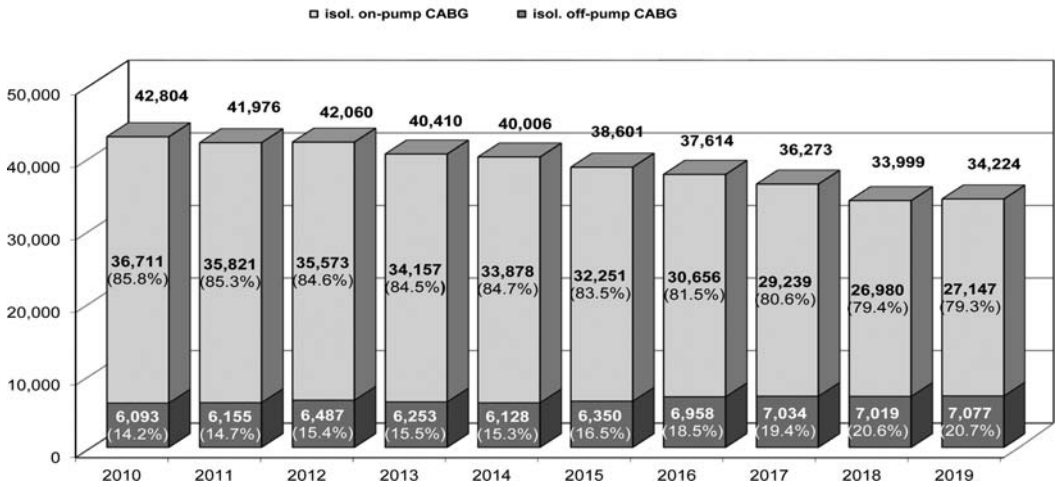


Fig. 4 Isolated coronary artery bypass grafting (2010–2019). CABG, coronary artery bypass grafting.

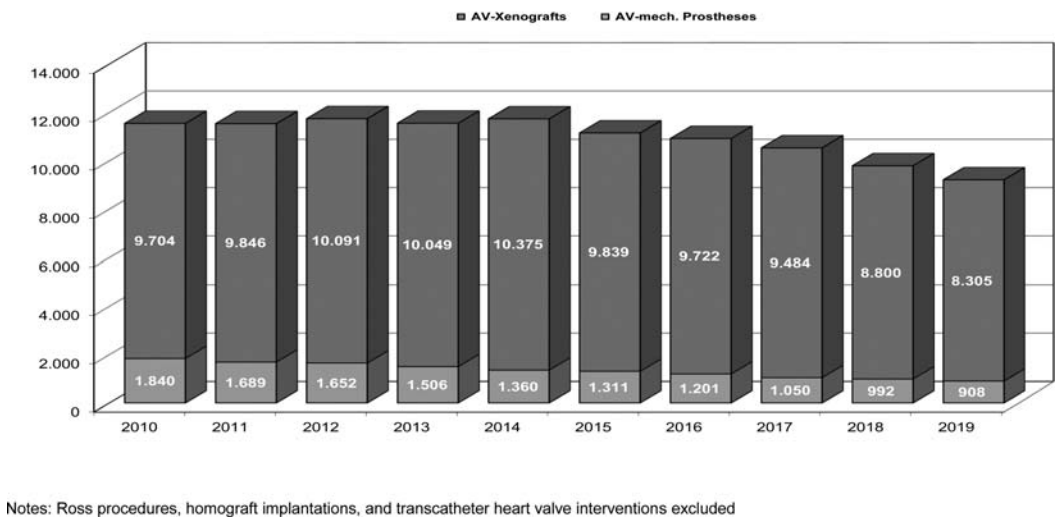


Fig. 5 Isolated aortic valve (AV) replacement (2010–2019). Notes: Ross procedures, homograft implantations, and transcatheter heart valve interventions excluded.

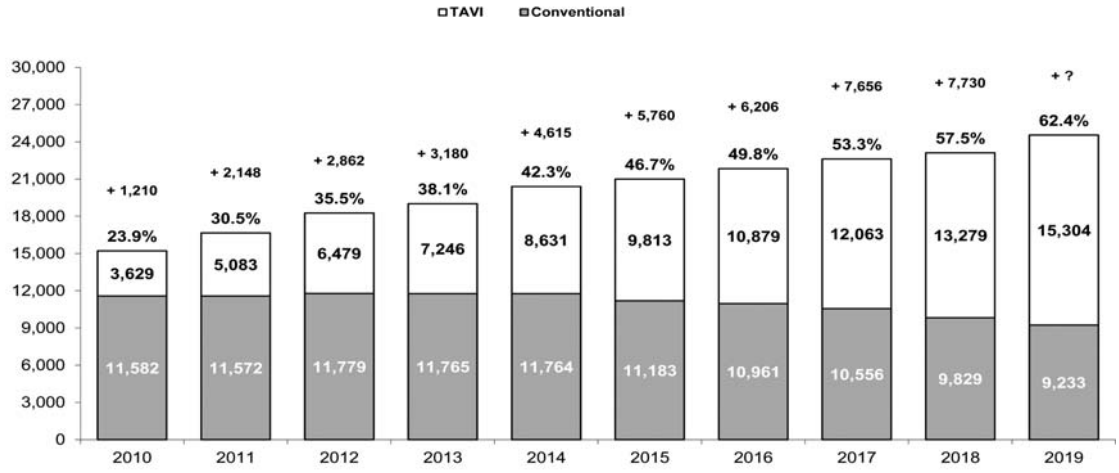


Fig. 6 Isolated aortic valve replacement and transcatheter aortic valve implantation (TAVI). The annual count of TAVI submitted to this voluntary registry does not represent all TAVI procedures performed in Germany in 2019. $^{+}$Additional TAVI procedures calculated from the German legal quality assurance program, §§ 135a/ 136/ 137 SGB V. The annual count of TAVI submitted to this voluntary registry does not represent all TAVI procedures performed in Germany in 2019 *Additional TAVI procedures calculated from the German legal quality assurance program, §§ 135a/ 136/ 137 SGB V.

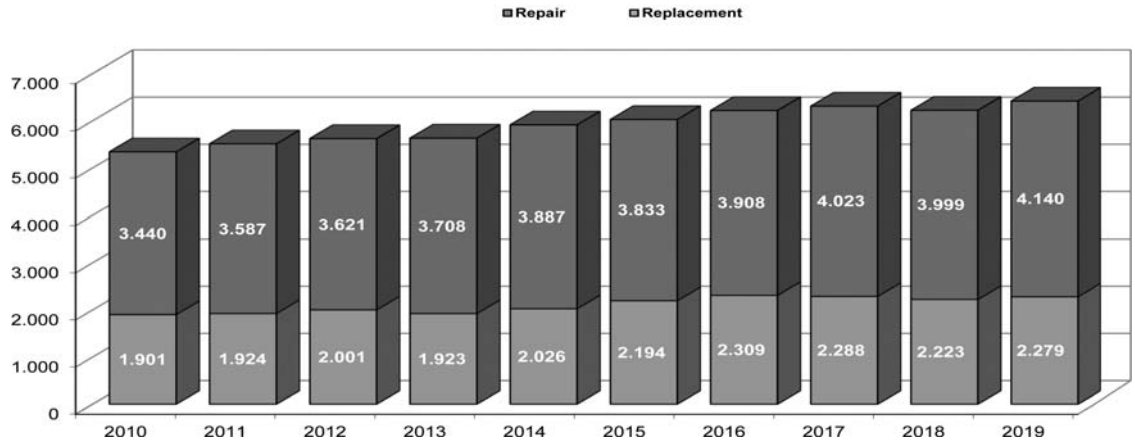


Fig. 7 Isolated mitral valve surgery (2010–2019).

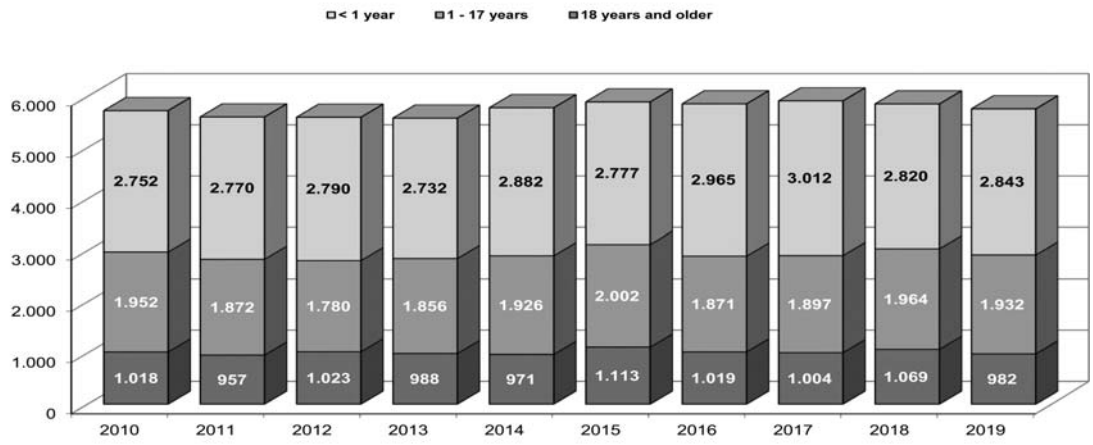


Fig. 8 Age distribution for congenital heart disease (CHD) (2010–2019). Notes: Bias possible due to the fact that not all relevant procedures can be allocated exactly to CHD-category in patients > 18 years (e.g., aortic valve disease). Notes: Bias possible due to the fact that not all relevant procedures can be allocated exactely to CHD-category in patients > 18 years (e.g., aortic valve disease).

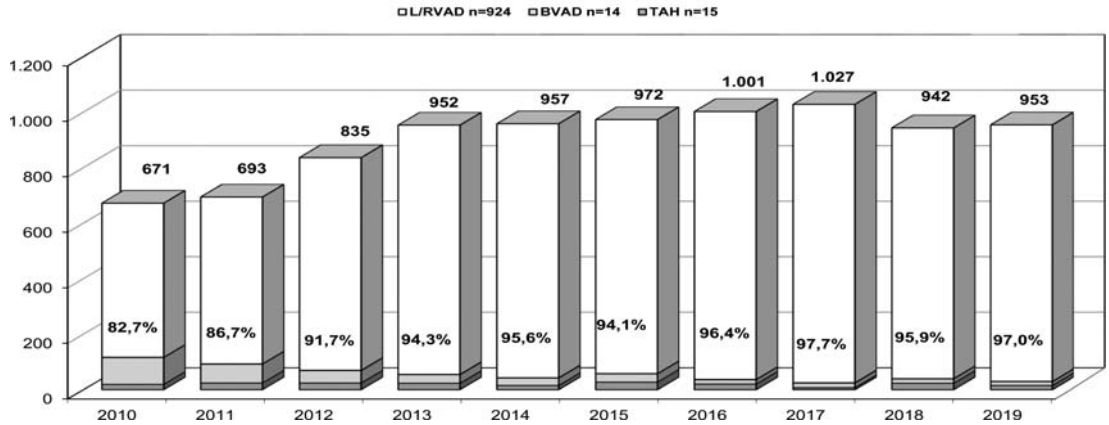


Fig. 9 Mechanical circulatory support devices (2010–2019).

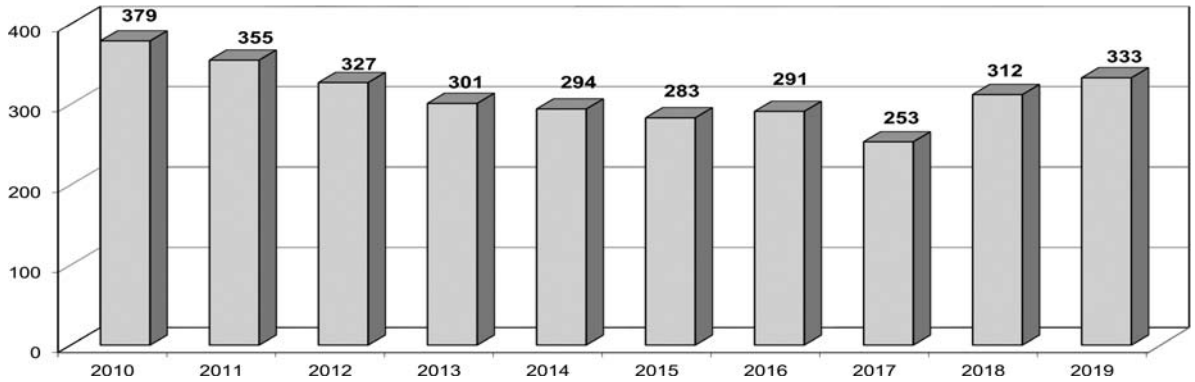


Fig. 10 Heart transplantations (2010–2019).

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12 Richtlinie zu minimalinvasiven Herzklappeninterventionen; Richtlinie über Maßnahmen zur Qualitätssicherung bei der Durchführung von minimalinvasiven Herzklappeninterventionen gemäß § 136 Absatz 1 Satz 1 Nummer 2 für nach § 108 SGB V zugelassene Krankenhäuser MHI-RL; Gemeinsamer Bundesausschuss (G-BA): https://www.g-ba.de/richtlinien/84/

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