German Heart Surgery Report 2023: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

Andreas Beckmann[1] Renate Meyer[2] Jana Eberhardt[1] Jan Gummert[3] Volkmar Falk[4]

[1] German Society for Thoracic and Cardiovascular Surgery, Langenbeck-Virchow-Haus, Berlin, Germany
[2] BQS Institute for Quality and Patient Safety, Hamburg, Germany
[3] Clinic for Thoracic and Cardiovascular Surgery, Heart and Diabetes, Center NRW, Bad Oeynhausen, Germany
[4] Department for Cardiac, Thoracic and Vascular Surgery, German Heart Center Charité, University Medicine, Germany

Address for correspondence Andreas Beckmann, MD, Deutsche Gesellschaft für, Thorax-, Herz- und Gefäßchirurgie (DGTHG), Langenbeck-Virchow-Haus, Luisenstr. 58-59, 10117 Berlin, Germany (e-mail: gf@dgthg.de).

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Abstract

Based on a voluntary registry, founded by the German Society for Thoracic and Cardiovascular Surgery (DGTHG) in 1980, a well-defined but limited dataset of all cardiac and vascular surgery procedures performed in 77 German heart surgery departments is reported annually. For the year 2023, a total of 168,841 procedures were submitted to the registry. Of these operations, 100,606 are defined as heart surgery procedures in a classical sense. The unadjusted in-hospital survival rate for the 28,996 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 2.8:1) was 97.6%; 97.7% for the 39,859 isolated heart valve procedures (23,727 transcatheter interventions included); and 99.2% for 19,699 pacemaker/implantable cardioverter defibrillator procedures. Concerning short and long-term mechanical circulatory support, a total of 2,982 extracorporeal life support/extracorporeal membrane oxygenation implantations and 772 ventricular assist device implantations (left/right ventricular assist device, BVAD, total artificial heart) were reported. In 2023, 324 isolated heart transplantations, 248 isolated lung transplantations, and 2 combined heart–lung transplantations were performed. This annually updated registry of the DGTHG represents nonrisk adjusted voluntary public reporting and encompasses acute data for nearly all heart surgical procedures in Germany. It constitutes trends in heart medicine and represents a basis for quality management (e.g., benchmark) for all participating institutions.

Keywords
- heart valve surgery
- congenital heart disease
- coronary artery bypass grafting
- aorta/aortic
- transplantation
- heart–lung transplantations

Introduction

Legitimate demands for sophisticated quality management in medicine—by authorities, scientific organizations, health care companies, and patients all over the world—have stimulated quality awareness. This resulted in the development of multiple quality assurance activities such as benchmark projects, public reporting, and registries. More than 30 years ago, the board of directors of the German Society for Thoracic and Cardiovascular Surgery (DGTHG, www.dgthg.de) decided to set up an annual data collection of all cardiac surgical procedures performed in Germany in terms of a voluntary, unaudited registry.[1,2] Since 1989, the registry is updated on an annual basis and published in the scientific journal of the

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DGTHG each year.[3–7] The aims are as follows: to detect developments and upcoming trends in cardiac surgery in Germany; to compile various acute in-hospital outcomes for nearly all cardiac surgical procedures; to provide each participant with a benchmark of the institutional results in comparison to the nationwide achievements; and to facilitate the comparison on an international level.

For monitoring trend developments in cardiac surgery, the registry covers all relevant techniques and innovative technologies including minimally invasive cardiac surgery and structural transcatheter heart valve interventions (e.g. transcatheter aortic valve implantations [TAVI] and transcatheter mitral valve replacement).

Data presented in this report comprehend the survey of the year 2023.

Material 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 asked to complete the structured questionnaire by January 22, 2024, submitting all performed procedures and related in-hospital mortality. The recommended path for data export is an electronic transmission of an encrypted file to the society office in Berlin. After the 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 the submission of complete datasets.

Inclusion criteria for the registry data 2023 were all cardiac surgical procedures performed on patients from January 1st to December 31st, 2023, 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 set-up of the registry—established over four 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. Finally, 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 2023, a total of 77 institutions performed heart surgery. As in the years before, all departments answered the questionnaire and delivered a complete data set for the surgical details, including unadjusted 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 possible.

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

Categorical data are displayed as absolute and/or relative frequencies. Due to the lack of complete data for patients' risk profiles, mortality rates generally are not risk adjusted. 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 31st, 2022.

The questionnaires were compiled using Microsoft Visual Basic for Applications. Analyses were performed with IBM SPSS Statistics v23 and Microsoft Excel 2010, and charts and tables were created with Microsoft Excel 2010.

Limitations

Since the data of this registry are voluntary and an external monitoring is not provided, reporting bias is possible. Due to missing data for appropriate risk estimation, a risk adjustment cannot be performed.

Registry Data 2023

►**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, 2022. The range of heart operations per 100,000 inhabitants shows a minimum of 104.1 (Bayern, population: 13,369,393) and a maximum of 160.7 (Sachsen-Anhalt, population: 2,186,643), while the nationwide mean value at the end of 2023 was 118.5 (►**Table 1**).

The size of programs can be analyzed by department dimension, which categorizes more than 64.9% of institutions into two clusters from 500 up to 1,499 procedures (2023: 55/77) 28.6% into those from 1,500 up to a maximum of 5,032 performed procedures (►**Table 2**).

Pediatric heart operations in patients suffering from congenital heart disease (CHD, <1 year, with extracorporeal

circulation [ECC]) are conducted in 21 centers, isolated heart transplantations in 19, and combined heart–lung transplantations in 1 institution (►**Table 3**).

Overall, as shown in ►**Tables 4** and **5**, 168,841 procedures were reported to the registry for the year 2023, an increase of 4.1% compared to 2022 (162,167 procedures), but still a decline compared to the prepandemic period (2019: 175,705 procedures). In 2023, the total number of 100,606 heart surgical procedures showed an increase compared to the previous year (93,913 procedures). Regarding CABG procedures, the numbers only showed a discrete difference, while heart valve and thoracic aortic procedures increased remarkably. In addition, the ventricular assist device procedures increased by 14.9% compared to 2022 (►**Table AD**).

The number of procedures using ECC from 2014 to 2023 is illustrated in ►**Table 4**. There was a gradual reduction until 2019, with a sharp decline in 2020 due to the Severe Acute Respiratory Syndrome Corona Virus type 2 (SARS CoV2) pandemic. Even in 2023, the prepandemic level was not reached. This presumably also reflects the growing field of transcatheter heart valve therapies.

Concerning gender distribution, the registry shows an overall male/female ratio of almost 2:1 with the greatest difference (4:1) in the patient group with coronary procedures (►**Table 5**). In total, 11,319 (11.3%) operations were classified as emergency procedures, and 7,037 (7.0%) were reoperations (►**Table 6**). These proportions appear quite consistent over the past years.

As shown in ►**Table V1**, 16,147 (37.1%) isolated heart valve procedures were performed as single, 3,112 as double (7.1%), and 292 (0.7%) as triple valve procedures. Furthermore, 3,763 (43.2%, $n = 8{,}702$) aortic valve and 4,161 (60.8%, $n = 6{,}840$) mitral valve operations were performed via a minimally invasive access (►**Table V2**). The isolated transvascular aortic, mitral, and tricuspid valve procedures show a continuous increase, while the rate of transapical transcatheter aortic valve implantations decreased. Concerning the surgical aortic valve replacements (sAVR), an increase of 9.7% in 2023 could be observed (►**Fig. 6**). The sAVR unadjusted mortality was 2.7%, nearly consistent over the last 3 years. With regard to the interpretation of this and every other reported mortality rate in this report, it is important to note that all mortality rates are nonrisk-adjusted and not clustered by indication. As a result, groups are inhomogeneous and enroll all emergency procedures and all valve pathologies including endocarditis. Concerning the unadjusted mortality rate of 1.8% in 2023 for TAVI, it must be considered that the included data are only those transferred by the heart surgery departments in Germany and therefore are incomplete (►**Table V2**).

In 7,678 (88.3%) isolated sAVR under ECC conditions, xenograft prostheses were implanted, also a consistent distribution over the last 5 years (►**Table V3**, ►**Fig. 5**). 64.7% (4,352) of the isolated mitral valve operations for primary and secondary mitral valve insufficiency, mitral stenosis and endocarditis were mitral valve repairs (►**Fig. 7**). In a total of 2,551 combined mitral valve repair procedures, 1,020 (40.0%) simultaneous CABG procedures, 893 tricuspid valve repairs (35.0%), 465 (18.2%) aortic valve procedures, and 173 (6.8%) concomitant CABG and surgical AVR were performed (►**Table V4**). The analyses of the crude mortality rates for mitral valve procedures demonstrate an improvement in the subgroup of isolated (3.2%) mitral valve surgery as well as for the combined procedures (8.2%) regarding repair (2.1%) and implantation/replacement (9.9%) (►**Table V4**). It is important to note that the registry does not allow the stratification of results based on mitral valve pathology, and hence, the data do not reflect the outcomes of mitral valve repair for isolated degenerative mitral valve insufficiency.

The subgroup of 3,404 multiple heart valve procedures includes 2,829 (83.1%) double heart valve operations as a combination of mitral + tricuspid ($n = 1{,}545$) or mitral + aortic ($n = 1{,}284$) valve procedures (►**Table V5**). In addition a total of 188 Ross procedures were performed, 151 (80.3%) in age from 18 years and 37 (19.7%) under 18 years (►**Table V6**). With regard to the 20,638 transcatheter aortic valve implantations reported in this registry and in line with international developments, an increase in procedures performed by transvascular access (19,947 [96.7%]) and a decrease in those performed by transapical access (691 [3.3%]) were observed. In TAVI procedures without ECC, the unadjusted mortality for those by transvascular access was 1.6% (314/19,882) and 5.3% (36/685) for those by the transapical access approach. For the very rare isolated TAVI procedures under ECC conditions ($n = 71$), the unadjusted mortality rate was 26.2% (17/65) resp. 66.7% (4/6) (►**Table V7**), probably related to severe complications during the initial procedure.

In total, 78.6% of 36,872 CABG operations were performed as isolated procedures ($n = 28.996$), 11.5% ($n = 4{,}243$) combined with sAVR, and 4.8% ($n = 1{,}770$) with simultaneous mitral valve operations (►**Table C1**). These numbers are in the range of previous years. ►**Table C2** provides an overview of the isolated CABG operations focused on the number of bypass grafts and indicates the corresponding unadjusted mortality rates for on- and off-pump surgery. The total number of isolated CABG procedures increased by 3.6%, and the subgroup without ECC increased to 7,598 (2022: 6,705). In addition, the unadjusted mortality rate of this subgroup was 1.5% (2022: 1.4%), independent of the number of grafts. Conversions from off- to on-pump CABG are not captured in the registry. The unadjusted mortality rate of all isolated CABG procedures was 2.4% in 2023 and therefore reached the best result within the last 10 years (►**Fig. 2**).

►**Tables Con1** and **2** show data for congenital heart surgery procedures. In this subcategory, the total number ($n = 5{,}449$) shows a slight increase. Meanwhile, the unadjusted overall mortality rate changed to 2.2% (►**Table Con1**) compared to 2.4% in 2022 ($n = 5{,}343$), and 2.1% in 2021 ($n = 5{,}589$).

►**Table Tx** shows a decrease of orthotopic heart transplantations by 10% from 356 in 2022 to 324 in 2023. An increase in organ donation can only be expected if the legal framework for organ donation in Germany would change.

►**Tables Mis1**–**2** to **3** demonstrate further compiled registry data under different aspects and for various categories, for example, aortic surgery. The number of permanent pacemaker and ICD procedures increased to 19,699, an

increase of 5.8% (2022: 18,627) (►**Fig. 11**). The unadjusted mortality rate for pacemaker procedures decreased to 0.7% (2022: 0.9%), while for ICD procedures it remained at 0.9% (2022: 0.9%) (►**Table Mis2**). As expected, the highest mortality rates for CIED procedures were detected in the redo subgroup.

Compared to the data of previous years some expected changes can be seen on one hand, while several developments remained almost unchanged in 2023 on the other hand. The number of CABG procedures, isolated or combined, show comparable levels after a decline during the SARSCoV2-pandemic. The number of isolated heart valve procedures increased to 43,512 procedures (+ 13.0%) and thereby reached a higher level than before the pandemic (►**Fig. 1**). However, unadjusted mortality rates for CABG, sAVR, and MV procedures vary slightly over the last decade, although CABG and sAVR reached the best results in 2023 (►**Fig. 2**). While the age distribution of patients over the years continued to evolve toward a higher percentage of elderly patients (≥80 years) as well as a continuous increase of adults ≤ 69 years, this trend did not continue in 2023 and remained quite consistent compared to 2022 (►**Fig. 3**). Presently, 30.5% of the cardiac procedures are performed in patients from 70 to 79 years of age, and 20.7% in octo-/nonagenarians. The relative amount of isolated off-pump CABG increased to 26.2% in 2023 (2022: 24.0%) (►**Fig. 4**).

With regard to aortic valve prostheses distribution, in 90.0% ($n = 7,687$), sAVR was performed using a xenograft (►**Fig. 5**), whereas in 10.0% ($n = 855$), a mechanical prosthesis was implanted: a consistent proportion over the past years. The unchanged development of transcatheter heart valve procedures in Germany led to a total of 23,752 reported procedures in 2023 (►**Table V7**). Focusing on the distribution of aortic valve procedures for 2023, 20,638 (70.7%) TAVI and 8,552 (29.3%) sAVR were reported to the registry (►**Fig. 6**). Since data were reported exclusively by departments for cardiac surgery, the registry cannot reach completeness for all TAVI procedures performed in Germany. On the basis of and in addition to the recommendations of international scientific guidelines on the management of valvular heart disease,[8–10] the German Federal Joint Committee (G-BA) implemented a quality assurance directive[11] for "minimally invasive heart valve interventions (TAVI, transcatheter mitral clip reconstruction)" in 2015. Further surveys for selected procedures, such as the legally compulsory quality assurance (§135a SGB V) or the voluntary nationwide German Aortic Valve Registry (GARY),[12–33] provide important findings in addition to this registry and thus also contribute to an exceptional patient benefit. It is expected that the GARY will become part of the mandatory German Implant Registry from 2025.

In 2023, the rate of isolated mitral valve repairs remains almost unchanged on a level of 63.5% (2022: 64.7%) (►**Fig. 7**). Based on the fact that all isolated mitral valve procedures regardless of the underlying mitral valve pathology or urgency of the operation are included, results cannot be compared to registry data published for isolated pathologies (such as degenerative mitral valve insufficiency).[34]

In 2023 almost half (43.7%; $n = 2,346$) of cardiac operations for CHD were performed in neonates/infants <1 year, 37.2% in children between 1 and 17 years and 19.1% in patients at least 18 years of age (►**Fig. 8**). These numbers show a relatively steady level over the past decade. In this context, a potential bias cannot be excluded due to the fact that the survey systematics do not allow the clear assignment of all relevant procedures to the CHD category (e.g., aortic valve disease in patients > 18 years).

As shown in ►**Fig. 9**, permanent ventricular assist device implantations increased by 14.9% compared to 2022. In addition, the total number of temporary circulatory support device implantations also increased by 6.2%, mainly attributed to the application of extracorporeal pumps without oxygenators (►**Table AD**). The number of heart transplantations decreased to 324, a decline of 9.0% compared to the previous year (►**Fig. 10**).

The distribution of procedures with/without ECC remained on a nearly stable level (►**Fig. 11**, ►**Table Mis2**).

Discussion

The registry of the DGTHG enables a comprehensive overview of all heart surgical procedures performed in German cardiac surgery departments. The accuracy of this registry remains high due to the implemented compilation algorithm using standardized operation coding as a relevant criterion for reimbursement purposes. This is supported by other authors who could demonstrate high accuracy for major outcome parameters in unaudited registries.[35] Considering the background of demographic evolvements, the population to be treated changes to patients at increased age combined with a higher proportion of related comorbidities and an accordingly complex perioperative risk profile.

Compared to 2022, the number of cardiac surgery procedures showed a steady state for isolated/combined CABG and a small increase of sAVR. Despite the demographic development of the German population, the rapid development of transcatheter procedures, and more restrictive recommendations for surgery in scientific guidelines,[10,36,37] a large volume increase is rather unlikely. The low level of heart transplantations as a result of donor shortage should trigger a political discussion with regard to regulation for organ transplantation in Germany.

Further improvements of the registry would be needed to allow for risk-adjusted data analyses and to inform about quality outcome data. In addition, An improved database should also allow for longitudinal follow-up.

Completeness, validity, and further progress depend on continued efforts and close collaboration of the DGTHG and all German cardiac surgical departments. This will continue to be of utmost importance to ensure patient safety and to provide evidence for the high quality of heart surgery in Germany.

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 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
Tx transplantation
VADs ventricular assist devices
VSD ventricular septal defect

Tables and Figures

Table 1 German federal states/heart surgery procedures

Federal state	Population[a]	Procedures[b]	100,000 inhabitants
Baden-Württemberg	11,280,257	11,807	104.7
Bayern	13,369,393	13,913	104.1
Berlin	3,755,251	4,209	112.1
Brandenburg	2,573,135	3,541	137.6
Bremen	684,864	752	109.8
Hamburg	1,892,122	2,325	122.9
Hessen	6,391,360	7,990	125.0
Mecklenburg-Vorpommern	1,628,378	1,989	122.1
Niedersachsen	8,140,242	10,460	128.5
Nordrhein-Westfalen	18,139,116	21,008	115.8
Rheinland-Pfalz	4,159,150	4,979	119.7
Saarland	992,666	1,223	123.2
Sachsen	4,086,152	5,337	130.6
Sachsen-Anhalt	2,186,643	3,514	160.7
Schleswig-Holstein	2,953,270	3,869	131.0
Thüringen	2,126,846	3,066	144.2
Deutschland	84,358,845	99,982	118.5

[a]Federal Office for Statistics of German: Population; due date December 31, 2022.
[b]$n = 624$, foreign residences excluded.

Table 2 Departments assorted by the number of heart surgery procedures (Σ^a [$n = 100{,}606$])

Procedures per department	<500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments	5	27	23	11	11
Average	305	767	1.186	1.683	2.961
Range	255–421	510–994	1,022–1,499	1,530–1,966	2,193–5,032

[a]Cardiac implantable electronic devices and extracardiac surgery without extracorporeal circulation are excluded.

Table 3 Departments categorized by heart surgery procedures

Category	Departments
Coronary artery bypass grafting	76
Heart valve surgery	76
Pacemaker/ICD procedures	73/70
Congenital heart disease procedures (pat <1 y with ECC)	21[a]
Heart transplantation	19[b]
Heart–lung transplantation	1

Abbreviations: ECC, extracorporeal circulation; ICD, implantable cardioverter defibrillator.
[a]$n = 1{,}755$ thereof: 7 operations in 1 unit, 22–43 operations in 5 units, 53–94 operations in 7 units, and 102–169 operations in 8 units.
[b]$n = 324$: thereof: 1–4 transplants in 6 units, 5–9 transplants in 5 units, 17–19 transplants in 2 units, and 22–75 transplants in 6 units.

Table 6 Emergency and redo procedures with ECC

Procedures	2023 (*n*)	(%)	2022 (*n*)	(%)
Emergency	11,319	(11)	10,994	(11.7)
Redo	7,037	(07)	6,740	(7.2)

Abbreviation: ECC, extracorporeal circulation.

Table 4 Heart surgery procedures with ECC (2014–2023)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Procedures	83,787	81,527	79,082	76,696	72,331	71,759	63,720	61,272	61,696	63,683
Departments	78	78	78	78	78	78	78	78	78	77
Average	1,074	1,045	1,014	983	927	920	817	786	791	827

Abbreviation: ECC, extracorporeal circulation.

Table 5 Number of heart surgery procedures/gender distribution

Category	ECC application						Gender				Total	Difference 2022 (%)
	With ECC *n* (%)			Without ECC *n* (%)			Female *n* (%)		Male *n* (%)			
CABG isolated	21,398	(74)	[a]	7,598	(26)	[a]	7,223	(20)	29,649	(80)	28,996	+ 3.6
• Combined	7,739	(98)	[a]	137	(02)	[a]					7,876	− 3.6
Heart valve procedures	19,914	(46)	[a]	23,598	(54)	[a]	18,330	(42)	25,182	(58)	43,512	+ 13.0
Surgery of thoracic aorta	7,999	(91)	[a]	816	(09)	[a]	2,865	(33)	5,950	(67)	8,815	+ 5.5
Congenital heart surgery	4,526	(84)	[a]	843	(16)	[a]	2,319	(43)	3,050	(57)	5,369	+ 1.6
Cardiac surgery, other	1,126	(45)	[a]	1,353	(55)	[a]	963	(39)	1,516	(61)	2,479	+ 2.1
Assist device procedures	614	(19)	[a]	2,578	(81)	[a]	850	(27)	2,342	(73)	3,192	+ 12.0
Extracardiac surgery	338	(01)	[a]	48,565	(99)		16,822	(34)	32,081	(66)	48,903	− 0.3
Pacemaker/ICD procedures	29	(00)	[a]	19,670	(100)		7,272	(37)	12,427	(63)	19,699	+ 0.9
Total	63,683	(38)		105,158	(62)		56,644	(34)	112,197	(66)	168,841	+ 4.1

Abbreviations: CABG, coronary artery bypass grafting; ECC, extracorporeal circulation; ICD, implantable cardioverter defibrillator.
[a]Sum: $n = 100{,}606$ (heart surgery procedures).

Table V1 Isolated heart valve procedures

Procedure	*n*	†	%
Single	16,147	487	3.0
Double	3,112	234	7.5
Triple	292	35	12.0
Transcatheter (single)	23,713	442	1.9
Transcatheter (double)	15	0	0.0
Unspecified	233	11	4.7
Total	43,512	1,209	2.8

Note: Transcatheter heart valve procedures: 20,638 aortic valve implantations; 300 mitral valve implantations; 1,892 mitral valve repairs; 28 tricuspid valve implantations; 854 tricuspidal valve repair; 15 double aortic and mitral valve procedures; 1 pulmonary valve implantation.

Table V2 Single heart valve procedures

Access path	*n*	†	%
Aortic			
Sternotomy	4,939	191	3.9
Partial sternotomy	3,763	42	1.1
Transvascular	19,947	331	1.7
Transapical	691	40	5.8
Mitral			
Sternotomy	2,688	173	6.4
Minimal invasive	4,161	47	1.1
Transcatheter	2,192	61	2.8
Tricuspid			
Sternotomy	350	22	6.3
Minimal invasive	189	6	3.2
Transcatheter	882	10	1.1
Pulmonary			
Sternotomy	56	6	10.7
Minimal invasive	0	0	–
Transcatheter	1	0	0.0
Total	39,859	929	2.3

Note: Apical aortic conduits procedures ($n = 1$) are not included.

Table V3 Protheses in isolated aortic/mitral valve surgery

Prosthesis/native heart valve	Aortic			Mitral		
	n	†	%	*n*	†	%
Xenograft	7,687	216	2.8	2,063	172	8.3
Allograft	855	16	1.9	429	14	3.3
Repair	150	0	0.0	4,352	33	0.8
Homograft	10	1	10.0	5	1	20.0
Total	8,702	233	2.7	6,849	220	3.2

Note: Transcatheter procedures and apical aortic conduits procedures ($n = 1$) are not included.

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

Mitral valve procedures	Repair			Implantation/replacement			Total		
	n	†	%	*n*	†	%	*n*	†	%
Isolated	4,352	33	0.8	2,497	187	7.5	6,849	220	3.2
+ CABG	1,020	45	4.4	750	99	13.2	1,770	144	8.1
+ Tricuspid valve repair[a]	893	22	5.5	576	52	9.0	1,469	74	5.0
+ sAVR	465	25	5.4	819	105	12.8	1,284	130	10.1
+ CABG + sAVR	173	18	10.4	266	41	15.4	439	59	13.4
Total	6,903	143	2.1	4,908	484	9.9	11,811	627	5.3

Abbreviations: CABG, coronary artery bypass grafting; sAVR, surgical aortic valve replacement.
[a]76 procedures (not specified mitral valve + tricuspid valve surgery) excluded.

Table V5 Multiple heart valve procedures

Combination	*n*	†	%
Mitral + tricuspid	1,545	87	5.6
Aortic + mitral	1,284	130	10.1
Aortic + mitral + tricuspid	290	35	12.1
Aortic + tricuspid	145	14	9.7
Aortic + pulmonary[a]	128	2	1.6
Tricuspid + pulmonary	10	1	10.0
Aortic + mitral + pulmonary	2	0	0.0
Total	3,404	269	7.9

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

Table V6 Ross procedures—autologous AV and PVR (2014–2023)

Age (years)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
<18	37	28	38	38	29	32	35	25	39	37
≥18	90	64	72	52	61	104	70	124	136	151
Total	127	92	110	90	90	136	105	149	175	188

Abbreviations: AV, aortic valve; PVR, pulmonary valve replacement.

Table V7 Transcatheter heart valve procedures

	Without ECC		With ECC		Total		
	n	†	*n*	†	*n*	†	%
Aortic valve implantation	20,567	350	71	21	20,638	371	1.8
Transvascular	19,882	314	65	17	19,947	331	1.7
Transapical	685	36	6	4	691	40	5.8
Mitral valve	2,135	61	57	0	2,192	61	2.8
Repair	1,843	46	49	0	1,892	46	2.4
Implantation	292	15	8	0	300	15	5.0
Tricuspid valve	880	10	2	0	882	10	1.1
Repair	852	9	2	0	854	9	1.1
Implantation	28	1	0	0	28	1	3.6
Aortic + mitral valve implantation	15	0	0	0	15	0	0.0
Aortic valve implantation[a] + CABG	13	4	11	3	24	7	29.2
Mitral valve implantation[b] + CABG	0	0	1	0	1	0	0.0
Aortic + mitral valve + CABG	0	0	0	0	0	0	–
Total	23,610	425	142	24	23,752	449	1.9

Abbreviations: CABG, coronary artery bypass grafting; ECC, extracorporeal circulation.
Note: Pulmonary valve implantation for CHD excluded.
[a]Femoral, subclavian, or transaortic access.
[b]Transvascular and transapical access.

Table C1 Isolated CABG and combined procedures

	n	†	%
Isolated CABG	28,996	687	2.4
+ sAVR	4,243	160	3.8
+ Other	1,331	60	4.5
+ Mitral valve repair	1,020	45	4.4
+ Mitral valve replacement	750	99	13.2
+ sAVR + mitral valve repair	173	18	10.4
+ sAVR + mitral valve replacement	266	41	15.4
+ Aneurysma resection	68	5	7.4
+ Transcatheter aortic valve implantation	24	7	29.2
+ Transcatheter mitral valve procedure	1	0	0.0
Total	36,872	1,122	3.0

Abbreviations: CABG, coronary artery bypass grafting; sAVR, surgical aortic valve replacements.

Table C2 Isolated CABG with/without ECC

Grafts	With ECC			Without ECC			Total		
	n	†	%	*n*	†	%	*n*	†	%
Single	623	41	6.6	1,570	32	2.0	2,193	73	3.3
Double	4,512	141	3.1	2,001	39	1.9	6,513	180	2.8
Triple	9,670	249	2.6	2,897	36	1.2	12,567	285	2.3
Quadruple	5,143	101	2.0	899	7	0.8	6,042	108	1.8
Quintuple + more	1,450	38	2.6	231	3	1.3	1,681	41	2.4
Total	21,398	570	2.7	7,598	117	1.5	28,996	687	2.4

Abbreviations: CABG, coronary artery bypass grafting; ECC, extracorporeal circulation.

Table Con1 Congenital heart surgery with/without ECC

Age (years)	With ECC			Without ECC			Total		
	n	†	%	*n*	†	%	*n*	†	%
<1	1,781	63	3.5	591	19	3.2	2,372	82	3.5
1–17	1,842	20	1.1	206	2	1.0	2,048	22	1.1
≥18	983	16	1.6	46	0	0.0	1,029	16	1.6
Total	4,606	99	2.1	843	21	2.5	5,449	120	2.2

Abbreviation: ECC, extracorporeal circulation.

Table Con2 CHD and procedures

Lesion/Procedure	Age < 1 y			Age 1 to 17 y			Age ≥ 18 y		
	n	†	%	*n*	†	%	*n*	†	%
ASD	47	2	4.3	231	0	0.0	228	0	0.0
Complete Atrioventricular Canal	179	2	11	137	3	2.2	21	0	0.0
VSD	233	1	0.4	110	1	0.9	15	0	0.0
Fallot's tetralogy	169	0	0.0	40	0	0.0	1	0	0.0
DORV	51	0	0.0	11	0	0.0	0	–	–
TGA	119	3	2.5	8	0	0.0	2	0	0.0
TGA + VSD	38	2	5.3	13	0	0.0	0	–	–
Truncus arteriosus	26	4	15.4	2	0	0.0	0	–	–
Fontan circulation	22	0	0.0	229	6	2.6	5	0	0.0
Norwood	110	17	15.5	1	0	0.0	0	–	–
Pulmonary valve	74	2	2.7	223	1	0.4	46	1	2.2
Transcatheter pulmonary valve implantation	0	–	–	4	0	0.0	9	0	0.0
sAVR	41	1	2.4	209	2	1.0	415	6	1.4
Ross procedure	6	0	0.0	31	1	3.2	31	0	0.0
Mitral valve	48	2	4.2	106	2	1.9	71	4	5.6
Tricuspid valve	99	0	0.0	95	0	0.0	52	3	5.8
PDA	109	4	3.7	12	0	0.0	3	0	0.0
Coarctation	187	1	0.5	34	0	0.0	3	0	0.0
Others	805	40	5.0	516	6	1.2	127	2	1.6
HTx	6	0	0.0	30	0	0.0	0	–	–
HLTx	0	–	–	0	–	–	0	–	–
LTx	3	1	33.3	6	0	0.0	0	–	–
Total	2,372	82	3.5	2,048	22	1.1	1,029	16	1.6

Abbreviations: ASD, atrial septal defect; CHD, congenital heart disease; DORV, double outlet right ventricle; HLTx, heart–lung transplantation; HTx, heart transplantation; LTx, lung transplantation; PDA, patent ductus arteriosus; sAVR, surgical aortic valve replacement; TGA, transposition of great arteries; VSD, ventricular septal defect.

Table Tx Heart and lung transplantation

Transplant	*n*	†	%
HTx	324	24	7.4
HLTx	2	0	0.0
LTx[a]	248	15	6.0

Abbreviations: HLTx, heart–lung transplantation; HTx, heart transplantation; LTx, lung transplantation.
Notes: All pediatric transplantations (demonstrated in Table Con2) are included in this table.
[a]237 LTx without ECC included.
Eurotransplant report 2023: 325 HTx, 0 HTx + kidneyTx, 3 HTx + liverTx, 2 HLTx, 243 DLTx, 20 SLTx, 0 LTx + kidneyTx, and 1 LTx + liverTx.

Table AD Assist device (temporary vs. permanent)

	n	†	%
Temporary			
ECLS/ECMO	406	1	0.2
Extracorporal pump without oxygenator	1,022	–	–
IABP	2,982	–	–
Permanent			
LVAD/RVAD Implantation	751	–	–
BVAD Implantation	7	–	–
TAH	14	–	–

Abbreviations: ECLS, extracorporeal life support; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; LVAD/RVAD/BVAD, left/right/bi ventricular assist device; TAH, total artificial heart.

Table Mis1 Aortic surgery

Procedures[a]	With ECC			Without ECC		
	n	†	%	*n*	†	%
Supracoronary replacement of ascending aorta	1,274	98	7.7			
Supracoronary ascending + aortic valve replacement	1,389	46	3.3			
Infracoronary replacement of ascending aorta						
Mechanical aortic valve conduit	311	13	4.2			
Biological aortic conduit	1,033	79	7.6			
David procedure	501	11	2.2			
Yacoub procedure	120	3	2.5			
Other	380	28	7.4			
Aortic arch replacement[b]	2,883	352	12.2			
Replacement of descending aorta	57	11	19.3	8	2	25.0
Thoraco-abdominal aortic replacement	48	7	14.6	24	1	4.2
Endostent descending aorta	3	1	33.3	784	40	5.1
Total	7,999	649	8.1	816	43	5.3

Abbreviation: ECC, extracorporeal circulation.
Notes: All procedures involving aortic surgery are included in this table. Isolated aortic surgery and all possible combined procedures (e.g. additional coronary artery bypass grafting) are summarized in this category.
[a]Procedures for abdominal aortic diseases excluded: 428 abdominal procedures and 47 endovascular abdominal stents.
[b]All possible combined procedures included; the only common denominator is aortic arch surgery.

Table Mis2 Pacemaker and ICD procedures

Device				With ECC		Without ECC	
	n	†	%	*n*	†	*n*	†
Pacemaker	12,927	88	0.7	14	4	12,913	84
Implantation	8,665	63	0.7	6	0	8,659	63
Battery exchange	1,957	2	0.1	0	0	1,957	2
Revision procedures	2,305	23	1.0	8	4	2,297	19
ICD	5,993	56	0.9	15	1	5,978	55
Implantation	2,659	12	0.5	2	0	2,657	12
Battery exchange	1,292	2	0.2	0	0	1,292	2
Revision procedures	2,042	42	2.1	13	1	2,029	41
Miscellaneous	779	6	0.8	0	0	779	6
Total	19,699	150	0.8	29	5	19,670	145

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

Table Mis3 Surgical procedures for tachyarrhythmia

	Endocardiac	Epicardiac	Total
	n	*n*	
Unipolar radio frequency	54	119	173
Unipolar cooled radio frequency	26	103	129
Bipolar radiofrequency	151	1,512	1,663
Cryotherapy	1,610	363	1,973
Microwave	1	1	2
Focused ultrasound	2	46	48
Laser	0	0	0
Other	1	1	2
Total	1,845	2,145	3,990

Note: 176 procedures are unspecified with regard to endocardiac/epicardiac ablation.

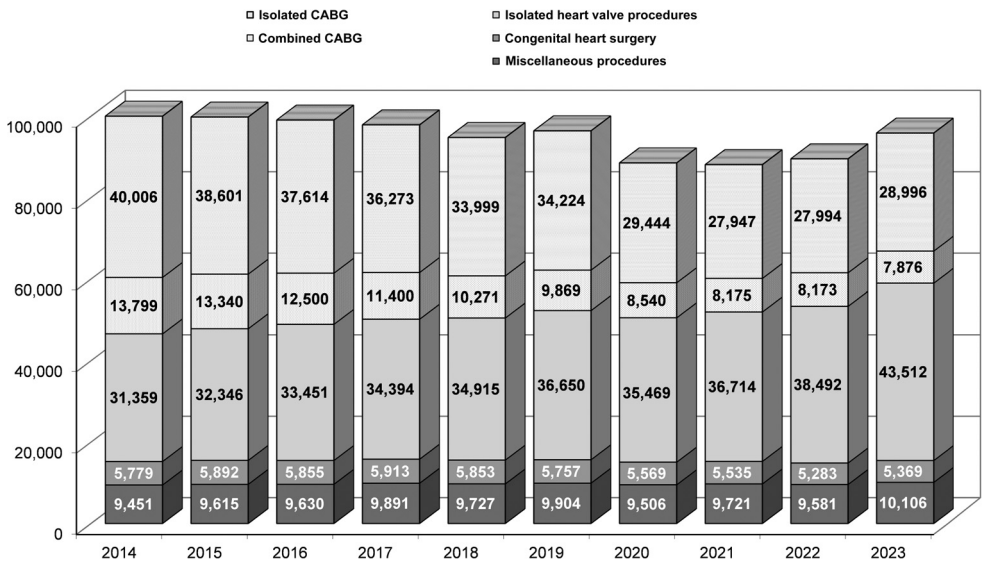

Fig. 1 Selected heart surgical categories (2014–2023). Notes: Congenital heart surgery: Atrial septal defect repairs in adults or in combination with coronary artery bypass grafting (CABG) or heart valve procedures are summarized in the CABG or heart valve procedure groups; miscellaneous procedures: all other types of procedures with extracorporeal circulation.

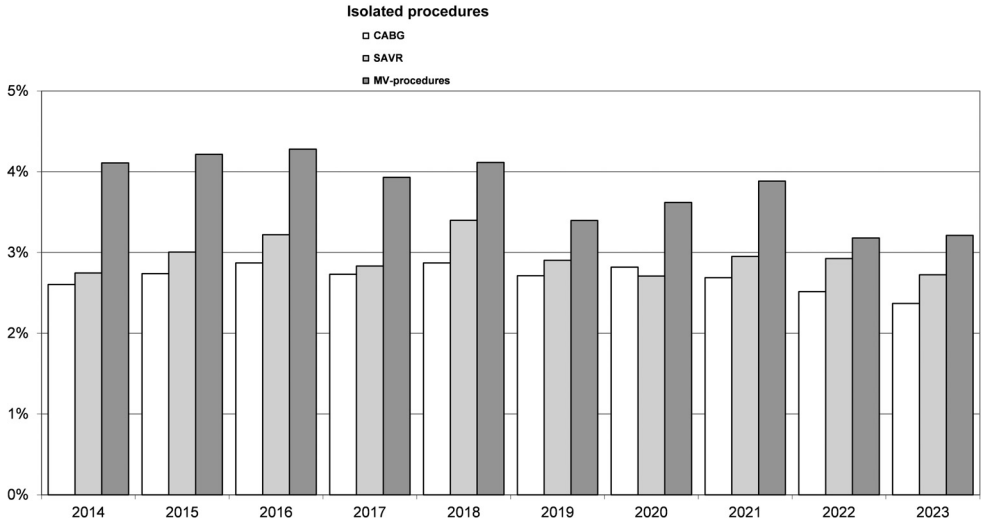

Fig. 2 Unadjusted mortality for selected procedures (2014–2023).

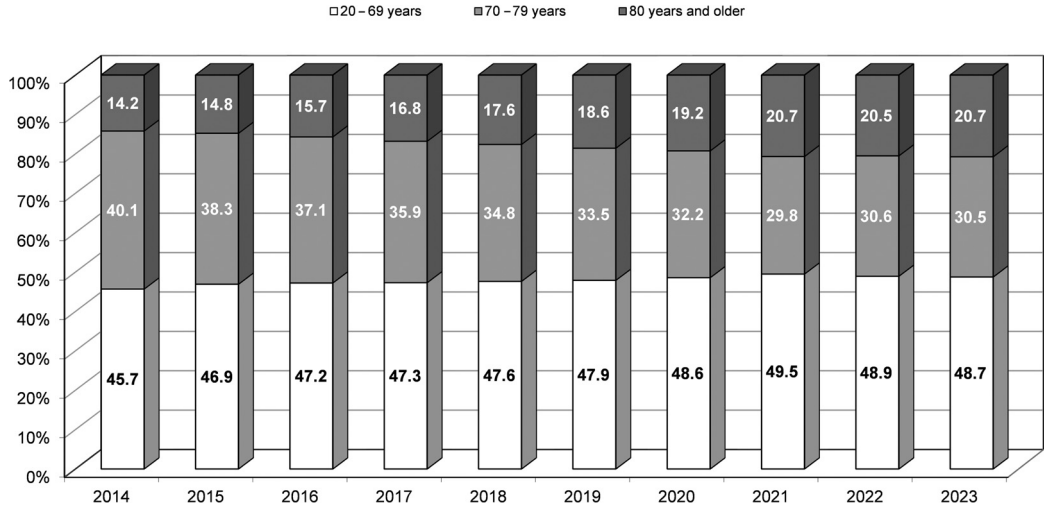

Fig. 3 Age distribution of cardiac procedures (2014–2023). Notes: Patients <20 years and CIED procedures were excluded.

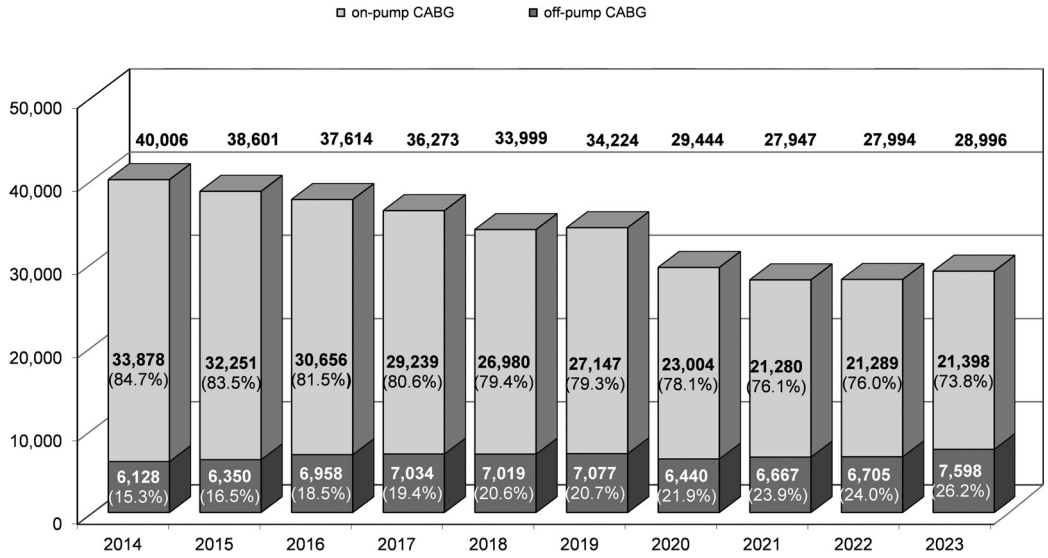

Fig. 4 Isolated coronary artery bypass grafting (CABG) (2014–2023).

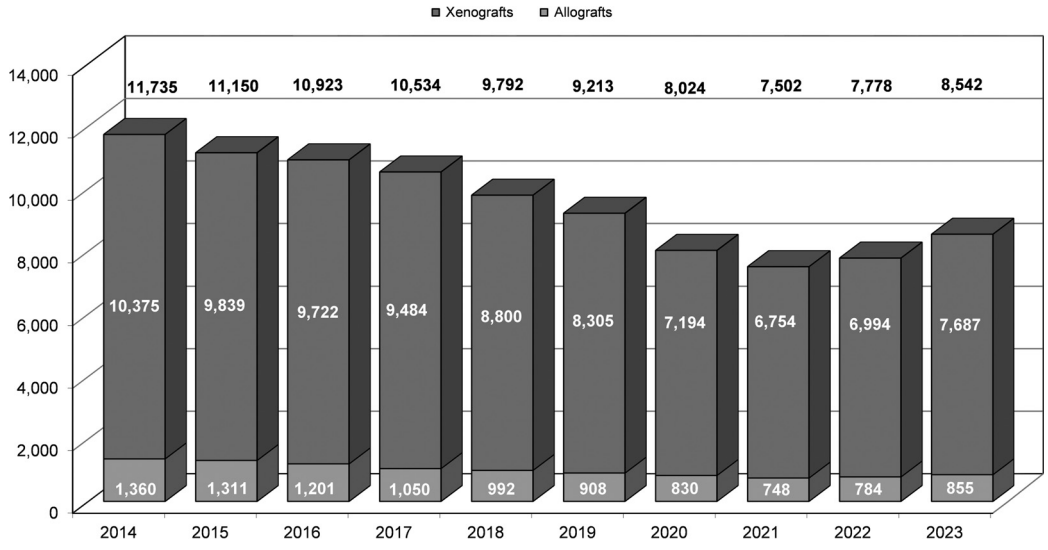

Fig. 5 Isolated surgical aortic valve replacements (2014–2023). Notes: Ross procedures, homograft implantations, and transcatheter heart valve interventions excluded.

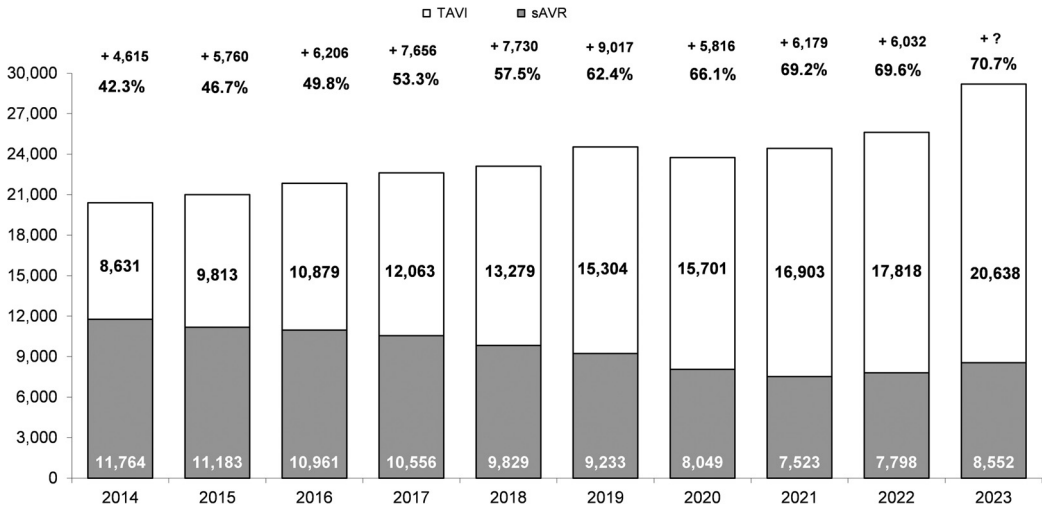

Fig. 6 Isolated surgical aortic valve replacements and transcatheter aortic valve implantation (TAVI) (2014–2023). Additional calculaton concerning TAVI from the German legal quality assurance program, §§ 135a/ 136/ 137 SGB V.

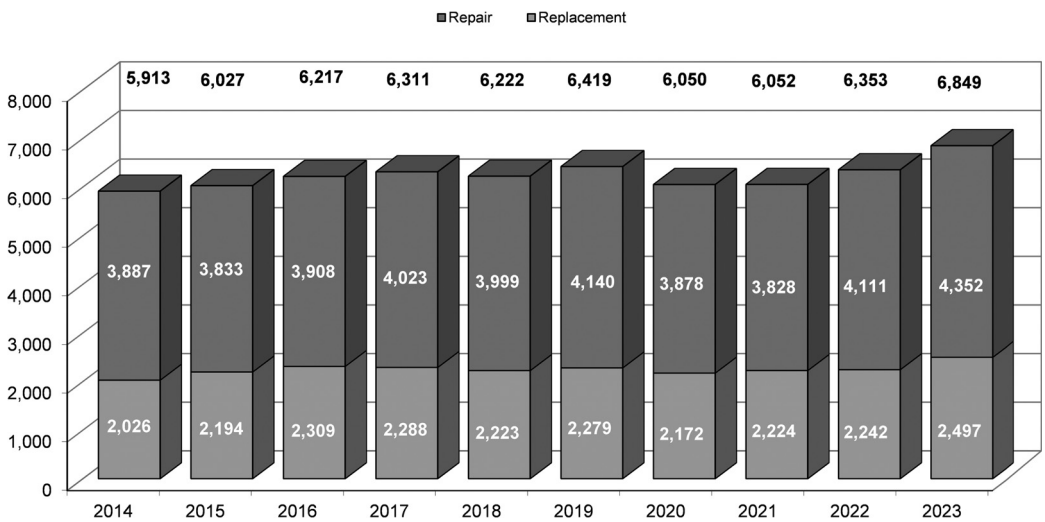

Fig. 7 Isolated mitral valve surgery (2014–2023).

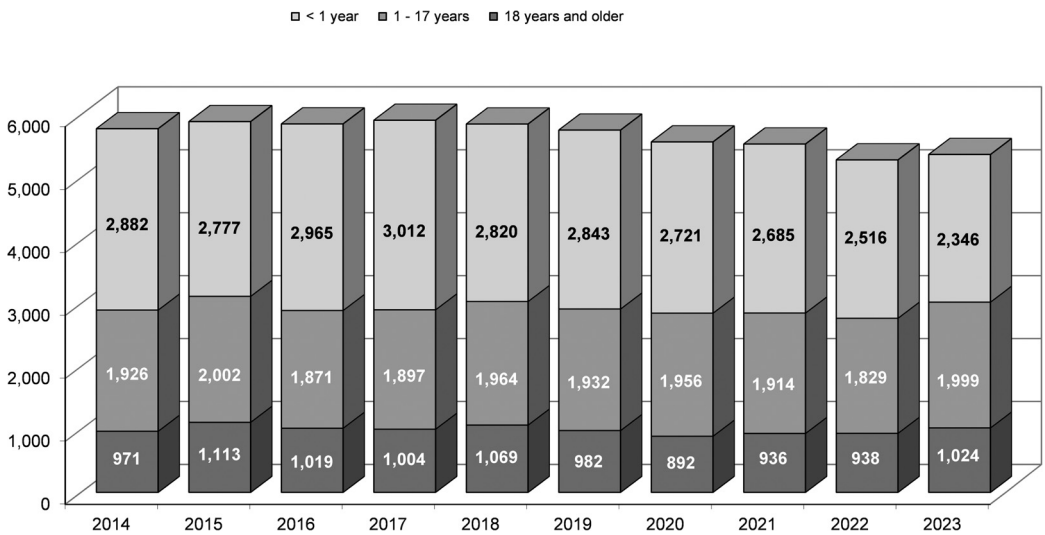

Fig. 8 Congenital heart surgery—age distribution (2014–2023).

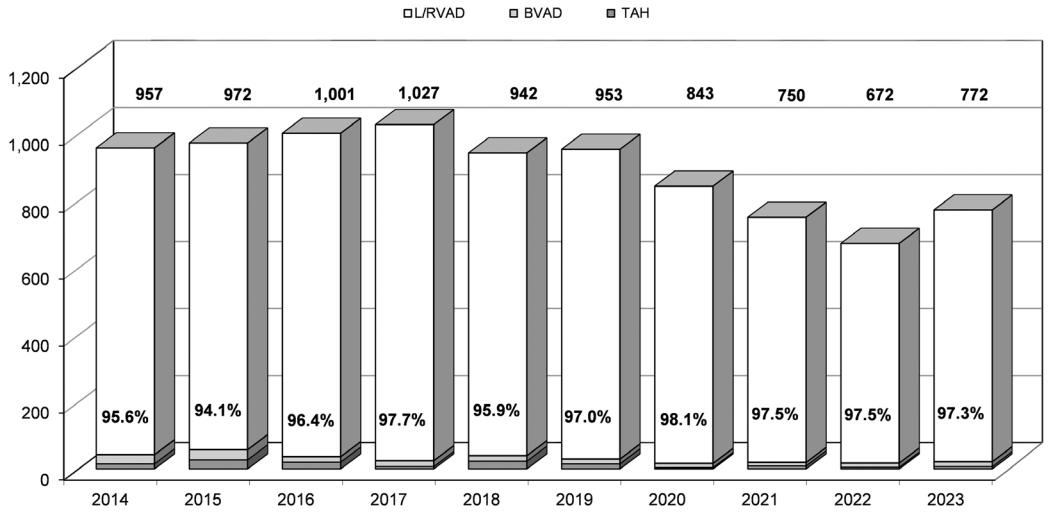

Fig. 9 Assist device implantation (2014–2023).

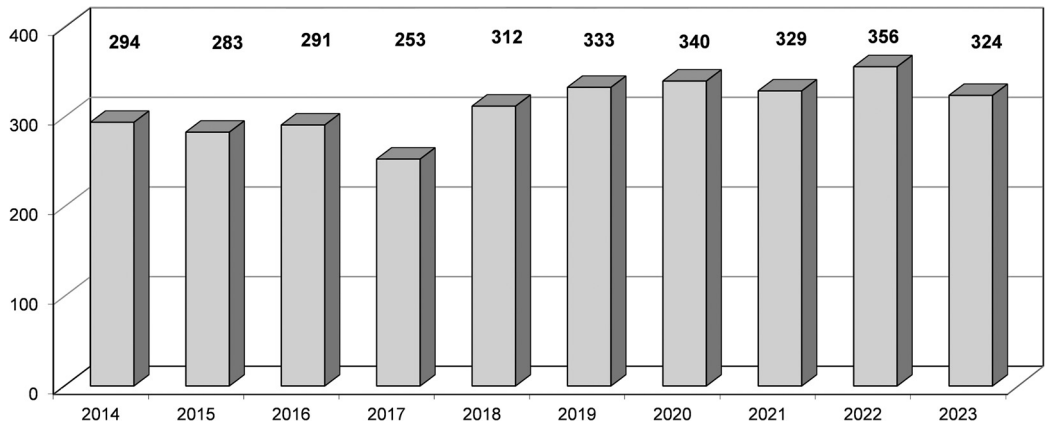

Fig. 10 Heart transplantation (2014–2023).

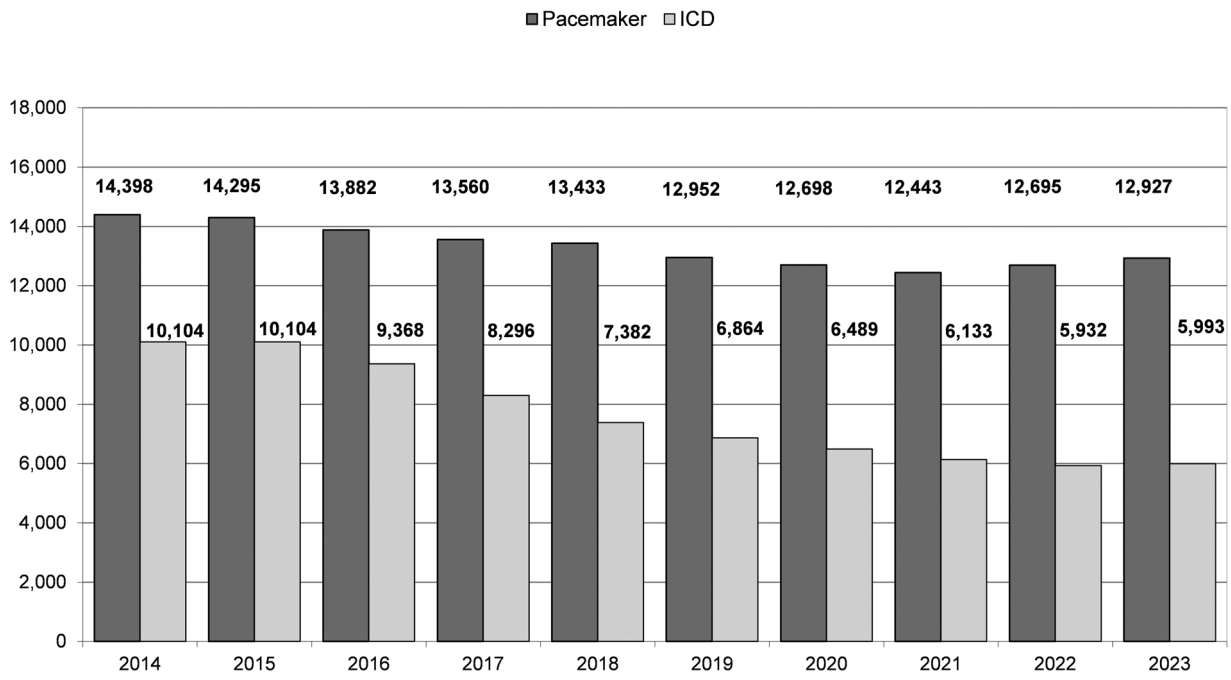

Fig. 11 Pacemaker and implantable cardioverter defibrillator procedures (2014–2023).

Conflict of Interest
None declared.

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