

# German Heart Surgery Report 2022: 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/DGTHG) in 1980, well-defined data of all cardiac, thoracic, and vascular surgery procedures performed in 78 German heart surgery departments during the year 2022 are analyzed. Under the decreasing interference of the worldwide coronavirus disease 2019 pandemic, a total of 162,167 procedures were submitted to the registry. A total of 93,913 of these operations are summarized as heart surgery procedures in a classical sense. The unadjusted in-hospital survival rate for the 27,994 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 3.2:1) was 97.5%. For the 38,492 isolated heart valve procedures (20,272 transcatheter interventions included) it was 96.9%, and for the registered pacemaker/implantable cardioverter-defibrillator procedures (19,531) 99.1%, respectively. Concerning short- and long-term circulatory support, a total of 2,737 extracorporeal life support/extracorporeal membrane oxygenation implantations, respectively 672 assist device implantations (L-/ R-/ BVAD, TAH) were registered. In 2022, 356 isolated heart transplantations, 228 isolated lung transplantations, and 5 combined heart-lung transplantations were performed. This annually updated registry of the GSTCVS/DGTHG 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 always available.

## Keywords

- ▶ heart valve surgery
- ▶ congenital heart disease
- ▶ CHD
- ▶ coronary artery bypass grafts surgery
- ▶ CABG
- ▶ aorta/aortic
- ▶ transplantation
- ▶ heart-lung

## Introduction

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

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

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Germany; to compile various results 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 an evaluation on an international level for the GSCVS/DGTHG.

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., transcatheter aortic valve implantation [TAVI]). Thereby, important findings for current patient safety and the future of patient care are collected for evaluation under different aspects.

Data presented in this report comprehend the survey of the year 2022. The circumstances caused by the worldwide coronavirus disease 2019 (COVID-19) pandemic must still be considered when interpreting the results of the past year.

## 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 (ICPM) called “operation code” (OPS: Operationen- und Prozedurenschlüssel).

All participating institutions were requested to complete the structured questionnaire by January 16, 2023, 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 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 data sets.

Inclusion criteria for the registry data 2022 were all cardiac surgical procedures performed on patients from January 1 to December 31, 2022, unrelated to the date of patients' admission or discharge as compared with other registries. Like in the earlier years, the number of procedures was counted rather than individual patients. For example, if a patient initially required isolated coronary artery bypass grafting (CABG), later followed by a mitral valve reconstruction due to an undesirable event, one count in the category “coronary surgery” and a second one in the category “mitral valve reconstruction” are enumerated. Thus, the registry contains more procedures than the real number of patients operated on.

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

The main reason for this structural setup of the registry—established over 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 hardware and software used locally.

In 2022, 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 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 covering 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, 2021.

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

## Registry Data 2022

► **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, 2021. Concerning patients' origin it must be considered that in 2022 a remarkable immigration of Ukrainian refugees to Germany, mostly considered as foreign residents and therefore not included, has to be taken into account. The range of heart operations per 100,000 inhabitants shows a minimum of 87.8 (Bremen, population: 676,463) and a maximum of 152.9 (Sachsen-Anhalt, population: 2,169,253), while the nationwide mean-value at the end of 2022 was 112.1 (► **Table 1**). In addition, ► **Table 1** shows a state-by-state representation of confirmed COVID-19 cases/100,000 population with a median of 35,547.5 (range: 13,522), a minimum of 27,736 in Thüringen and a maximum of 41.258 in Saarland. Thus, the mean of confirmed COVID-19 cases was fivefold higher than in 2021 and a broader range among the federal states (2021: 9,594) was observed.

Analyzing quantified categories of heart operations by department dimension, categorizes 71.8% of institutions into the two clusters from 500 up to 1,499 procedures (2022: 56/78) respectively 20.5% into those from 1,500 up to a maximum of 4,422 performed procedures (► **Table 2**). Before the pandemic

started in January 2020, the caseload of the heart surgery departments was considerably higher.

Summarizing the departments by various heart surgical procedures, it can be asserted that heart operations in patients suffering from congenital heart disease (CHD) (< 1 year, with extracorporeal circulation [ECC]) are conducted in 21, isolated heart transplantations in 18, and combined heart-lung transplantations in 2 institutions (►Table 3).

Overall, as shown in ►Tables 4 and 5, 162,167 procedures were reported to the registry for the year 2022, a decrease of 0.6% compared with 2021 (161,261 procedures), and still a remarkable decline compared with the prepandemic period (175,705 procedures). In 2022, the total number of 93,913 heart surgical procedures in the narrower sense showed a minor increase compared with the previous year (92,838 procedures), while from 2020 (92,809 procedures) to 2019 (100,446 procedures) a COVID-19 influenced decrease of 7.6% was seen. Regarding CABG procedures, the numbers hardly changed while heart valve and thoracic aorta procedures increased slightly. The remarkable decrease of assist device procedures by 16.4% (►Table 4) is caused by a drop of nonpermanent systems, almost certainly an effect of the COVID-19 pandemic, causing a rise of these numbers in 2021 (+12.5%).

The number of procedures with ECC application in Germany from 2013 to 2022 is illustrated in ►Table 4. Since 2013, a gradual reduction can be observed with the strongest decline in 2020. On one hand, this presumably reflects achievements of established innovations, for instance minimally invasive heart surgical procedures, and on the other hand, a still existing effect of the COVID-19 pandemic. In addition, a comparison of cardiac procedures using ECC in 2021 versus 2022 shows a stable level.

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). A total of 10,994 (11.7%) operations were classified as emergency procedures, and 6,740 (7.2%) were reoperations (►Table 6). These proportions appear quite consistent over the past years.

As shown in ►Table V1, 14,852 (38.6%) isolated heart valve procedures were performed as single, 2,880 as double (7.5%), and 296 (0.8%) as triple valve procedures. Furthermore, 3,155 (39.7%,  $n = 7,949$ ) aortic valve and 3,773 (59.4%,  $n = 6,353$ ) mitral valve operations were performed via a minimally invasive access (►Table V2). The numbers of single heart valve procedures via a transcatheter approach increased over the last 2 years, primarily concerning the aortic and tricuspid valve, while the rate of transapical TAVIs decreased. After a stepwise decrease over the past couple of years the surgical aortic valve replacements (sAVRs) showed a slight increase in 2022 (►Fig. 1). The unadjusted mortality of the surgical aortic valve procedures amounts to 2.9%, nearly consistent over the last 3 years. Regarding the mortality rate, it should be mentioned that this nonrisk-adjusted inhomogeneous group includes all emergency procedures, aortic valve stenosis or insufficiency, and endocarditis. Concerning the TAVIs, the data of which were transferred by the heart surgery departments in

Germany, the unadjusted mortality rate was 1.9% in 2022, also unchanged compared with the previous year (►Table V2).

In 6,994 (88.0%) isolated aortic valve operations under ECC conditions, xenograft prostheses were implanted, also a consistent distribution over the last 5 years (►Table V3, ►Fig. 2). Concerning the treatment of mitral valve disease, in 64.7% (4,111) of the isolated mitral valve operations a reconstruction with preservation of the native valve could be achieved (►Fig. 3). In a total of 2,433 combined mitral valve repair procedures, 1,070 (44.0%) simultaneous CABG procedures, 751 tricuspid valve repairs (30.9%), 419 (17.2%) aortic valve procedures, and 193 (7.9%) concomitant CABG and sAVR were performed (►Table V4). The analyses of the mortality rates concerning mitral valve procedures demonstrate an improvement, in the subgroup of isolated (3.2%) as well as for the combined procedures (9.5%) regarding repair (2.5%) and implantation/replacement (10.7%) (►Table V4).

The subgroup of 3,176 multiple heart valve procedures amounted to 2,614 (82.3%) double heart valve operations as a combination of mitral + tricuspid ( $n = 1,366$ ) and as mitral + aortic ( $n = 1,248$ ) valve procedures (►Tables V5 and V6). Regarding the 17,818 TAVIs, an increase to 17,037 (95.6%) procedures performed by transvascular access and an ongoing decrease to 781 (4.4%) for transapical access were observed. In TAVI procedures without ECC the unadjusted mortality for those by transvascular access was 1.7% (283/16,949), respectively 4.8% (37/771) for the transapical approach. On the other hand, TAVI under use of ECC still shows a remarkably high unadjusted mortality rate of 23.9% (21/88), respectively 30.0% (3/10) (►Table V7), probably related to severe complications during the initial procedure.

Concerning the transmitted data of 36,167 CABG operations, 77.4% were performed as isolated procedures ( $n = 27,994$ ), 12.0% ( $n = 4,347$ ) combined with sAVR, and 5.0% ( $n = 1,814$ ) with simultaneous mitral valve operations (►Table C1). These numbers depict a stable condition compared with the previous year. ►Table C2 provides an overview of the isolated CABG operations focused on the number of bypass grafts and indicates the corresponding unadjusted mortality rates for on-/off-pump surgery. While the total number of isolated CABG procedures is stable, the subgroup of isolated CABG without ECC increased slightly to 6,705 (2021: 6,667). In addition, the unadjusted mortality rate of this subgroup decreased to 1.4% (2021: 1.6%), independent of the number of grafts. In this context, it has to be taken into account that conversions from off- to on-pump CABG are not captured. Nevertheless, the unadjusted mortality rate of all isolated CABG procedures was 2.5% in 2022 and therefore reached the best result within the past 10 years (►Fig. 4). ►Tables Con 1 and 2 show data concerning congenital heart surgery procedures. In this subcategory the total number ( $n = 5,343$ ) shows a small decline. Meanwhile, the unadjusted overall mortality rate changed to 2.4% (►Table Con 1) compared with 2021 ( $n = 5,589$ ; 2.1%), respectively 2020 ( $n = 5,637$ ; 2.6%). ►Table Tx shows an increase of orthotopic heart transplantations to 356 in 2022 (2021: 329). This increase is most certainly due to the fact that within the Eurotransplant International Foundation donor hearts from countries with an objection regulation for donation of organs were transferred and

implanted in Germany. ► **Tables Mis 1,2,3** demonstrate further compiled registry data under different aspects and for various categories, for example, aortic surgery. With a total of 18,627 specified permanent pacemaker and implantable cardioverter-defibrillator (ICD) procedures a slight increase was detectible (2021: 18,576) (► **Fig. 5**). The unadjusted mortality rate of 0.9% (2021: 0.9%) was consistent for pacemaker procedures while for ICD procedures it improved to 0.9% (2021: 1.2%) (► **Table Mis 2**). As expected, the highest mortality rates for cardiac implantable electronic device procedures were detected in the revision subgroup.

Compared with the data of previous years some significant changes can be seen on one hand, while several developments remained almost unchanged in 2022 on the other hand. The number of CABG procedures, isolated or combined, shows a stable number after a decline during the two first years of the COVID-19 pandemic. The number of isolated heart valve procedures increased to 38,492 procedures (+5.0%) and thereby reached a higher level than before the pandemic (► **Fig. 1**). However, unadjusted mortality rates for CABG, sAVR, and mitral valve procedures vary slightly over the last decade, although CABG and mitral valve procedures reached the best results in 2022 (► **Fig. 4**). While the age distribution of patients continued to evolve toward a higher percentage of elderly patients ( $\geq 80$  years) as well as a continuous increase of adults  $\leq 69$  years over the last years, this trend did not continue in 2022 and remained quite consistent compared with 2021 (► **Fig. 7**). Presently, 30.6% of the cardiac procedures are performed in patients from 70 to 79 years of age, and 20.5% in octo-/nonagenarians. The relative amount of isolated off-pump CABG increased slightly, presumably reaching a stable level with 24.0% in 2022 (2021: 23.9%) (► **Fig. 8**).

With regard to heart valve prostheses distribution, in 89.9% ( $n = 6,994$ ) sAVR was performed using a xenograft (► **Fig. 2**), whereas in 10.1% ( $n = 784$ ) a mechanical prosthesis was implanted: a consistent proportion over the past 5 years. The unchanged development of transcatheter heart valve procedures in Germany lead to a total of 20,297 transferred procedures in 2022 (► **Table V7**). Focusing on the distribution of aortic valve procedures for 2022, 17,818 (69.6%) TAVI and 7,798 (30.4%) sAVR were reported to the registry (► **Fig. 1**). It must again be emphasized that exclusively the German departments for cardiac surgery contributed these data. Therefore, the registry cannot reach completeness of TAVI procedures due to the fact that TAVI documented by cardiology departments are incompletely included. On the basis of and in addition to the recommendations of international scientific guidelines, respectively, expert consensus on the management of valvular heart disease,<sup>8–10</sup> the German Federal Joint Committee (G-BA) implemented a quality assurance directive<sup>11</sup> 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),<sup>12–30</sup> provide various important findings and thus also contribute to an exceptional patient benefit.

In 2022, the rate of isolated mitral valve reconstructions remains almost unchanged on a remarkable level of 64.7% (2021:

63.3%) (► **Fig. 3**). Based on the fact that all isolated mitral valve procedure are 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), like in other publications, for example, Gammie et al.<sup>31</sup> Therefore, other published rates of mitral valve repair have to be interpreted with caution if compared with this registry.

In 2022, almost half (47.6%;  $n = 2,516$ ) of cardiac operations for CHD were performed in neonates/infants  $< 1$  year, 34.6% in children between 1 and 17 years, and 17.8% in patients at least 18 years of age (► **Fig. 9**). 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).

Concerning permanent ventricular assist device (L-/ R-/ BVAD, TAH) implantations ( $n = 672$ ) a further significant decrease of 10.4% compared with 2021 ( $n = 750$ ) (► **Fig. 10**) could be observed, while the number of implantations of extracorporeal pumps without oxygenator increased ( $n = 786$ ) (► **Table AD**). The number of heart transplantations increased to 356, an increase of 8.2% compared with the previous year (► **Fig. 11**). The mechanical circulatory support therapy, in particular left ventricular assist device, is still of outstanding importance for patients with end-stage heart failure.

The number of ICD procedures showed a small decrease, an ongoing trend over more than 5 years, while the pacemaker procedures remained quite consistent. The same is true for the distribution of procedures with/without ECC and the associated mortality rates (► **Fig. 5**, ► **Table Mis 2**).

## Discussion

Even under the still existing conditions of the COVID-19 pandemic in 2022, the registry of the GSTCVS/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 a high accuracy for major outcome parameters in unaudited registries.<sup>32</sup> As observed in recent years, heart surgery in Germany is performed on a high level with superior in-hospital patient survival compared with international surveys. In addition, the registry demonstrates that the provision of cardiac surgery in Germany could be always enabled (24/7/365) nationwide, even under COVID-19 conditions. These aspects are especially important in the context of various developments in the German health care policy and considering the background of demographic trends of the German population, leading to more patients at increased age combined with a higher proportion of related comorbidities and an accordingly complex perioperative risk profile.



Compared with 2021, the number of cardiac surgery procedures showed a steady state for isolated/combined CABG and even a marginal increase of sAVR, probably a result of a reduced influence of the COVID-19 pandemic in 2022. Due to limited intensive care resources in all German cardiac centers, provision of elective/urgent heart surgical procedures was more affected from 2020 to 2021 than in 2022. Nevertheless, considering the ongoing trend in the view of the German population characteristics and in the context of application of the scientific guidelines,<sup>10,33,34</sup> a large volume increase may not be expected at the moment. Apart from that, the low level in heart transplantations needs more efforts, in particular through health policy decisions concerning the “objection regulation for organ transplantation,” to enable a positive development in the future.

Further improvements of the registry are recommended to realize 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 German Society for Thoracic and Cardiovascular Surgery and all German cardiac surgical departments. 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.

## Tables and Figures

**Table 1** German federal states/heart surgery procedures/confirmed COVID-19 cases

Federal state	Population <sup>a</sup>	Quantity <sup>b</sup>	procedures/ 100,000 inhabitants	Total number of COVID-19 cases <sup>c</sup>	COVID-19 cases/ 100,000 population <sup>c</sup>
Baden-Württemberg	11,124,642	11,153	100.3	3,955,783	35,559
Bayern	13,176,989	13,241	100.5	5,286,329	40,118
Berlin	3,677,472	3,745	101.8	1,074,467	29,218
Brandenburg	2,537,868	3,159	124.5	851,341	33,546
Bremen	676,463	594	87.8	250,162	36,981
Hamburg	1,853,935	2,157	116.3	657,303	35,454
Hessen	6,295,017	7,251	115.2	2,371,673	37,675
Mecklenburg-Vorpommern	1,611,160	1,785	110.8	598,391	37,140
Niedersachsen	8,027,031	9,789	122.0	3,307,244	41,201
Nordrhein-Westfalen	17,924,591	19,695	109.9	6,408,907	35,755
Rheinland-Pfalz	4,106,485	4,777	116.3	1,442,554	35,129
Saarland	982,348	1,105	112.5	405,301	41,258
Sachsen	4,043,002	5,147	127.3	1,282,337	31,717
Sachsen-Anhalt	2,169,253	3,316	152.9	721,705	33,270
Schleswig-Holstein	2,922,005	3,738	127.9	1,038,374	35,536
Thüringen	2,108,863	2,685	127.3	584,916	27,736
<b>Deutschland</b>	<b>83,237,124</b>	<b>93,337</b>	<b>112.1</b>	<b>30,236,787</b>	<b>36,326</b>

<sup>a</sup>Federal Office for Statistics of German Population; due date December 31, 2021.

<sup>b</sup>n = 576, foreign residences excluded.

<sup>c</sup>Robert Koch Institute: laboratory confirmed COVID-19 cases; due date December 30, 2022.

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## Abbreviations

ASD	atrial septal defect
AVC	Atrioventricular canal
CABG	coronary artery bypass grafting
CHD	congenital heart disease
CIED	Cardiac Implantable Electronic Devices
DLTx	double lung transplantation
DORV	double outlet right ventricle
ECC	extracorporeal circulation
ECLS	extracorporeal life support
ECMO	extracorporeal membrane oxygenation
HLTx	heart-lung transplantation
HTx	heart transplantation
ICD	implantable cardioverter defibrillator
LTx	lung transplantation
PDA	patent ductus arteriosus
PTS	patients
PVR	pulmonary valve replacement
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

**Table 2** Departments assorted by number of heart surgery procedures ( $\Sigma^a$  [n = 93,913])

Procedures per department	< 500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments	6	34	22	5	11
Average	323	773	1.247	1.704	2.703
Range	188–448	505–991	1,018–1,497	1,533–1,900	2,075–4,422

<sup>a</sup>Cardiac implantable electronic device (CIED) and extracardiac surgery without extracorporeal circulation (ECC) are excluded.

**Table 3** Departments categorized by heart surgery procedures

Category	Departments
Coronary artery bypass grafting	77
Heart valve surgery	77
Pacemaker/ICD procedures	74/72
Congenital heart disease procedures (pat, <1 year with ECC)	21 <sup>a</sup>
Heart transplantation	18 <sup>b</sup>
Heart-lung transplantation	2

<sup>a</sup>N = 1,882 thereof: 1–12 operations in 1 unit, 21–47 operations in 4 units, 50–95 operations in 7 units, 104–186 operations in 9 units.

<sup>b</sup>N = 356: thereof: 1–4 transplants in 3 units, 5–6 transplants in 4 units, 10–20 transplants in 5 units, 21–96 transplants in 6 units.

**Table 6** Emergency and Redo procedures with ECC compared with previous year

Procedures	2022		2021	
	n (%)		n (%)	
Emergency	10,994	(11.7)	10,560	(11.4)
Redo	6,740	(7.2)	6,783	(7.3)

**Table 4** Heart surgery procedures with ECC (2013–2022)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Procedures	84,040	83,787	81,527	79,082	76,696	72,331	71,759	63,720	61,272	61,696
Departments	79	78	78	78	78	78	78	78	78	78
Average	1,064	1,074	1,045	1,014	983	927	920	817	786	791

**Table 5** Number of heart surgery procedures/gender distribution

Category	ECC application						Gender				Total	Difference 2021 (%)
	With n (%)			Without n (%)			Female, n (%)		Male, n (%)			
CABG - isolated	21,289	76	<sup>a</sup>	6,705	24	<sup>a</sup>	7,438	21	28,729	79	27,994	+0.2%
CABG - combined	8,026	98	<sup>a</sup>	147	02	<sup>a</sup>					8,173	-0.0%
Heart valve procedures	18,399	48	<sup>a</sup>	20,093	52	<sup>a</sup>	16,257	42	22,235	58	38,492	+4.8%
Surgery of thoracic aorta	7,647	92	<sup>a</sup>	707	08	<sup>a</sup>	2,839	34	5,515	66	8,354	+1.8%
Congenital heart surgery procedures	4,401	83	<sup>a</sup>	882	17	<sup>a</sup>	2,373	45	2,910	55	5,283	-4.6%
Cardiac surgery, other	1,070	44	<sup>a</sup>	1,357	56	<sup>a</sup>	1,419	58	1,008	42	2,427	-4.1%
Assist device procedures	524	18	<sup>a</sup>	2,326	82	<sup>a</sup>	869	30	1,981	70	2,850	-16.4%
Extracardiac surgery	317	01	<sup>a</sup>	48,746	99		17,085	35	31,978	65	49,063	-0.4%
Pacemaker/ICD procedures	23	00	<sup>a</sup>	19,508	100		7,488	38	12,043	62	19,531	+0.2%
<b>Total</b>	<b>61,696</b>	<b>38</b>		<b>100,471</b>	<b>62</b>						<b>162,167</b>	<b>-0.6%</b>

<sup>a</sup>Sum: n = 93,913 (heart surgery procedures).

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**Table V1** Isolated heart valve procedures

Procedure	n	†	%
Single	14,852	479	3.2
Double	2,880	259	9.0
Triple	296	33	11.1
Transcatheter (single)	20,246	415	2.0
Transcatheter (double)	26	3	11.5
Unspecified	192	14	7.3
<b>Total</b>	<b>38,492</b>	<b>1,203</b>	<b>3.1</b>

Note: Transcatheter heart valve procedures: 17,818 aortic valve implantation; 282 mitral valve implantation; 1,493 mitral valve repair; 30 tricuspid valve implantation; 623 tricuspidal valve repair; 26 double aortic and mitral valve procedure; no pulmonary valve implantation.

**Table V3** Prostheses in isolated aortic/mitral valve surgery

Prosthesis/ native heart valve	Aortic			Mitral		
	n	†	%	n	†	%
Xenograft	6,994	209	3.0	1,833	138	7.5
Allograft	784	17	2.2	407	23	5.7
Repair	151	2	1.3	4,111	41	1.0
Homograft	20	2	10.0	2	0	0.0
<b>Total</b>	<b>7,949</b>	<b>230</b>	<b>2.9</b>	<b>6,353</b>	<b>202</b>	<b>3.2</b>

Note: Transcatheter procedures and apical aortic conduits procedures ( $n = 0$ ) are not included.

**Table V2** Single heart valve procedures

Access path	n	†	%
<b>Aortic</b>			
Sternotomy	4,794	190	4.0
Partial sternotomy	3,155	40	1.3
Transvascular	17,037	304	1.8
Transapical	781	40	5.1
<b>Mitral</b>			
Sternotomy	2,580	176	6.8
Minimal invasive	3,773	26	0.7
Transcatheter	1,775	54	3.0
<b>Tricuspid</b>			
Sternotomy	337	38	11.3
Minimal invasive	124	6	4.8
Transcatheter	653	17	2.6
<b>Pulmonary</b>			
Sternotomy	87	2	2.3
Minimal invasive	2	1	50.0
Transcatheter	0	0	—
<b>Total</b>	<b>35,098</b>	<b>894</b>	<b>2.5</b>

Note: Apical aortic conduits procedures ( $n = 0$ ) are not included.

**Table V5** Multiple heart valve procedures

Combination	n	†	%
Mitral + tricuspid	1,366	89	6.5
Aortic + mitral	1,248	152	12.2
Aortic + mitral + tricuspid	294	33	11.2
Aortic + tricuspid	142	14	9.9
Aortic + pulmonary <sup>a</sup>	111	4	3.6
Tricuspid + pulmonary	13	0	0.0
Aortic + mitral + pulmonary	2	0	0.0
<b>Total</b>	<b>3,176</b>	<b>292</b>	<b>9.2</b>

Note: Transcatheter procedures are excluded.

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

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

Mitral valve procedures	Repair			Implantation/replacement			Total		
	n	†	%	n	†	%	n	†	%
Isolated	4,111	41	1.0	2,242	161	7.2	6,353	202	3.2
+ CABG	1,070	54	5.0	744	108	14.5	1,814	162	8.9
+ Tricuspid valve repair <sup>a</sup>	751	27	3.6	560	49	8.8	1,311	76	5.8
+ sAVR	419	20	4.8	829	132	15.9	1,248	152	12.2
+ CABG + sAVR	193	22	11.4	234	43	18.4	427	65	15.2
<b>Total</b>	<b>6,544</b>	<b>164</b>	<b>2.5</b>	<b>4,609</b>	<b>493</b>	<b>10.7</b>	<b>11,153</b>	<b>657</b>	<b>5.9</b>

<sup>a</sup>55 procedures (not specified mitral valve + tricuspid valve surgery) excluded.

**Table V6** Ross procedures—autologous sAVR and PVR (2013–2022)

Age (y)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
< 18	33	37	28	38	38	29	32	35	25	39
≥ 18	107	90	64	72	52	61	104	70	124	136
<b>Total</b>	<b>140</b>	<b>127</b>	<b>92</b>	<b>110</b>	<b>90</b>	<b>90</b>	<b>136</b>	<b>105</b>	<b>149</b>	<b>175</b>

**Table V7** Transcatheter heart valve procedures

	Without ECC		With ECC		Total		
	<i>n</i>	†	<i>n</i>	†	<i>n</i>	†	%
Aortic valve implantation	17,720	320	98	24	17,818	344	1.9
Transvascular	16,949	283	88	21	17,037	304	1.8
Transapical	771	37	10	3	781	40	5.1
Mitral valve	1,697	50	78	4	1,775	54	3.0
Repair	1,424	23	69	3	1,493	26	1.7
Implantation	273	27	9	1	282	28	9.9
Tricuspid valve	651	17	2	0	653	17	2.6
Repair	621	15	2	0	623	15	2.4
Implantation	30	2	0	0	30	2	6.7
Aortic + mitral valve implantation	25	3	1	0	26	3	11.5
Aortic valve implantation <sup>a</sup> + CABG	7	0	13	3	20	3	15.0
Mitral valve implantation <sup>b</sup> + CABG	0	0	5	1	5	1	20.0
Aortic + mitral valve + CABG	0	0	0	0	0	0	–
<b>Total</b>	<b>20,100</b>	<b>390</b>	<b>197</b>	<b>32</b>	<b>20,297</b>	<b>422</b>	<b>2.1</b>

Note: Pulmonary valve implantation for CHD excluded.

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

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

**Table C1** Isolated CABG and combined procedures

	<i>n</i>	†	%
Isolated CABG	27,994	704	2.5
+ sAVR	4,347	182	4.2
+ Other	1,478	83	5.6
+ Mitral valve repair	1,070	54	5.0
+ Mitral valve replacement	744	108	14.5
+ sAVR + mitral valve repair	193	22	11.4
+ sAVR + mitral valve replacement	234	43	18.4
+ Aneurysm resection	82	4	4.9
+ Transcatheter aortic valve implantation	20	3	15.0
+ Transcatheter mitral valve procedure	5	1	20.0
<b>Total</b>	<b>36,167</b>	<b>1,204</b>	<b>3.3</b>



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

Grafts	With ECC			Without ECC			Total		
	n	†	%	n	†	%	n	†	%
Single	651	38	5.8	1,253	27	2.2	1,904	65	3.4
Double	4,340	174	4.0	1,673	25	1.5	6,013	199	3.3
Triple	9,460	254	2.7	2,562	31	1.2	12,022	285	2.4
Quadruple	5,319	107	2.0	922	13	1.4	6,241	120	1.9
Quintuple + more	1,519	35	2.3	295	0	0.0	1,814	35	1.9
<b>Total</b>	<b>21,289</b>	<b>608</b>	<b>2.9</b>	<b>6,705</b>	<b>96</b>	<b>1.4</b>	<b>27,994</b>	<b>704</b>	<b>2.5</b>

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

Age (y)	With ECC			Without ECC			Total		
	n	†	%	n	†	%	n	†	%
< 1	1,914	60	3.1	634	19	3.0	2,548	79	3.1
1–17	1,653	26	1.6	204	1	0.5	1,857	27	1.5
≥ 18	894	18	2.0	44	2	4.5	938	20	2.1
<b>Total</b>	<b>4,461</b>	<b>104</b>	<b>2.3</b>	<b>882</b>	<b>22</b>	<b>2.5</b>	<b>5,343</b>	<b>126</b>	<b>2.4</b>

**Table Con 2** CHD and procedures

Lesion/Procedure	Age < 1 y			Age 1 to 17 y			Age ≥ 18 y		
	n	†	%	n	†	%	n	†	%
ASD	42	1	2.4	226	0	0.0	207	5	2.4
Complete AV canal	178	4	2.2	92	2	2.2	4	0	0.0
VSD	297	3	1.0	100	0	0.0	4	1	25.0
Fallot's tetralogy	157	2	1.3	32	1	3.1	0	0	–
DORV	59	1	1.7	11	1	9.1	0	–	–
TGA	144	6	4.2	7	0	0.0	1	0	0.0
TGA + VSD	58	1	1.7	8	0	0.0	0	–	–
Truncus arteriosus	29	3	10.3	4	0	0.0	1	0	0.0
Fontan circulation	2	0	0.0	211	4	1.9	3	1	33.3
Norwood	115	10	8.7	1	0	0.0	0	–	–
Pulmonary valve	76	0	0.0	229	4	1.7	48	0	0.0
Transcatheter pulmonary valve implantation	0	–	–	4	0	0.0	7	1	14.3
sAVR	43	0	0.0	198	2	1.0	360	6	1.7
Ross procedure	13	1	7.7	26	1	3.8	35	0	0.0
Mitral valve	58	2	3.4	90	0	0.0	79	3	3.8
Tricuspid valve	97	3	3.1	82	1	1.2	53	3	5.7
PDA	126	5	4.0	14	0	0.0	0	0	–
Coarctation	210	0	0.0	34	0	0.0	4	0	0.0
Others	838	36	4.3	445	11	2.5	132	0	0.0
HTx	5	1	20.0	40	0	0.0	0	–	–
HLTx	0	–	–	1	0	0.0	0	–	–
LTx	1	0	0.0	2	0	0.0	0	–	–
<b>Total</b>	<b>2,548</b>	<b>79</b>	<b>3.1</b>	<b>1,857</b>	<b>27</b>	<b>1.5</b>	<b>938</b>	<b>20</b>	<b>2.1</b>

**Table Tx** Heart and lung transplantation

Transplant	n	†	%
HTx	356	37	10.4
HLTx	5	0	0.0
LTx <sup>a</sup>	228	8	3.5

Note: All pediatric transplantations (demonstrated in ► **Table Con 2**) are included in this table. Eurotransplant (ET) report 2022: 353 HTx, 0 HTx + kidneyTx, 0 HTx + liverTx, 5 HLTx, 232 DLTx, 15 SLTx, 0 LTx + kidneyTx and 2 LTx + liverTx.  
<sup>a</sup>193 LTx without ECC included.

**Table AD** Assist device (temporary versus permanent)

	n
<b>Temporary</b>	
ECLS / ECMO	2,737
Extracorporeal pump without oxygenator	786
IABP	685
<b>Permanent</b>	
LVAD / RVAD Implantation	655
BVAD Implantation	12
TAH	5

**Table Mis 1** Aortic surgery

Procedures <sup>a</sup>	With ECC			Without ECC		
	n	†	%	n	†	%
Supracoronary replacement of ascending aorta	1,158	90	7.8			
Supracoronary ascending + aortic valve replacement	1,317	68	5.2			
<b>Infracoronary replacement of ascending aorta</b>						
Mechanical aortic valve conduits	285	23	8.1			
Biological aortic conduits	988	84	8.5			
David procedure	477	4	0.8			
Yacoub procedure	108	1	0.9			
Other	381	40	10.5			
Aortic arch replacement <sup>b</sup>	2,820	372	13.2			
Replacement of descending aorta	48	5	10.4	6	1	16.7
Thoracoabdominal aortic replacement	58	5	8.6	20	4	20.0
Endostent descending aorta	7	0	0.0	681	35	5.1
<b>Total</b>	<b>7,647</b>	<b>692</b>	<b>9.0</b>	<b>707</b>	<b>40</b>	<b>5.7</b>

Note: 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: 378 abdominal procedures and 26 endovascular abdominal stents.  
<sup>b</sup>All possible combined procedures included; the only common denominator is aortic arch surgery.

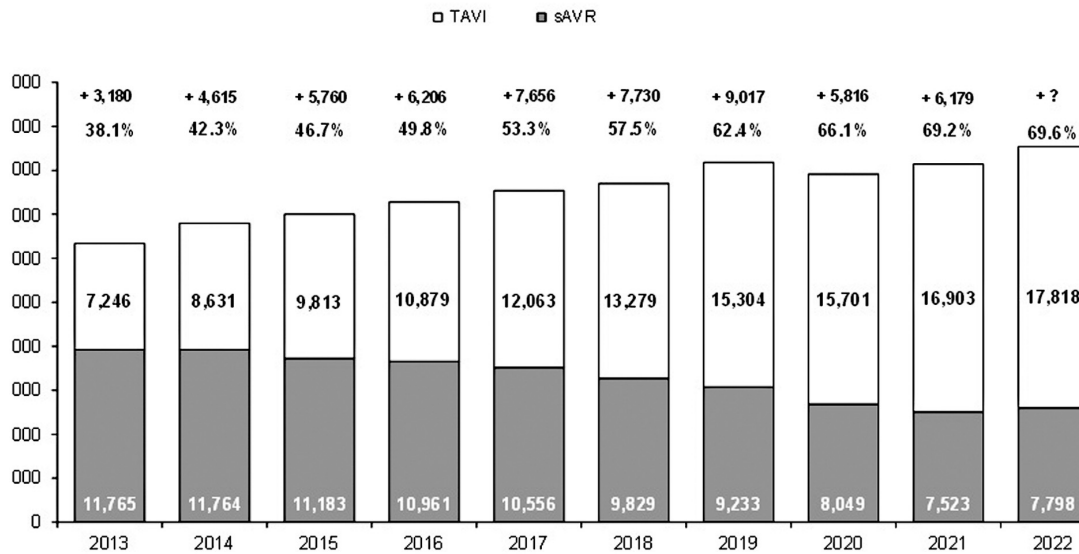
**Table Mis 2** Pacemaker and ICD procedures

Device				With ECC		Without ECC	
	n	†	%	n	†	n	†
<b>Pacemaker</b>	<b>12,695</b>	<b>111</b>	<b>0.9</b>	<b>7</b>	<b>2</b>	<b>12,688</b>	<b>109</b>
Implantation	8,381	70	0.8	3	0	8,378	70
Battery exchange	2,161	5	0.2	0	0	2,161	5
Revision procedures	2,153	36	1.7	4	2	2,149	34
<b>ICD</b>	<b>5,932</b>	<b>52</b>	<b>0.9</b>	<b>14</b>	<b>5</b>	<b>5,918</b>	<b>47</b>
Implantation	2,557	11	0.4	0	0	2,557	11
Battery exchange	1,448	5	0.3	0	0	1,448	5
Revision procedures	1,927	36	1.9	14	5	1,913	31
<b>Miscellaneous</b>	<b>904</b>	<b>16</b>	<b>1.8</b>	<b>2</b>	<b>0</b>	<b>902</b>	<b>16</b>
<b>Total</b>	<b>19,531</b>	<b>179</b>	<b>0.9</b>	<b>23</b>	<b>7</b>	<b>19,508</b>	<b>172</b>

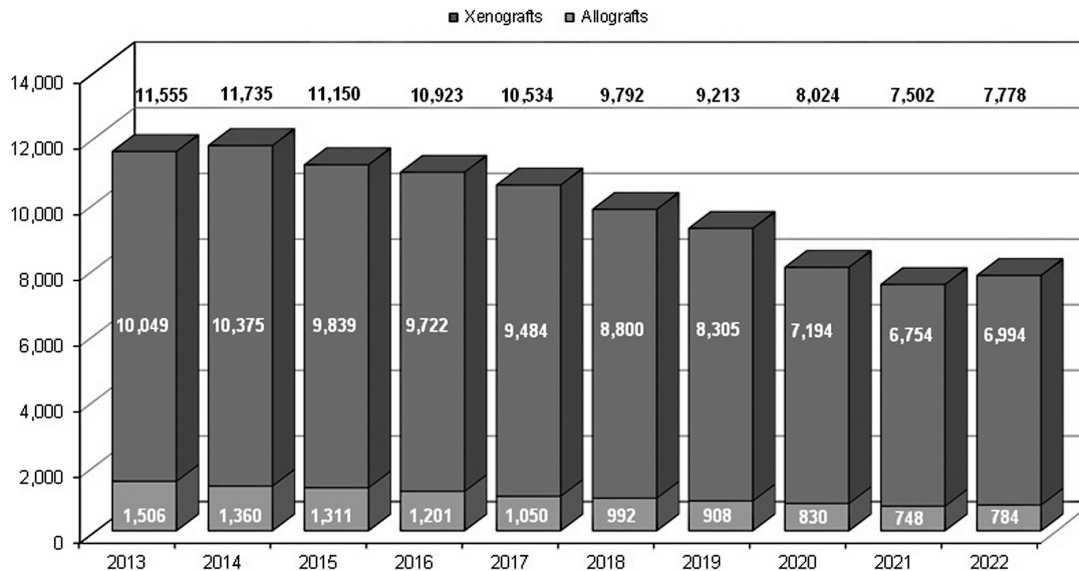
**Table Mis 3** Surgical procedures for tachyarrhythmia

	Endocardiac	Epicardiac	Total
	<i>n</i>	<i>n</i>	
Unipolar radiofrequency	59	122	181
Unipolar cooled radiofrequency	50	117	167
Bipolar radiofrequency	173	1,593	1,766
Cryotherapy	1,607	288	1,895
Microwave	0	0	0
Focused ultrasound	1	81	82
Laser	0	0	0
Other	1	8	9
<b>Total</b>	<b>1,891</b>	<b>2,209</b>	<b>4,100</b>

Note: 210 procedures are unspecified regarding endocardiac/epicardiac ablation.



**Fig. 1** Isolated surgical aortic valve replacement (sAVR) and transcatheter aortic valve implantation (TAVI) (2013–2022). + Additional patients (TAVI) calculated from the German legal quality assurance program, §§ 135a/ 136/ 137 SGB V.



**Fig. 2** Isolated surgical aortic valve replacement (sAVR) (2013–2022). Notes: Ross procedures, homograft implantations, and transcatheter heart valve interventions excluded.

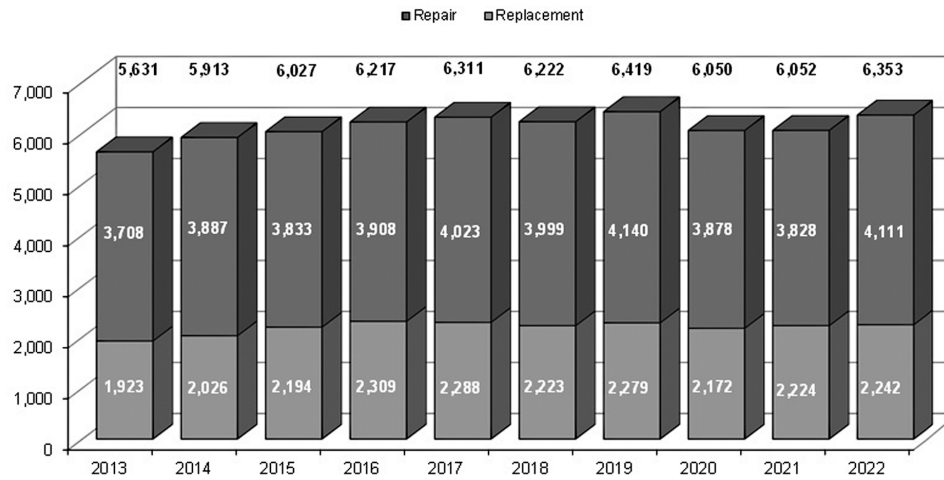


Fig. 3 Isolated mitral valve surgery (2013–2022).

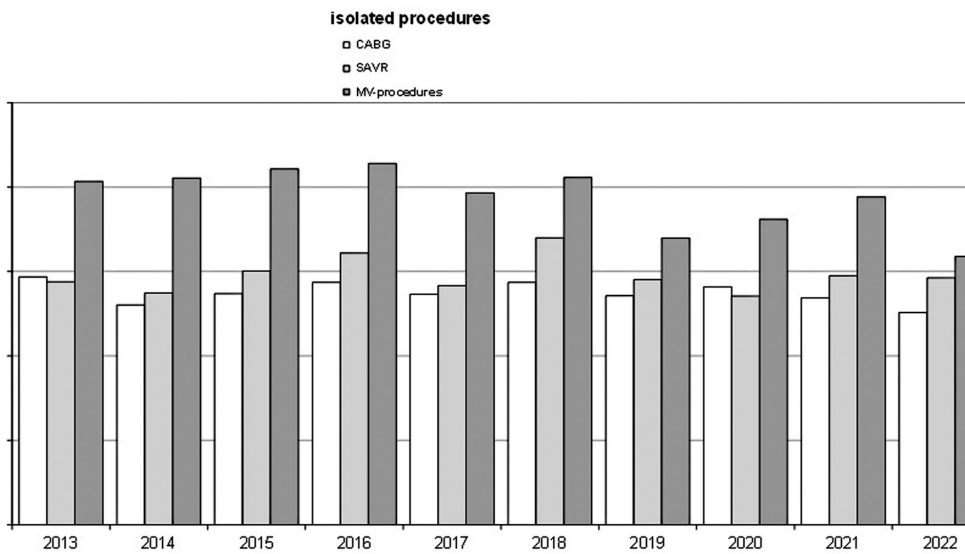


Fig. 4 Unadjusted mortality for selected procedures (2013–2022).

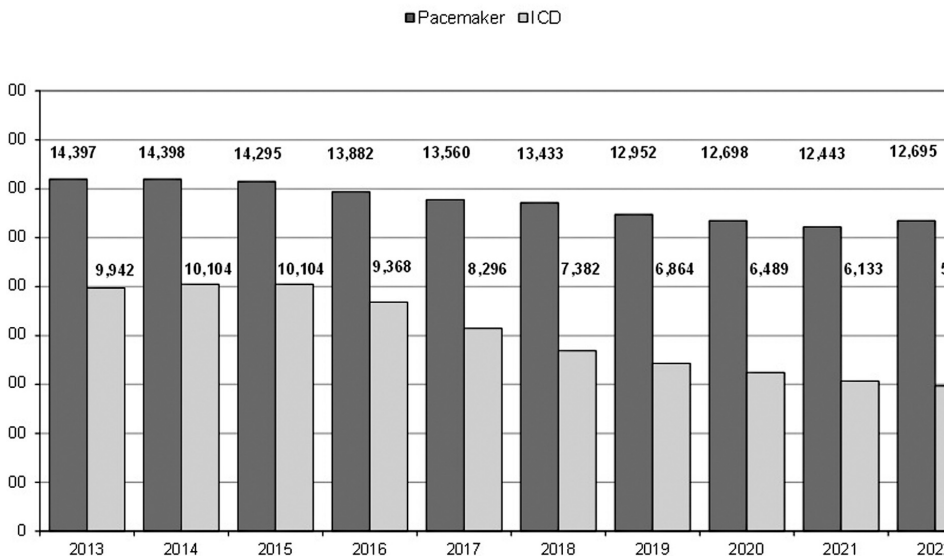
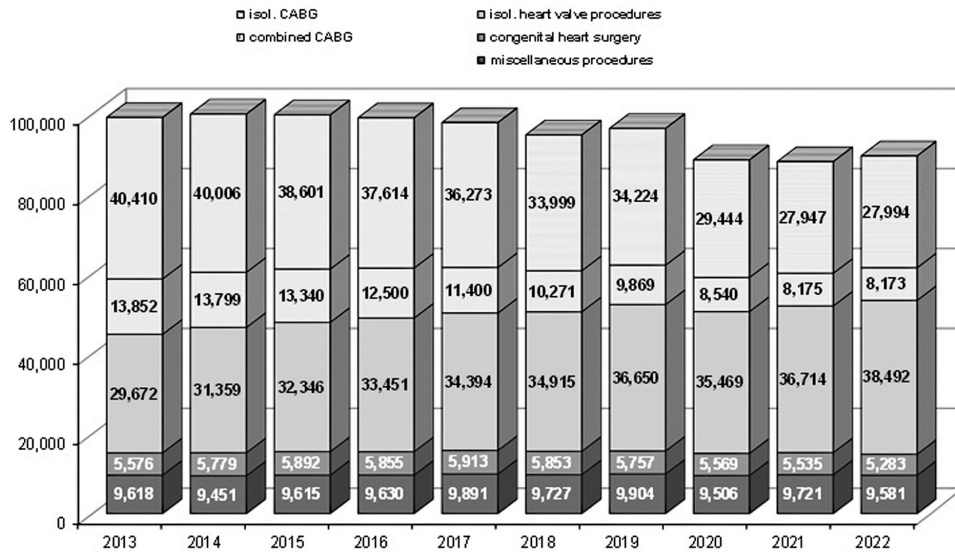
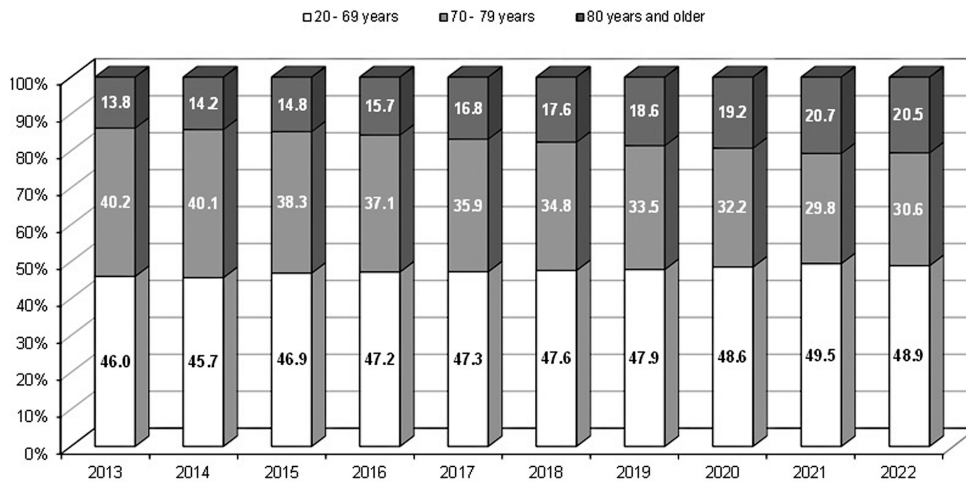


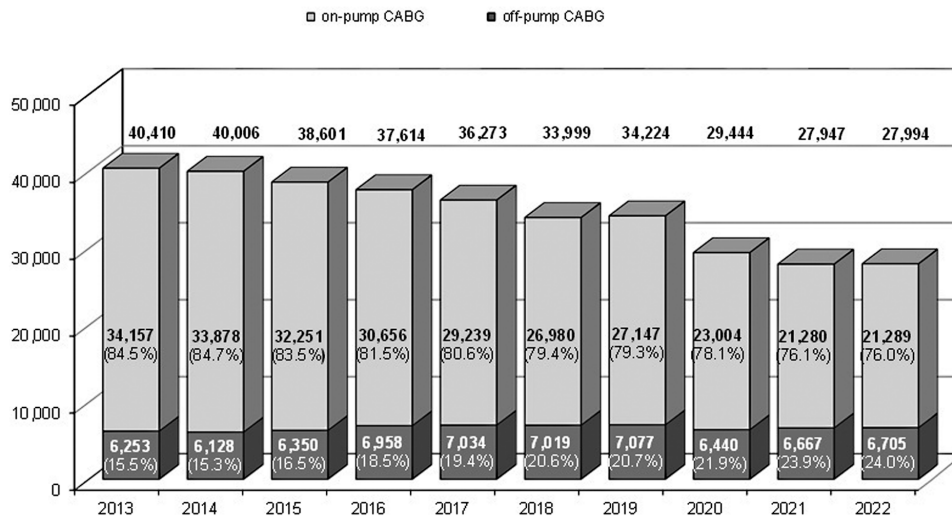
Fig. 5 Pacemaker and implantable cardioverter-defibrillator (ICD) procedures (2013–2022).



**Fig. 6** Selected heart surgical categories (2013–2022). 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. 7** Age distribution of cardiac procedures (2013–2022). Notes: Patients < 20 years and cardiac implantable electronic device (CIED) procedures excluded.



**Fig. 8** Isolated coronary artery bypass grafting (CABG) (2013–2022).



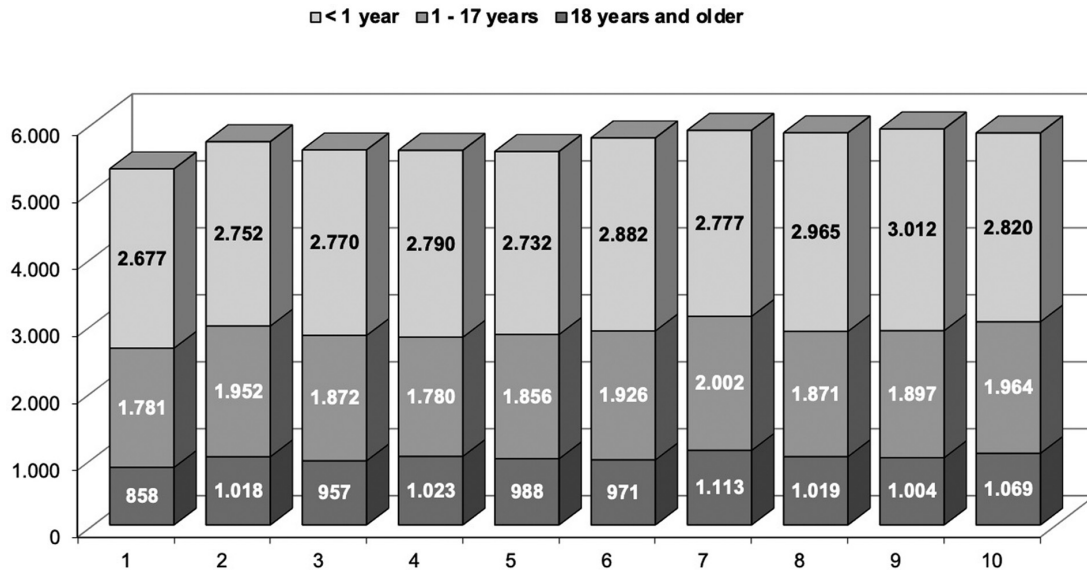


Fig. 9 Congenital heart surgery—age distribution (2013–2022).

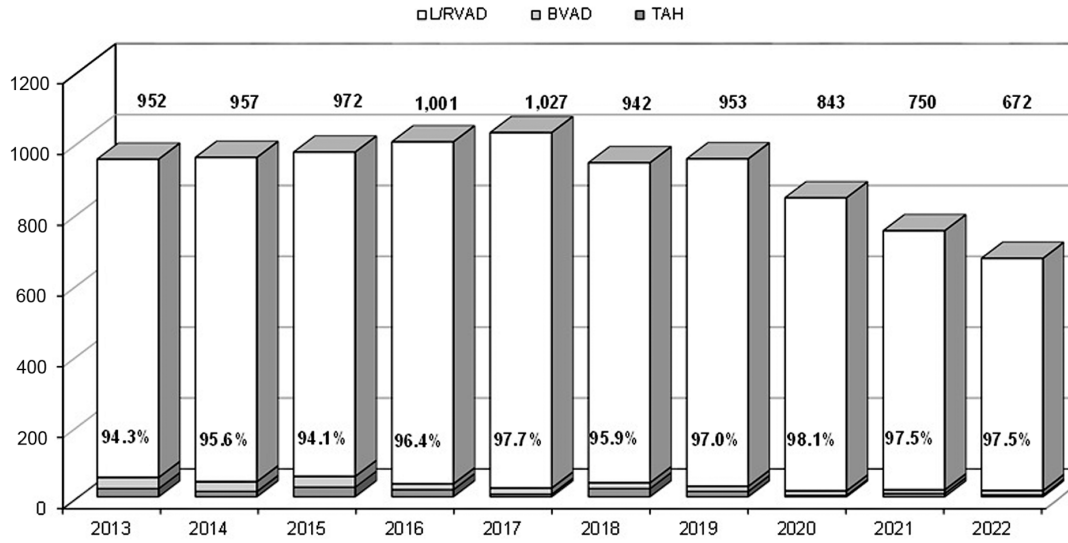


Fig. 10 Assist device implantation (2013–2022).

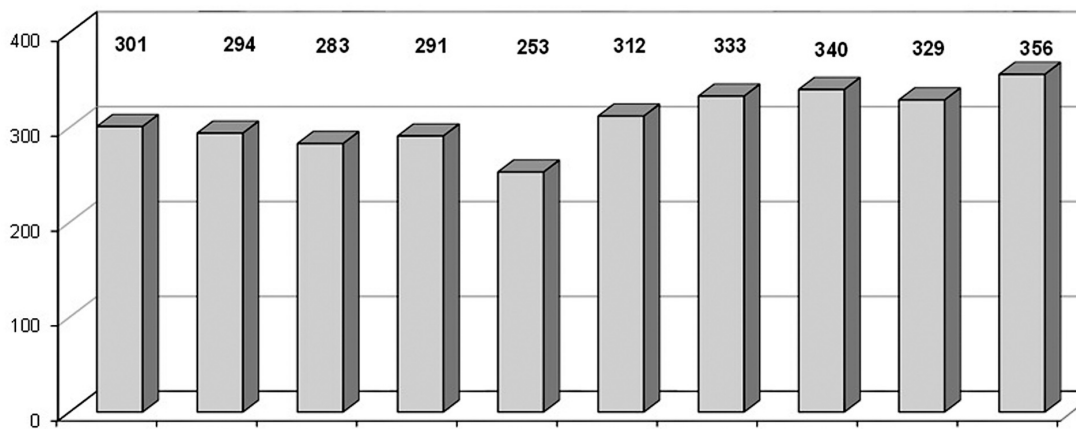


Fig. 11 Heart transplantation (2013–2022).

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