

German Heart Surgery Report 2016: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

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Abstract

Based on a long-standing voluntary registry founded by the German Society for Thoracic and Cardiovascular Surgery (GSTCVS), well-defined data of all cardiac, thoracic, and vascular surgery procedures performed in 78 German heart surgery departments during the year 2016 are analyzed. In 2016, a total of 103,128 heart surgery procedures (implantable defibrillator, pacemaker, and extracardiac procedures excluded) were submitted to the registry. Approximately 15.7% of the patients were at least 80 years of age, resulting in an increase of 0.9% compared with the data of 2015. For 37,614 isolated coronary artery bypass grafting procedures (relationship on-/off-pump 4.4:1), an unadjusted in-hospital mortality of 2.9% was observed. Concerning the 33,451 isolated heart valve procedures (including 11,701 catheter-based procedures), the unadjusted in-hospital mortality was 4.3%.

This annual updated registry of the GSTCVS represents voluntary public reporting by accumulating actual information for nearly all heart surgical procedures in Germany, describes advancements in heart medicine, and is a basis for internal and external quality assurances for all participants. In addition, the registry demonstrates that the provision of cardiac surgery in Germany is appropriate and patients are treated nationwide at all times.

Keywords

- ▶ heart surgery
- ▶ outcomes
- ▶ registry
- ▶ quality assurance
- ▶ congenital heart disease
- ▶ aortic surgery

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Introduction

Legitimate demands for a sophisticated quality management in medicine—by authorities, scientific organizations, health care companies, and patients all over the world—have stimulated a quality awareness resulting in the development of versatile quality assurance activities such as benchmark projects, registries, and others to answer those needs. As early as 1978, the board of directors of the German Society for Thoracic and Cardiovascular Surgery (GSTCVS, www.dgthg.de) decided to set up an annually updated data collection of all cardiac surgical procedures in terms of a voluntary registry. Since 1989, the data are annually updated, summarized in registry format, and published in the scientific journal of the GSTCVS.^{1–27} The aims of this registry are to gather developments and upcoming trends in cardiac surgery in Germany; to compile various results for nearly all cardiac surgical procedures; to enable each participant a comparison of the reached individual institutional results to the nationwide achievements; and to facilitate an evaluation on an international level for the German society.

For monitoring actual conditions as well as developments in cardiac medicine, the registry covers all relevant techniques and also innovative technologies including minimally invasive cardiac surgery and all kinds of heart valve operations including transcatheter heart valve interventions (e.g. TAVI). Thereby, important findings for current patient safety and the future of patient care are collected and can be evaluated under different aspects.

Data and results presented in this report comprehend assorted data of the year 2016.

Materials and Methods

Since 2004, a standardized questionnaire gathers specific information for well-defined procedures exactly described by an annually updated German adaption of the International Classification of Procedures in Medicine called operation code (Operationen- und Prozedurenschlüssel).

All participating institutions were requested to complete the structured questionnaire by January 22, 2017, entering all performed procedures and associated in-hospital mortality. The recommended path for data export is an electronic transmission of an encrypted file to the office of the GSTCVS in Berlin. After transaction, the data are decrypted, evaluated for completeness, and compiled for further analysis, thus ensuring anonymity for each participating institution. This compilation algorithm guarantees a high compliance for submission of complete datasets.

Inclusion criteria for the registry 2016 were all cardiac surgical procedures performed on patients between January 1, 2016, and December 31, 2016, unrelated to the date of admission or discharge of the patients as compared with other registries. Like in the earlier years, the number of procedures was counted rather than individual patients. For example, if during one admission a patient initially required isolated mitral valve reconstruction later followed

by a coronary artery bypass grafting (CABG) due to an undesirable event, one count in the category “mitral valve reconstruction” and a second one in the category “coronary surgery” 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, e.g. patient mortality will be attributed to an initial CABG procedure even if in a second procedure a replacement of the ascending aorta is performed due to a complication of the first operation. In case of fixing an undesirable event during the initial procedure, mortality will be counted under the more complex part of the operation.

The main reason for this structural setup of the registry—established over several decades—is to keep in accordance with the German data privacy act with its specific regulations for patients. Furthermore, it seemed to be relevant to get detailed information about all performed procedures and not only the number of treated patients. Last but not least, the process of data acquisition had to be standardized and feasible for all participants in Germany, thus enabling the submission of a complete dataset, regardless of the locally existing hardware and software used for data acquisition.

In 2016, a total of 78 institutions performed heart surgery. Fortunately, all departments answered the questionnaire and delivered a complete dataset for the year 2016 including hospital mortality rates.

Registry Data 2016

► **Table 1** gives an overview of cardiac surgical procedures by distribution between the 16 German states, based on the population count of the Federal Office for Statistics as of December 31, 2014. In this table, the range of heart operations per 100,000 inhabitants shows a minimum of 105.9 (Baden Württemberg) and a maximum of 168.8 (Sachsen-Anhalt), resulting in a nationwide mean value of 125.7 (2015: 126.6). Analyzing the heart operations by department dimension, 56% performed between 519 and 1,363 procedures (► **Table 2**). Summarizing the departments by various heart surgical procedures, it can be determined that heart operations in patients for congenital heart disease (< 1 year, with extracorporeal circulation [ECC]) are conducted in 21 institutions and heart transplantations in 22 institutions (► **Table 3**), in near accordance to the previous year. ► **Table 4** illustrates the number of procedures using ECC from 2007 to 2016 in Germany. Over the past decade, the number of heart operations using ECC shows a diminution by 12,536 procedures, certainly an achievement of established innovations and minimally invasive therapies in heart surgery.

Overall, 184,789 procedures were reported to the registry for the year 2016 (► **Table 5**), a decrease of 0.3% (2015: 185,270 procedures). A total of 103,128 heart

surgical procedures (excluded: implantable cardioverter defibrillator, pacemakers, and miscellaneous procedures without ECC) in 2016 display a comparable quantity with a difference of 0.8% ($n = 839$) compared with 2015 (103,967 procedures) –Tables 6, 7, V1 to V7, C1, C2, Con1, Con2, and Mis1 to Mis5 and –Figs. 1 to 9 demonstrate various compiled registry data concerning 2016 under different aspects and for various categories.

Compared with the data of previous years, several important developments continued in 2016 almost unchanged. The age distribution of patients (–Fig. 6) shows a continuous shift to an elderly patient population with presently 52.8% of the cardiac procedures performed in patients of at least 70 years of age and 15.7% in octogenarians. However, mortality remained on the same low level over the represented decade (–Fig. 2). In this context it has to be noted that all designated mortality rates of this registry are unadjusted values. This must be taken into account for any interpretation. The rate of CABG procedures decreased over the past decade, while the relative number for off-pump CABG now reached a level of 18.5% (2015: 16.5%) (–Fig. 3).

A still ongoing trend is the increase of TAVI procedures in Germany (–Fig. 5, –Table V7), while the count of isolated aortic valve replacement procedures remained on a comparable level with just a slight decrease of 2.0%. Starting in 2006 with just 78 implantations (0.67% of isolated aortic valve procedures), in 2016 a total of 10,879 (49.8%) TAVIs was reported to the registry. It must be emphasized that the 78 institutions which contribute their data to this registry do not represent all departments performing TAVI in Germany. In each case, the proceeding must correlate to the recommendations of international guidelines.^{28–30} For the German health service, a quality assurance directive for “minimally invasive heart valve interventions (TAVI, mitral valve clip reconstruction)” came into effect by law in July 2015, in which obligatory structures, defined processes, and qualified personnel are precisely specified. In addition to this registry responding to the directive of the Federal Joint Committee (G-BA), the results of the voluntary German Aortic Valve Registry^{31–38} as well as the annual analyses for selected procedures in the context of the legally compulsory quality assurance (§137 SGB V) contribute to an exceptional patient benefit.

Since 2004, more than 50% of isolated mitral valve procedures have been reconstructions. In 2016, a mitral valve reconstruction could be achieved in 62.9% of the procedures (–Fig. 8). Based on the fact that all isolated mitral valve procedures are included without exception, regardless of the underlying valve disease concerning morphology or urgency of operation, it has to be assumed that the relative rate of mitral valve reconstruction would certainly be even higher if patients without possibility or indication for reconstruction would have been excluded (e.g., mitral valve stenosis, calcifications, or endocarditis). In other publications, for example, Gammie et al,³⁹ patients

with mitral valve stenosis, endocarditis, and emergency procedures are usually excluded. Therefore, the published rates of mitral valve repair have to be interpreted with caution if compared with this registry.

The continued increase of left ventricular assist device implantations (–Fig. 10) emphasizes the importance of mechanical circulatory support therapies, while biventricular assist device and total artificial heart implantations are of subordinate importance with only 3.6%.

Discussion

The registry of the GSTCVS enables a comprehensive overview of all heart surgical procedures performed in Germany in 2016. The accuracy of this registry is considered to be high due to the implemented compilation algorithm using standardized operation coding which is 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.⁴⁰ In continuation with previous years, it can be concluded that heart surgery in Germany is performed on a constantly high level with superior in-hospital patient survival rates compared with international registries. In addition, the registry demonstrates that the German heart surgical provision is appropriate and the treatment of patients is guaranteed nationwide at any time (24/7/365). These aspects are especially important in the context of various activities in health care policy and the demographic change of the German population leading to an increase of patient age and related comorbidities and resulting in higher preoperative risk profile.

Compared with 2015, the number of cardiac surgery procedures remains on nearly the same level, due to the continuous increase of catheter-based heart valve procedures.

Further improvements in the basic configuration of the registry are recommended to enable more detailed and particularly risk-adjusted data analyses. However, if significant structural changes of data collection for the registry are conducted, it must be ensured that data compatibility still allows further longitudinal data analysis.

Completeness, validity, and further developments will depend on continued efforts of the GSTCVS in close collaboration with all cardiac surgical departments in Germany. This will be of outstanding importance in the sense of a contribution for patient safety and to obtain evidence for the high quality of heart surgery in Germany.

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Tables and Figures

Table 1 Heart operations/German states

German states	Quantity ^a	Population ^b	Heart procedures/ 100,000 inhabitants
Baden Württemberg	11,348	10,716,644	105.9
Bayern	14,159	12,691,568	111.6
Berlin	3,897	3,469,849	112.3
Brandenburg	3,332	2,457,872	135.6
Bremen	875	661,888	132.2
Hamburg	2,387	1,762,791	135.4
Hessen	7,599	6,093,888	124.7
Mecklenburg-Vorpommern	1,926	1,599,138	120.4
Niedersachsen	10,734	7,826,739	137.1
Nordrhein-Westfalen	23,134	17,638,098	131.2
Rheinland-Pfalz	5,360	4,011,582	133.6
Saarland	1,471	989,035	148.7
Sachsen	5,070	4,055,274	125.0
Sachsen-Anhalt	3,773	2,235,548	168.8
Schleswig-Holstein	4,078	2,830,864	144.1
Thüringen	2,945	2,156,759	136.5
Deutschland	102,088	81,197,537	125.7

^a1,018 foreign residents excluded.

^bFederal Office for Statistics of Germany: Population; due date December 31, 2014.

Table 2 Units assorted by quantified categories ($\sum^a [n = 103,128]$)

Procedures (quantity)	<500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments (number)	8	21	23	13	13
Average	387	817	1,156	1,698	2,632
Range	216–490	519–996	1,019–1,363	1,517–1,926	2,008–3,939

^aPacemaker/implantable cardioverter defibrillator and extracardiac surgery without ECC excluded.

Table 3 Departments summarized by heart surgery procedures 2016

Type of surgery performed	N
Coronary artery bypass grafting	77
Heart valve surgery	77
Surgery for CHD in pts <1 y with ECC	21 ^a
HTx	22 ^b
HLTx	4

Abbreviations: CHD, congenital heart disease; ECC, extracorporeal circulation; HTx, heart transplantation; HLTx, heart–lung transplantation; pts, patients; Tx, transplantation.

^aN = 2,130: thereof: 15 to 19 procedures in 3 units, 30 to 49 procedures in 4 units, 57 to 94 procedures in 4 units, and 100 to 274 procedures in 10 units.

^bN = 291: thereof: 1 to 3 Tx in four units, 5 to 9 Tx in eight units, 10 to 19 Tx in eight units, and 23 to 82 Tx in two units.

Table 4 Cardiac procedures using extracorporeal circulation (2007–2016)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Units	80	79	80	79	78	79	79	78	78	78
Operations	91,618	89,773	86,916	84,686	84,402	84,388	84,040	83,787	81,527	79,082
Average	1,145	1,136	1,086	1,072	1,082	1,068	1,064	1,074	1,045	1,014

Table 5 Frequency of cardiac procedures 2016

Category	With ECC	Without ECC	Total	Difference 2015 (%)
Coronary artery bypass grafting	42,813*	7,301*	50,114	−3.5
Heart valve procedures	21,877*	11,574*	33,451	+3.4
Surgery of thoracic aorta	7,369*	750*	8,119	+2.5
Surgery for CHD	4,762*	1,093*	5,855	−0.6
Cardiac surgery, other	1,072*	1,183*	2,255	−5.2
Assist device procedures**	789*	2,145*	2,934	−4.6
Extracardiac surgery	358*	57,023	57,381	+4.1
Pacemaker and ICD procedures	42*	24,638	24,680	−7.1
Total	79,082	105,707	184,789	−0.3

*Sum: n = 103,128 (heart surgery procedures).

**Sum: VADs / TAH / others devices (e.g. ECLS/ECMO).

Abbreviations: CHD, congenital heart disease; ECC, extracorporeal circulation; ICD, implantable cardioverter defibrillator; VADs; Ventricular assist devices; TAH, total artificial heart; ECLS, Extracorporeal life support; ECMO, Extracorporeal membrane oxygenation.

Table 6 Additional data for heart procedures with ECC in 2016 versus 2015

Procedures	2016		2015	
Emergency	12,745	12.4%	12,843	12.4%
Redo	9,186	8.9%	8,994	8.7%

Abbreviation: ECC, extracorporeal circulation.

Table 7 Gender distribution

	Female (%)	Male (%)
Heart valve procedures	43	57
Coronary procedures	23	77
Surgery for CHD	45	55
Surgery of thoracic aorta	34	66
Cardiac surgery, other	57	43
Assist devices	26	74
Pacemaker and ICD	36	64
Extracardiac surgery	35	65
Total	34	66

Abbreviations: CHD, congenital heart disease; ICD, implantable cardioverter defibrillator.

Table V1 Isolated valve procedures

Procedures	N	†	%
Single	17,855	680	3.8
Double	3,298	323	9.8
Triple	409	59	14.4
Transcatheter access (single valve)	11,701	363	3.1
Transcatheter access (double valve)	15	2	13.3
Not specified	173	9	5.2
Total	33,451	1,436	4.3

Note: Transcatheter valve procedures: 10,879 aortic valve implantations; 147 mitral valve implantations; 650 mitral valve repairs; 2 tricuspid valve implantations; 23 tricuspid valve repairs; 15 double aortic and mitral valve procedures; no pulmonary valve implantation.

Table V2 Single heart valve procedures: access type

Heart valve/access	N	†	%
Aortic valve	21,963	680	3.1
Sternotomy	7,879	310	3.9
Partial sternotomy	3,205	45	1.4
Transvascular	8,792	231	2.6
Transapical	2,087	94	4.5
Mitral valve	7,014	303	4.3
Sternotomy	3,115	214	6.9
Minimal invasive	3,102	52	1.7
Transcatheter	797	37	4.6
Tricuspid valve	531	58	10.9
Sternotomy	381	47	12.3
Minimal invasive	125	10	8.0
Transcatheter	25	1	4.0
Pulmonary valve	48	2	4.2
Sternotomy	48	2	4.2
Minimal invasive	0	0	–
Transcatheter	0	0	–
Total	29,556	1,043	3.5

Table V3 Isolated aortic valve procedures

Prosthesis/native valve	N	†	%
Xenograft	9,722	322	3.3
Mechanical prosthesis	1,201	28	2.3
Repair	123	2	1.6
Homograft	38	3	7.9
Total	11,084	355	3.2

Table V6 Isolated/combined mitral valve surgery—implantation/replacement versus repair

Mitral valve surgery	Repair			Implantation/ replacement			All procedures			
	N	†	%	N	†	%	N	% repair	†	%
Isolated	3,908	49	1.3	2,309	217	9.4	6,217	62,9	266	4.3
+ Aortic valve	563	42	7.5	838	115	13.7	1,401	40,2	157	11.2
+ Tricuspid valve repair ^a	977	44	4.5	631	86	13.6	1,608	60,8	130	8.1
+ CABG	1,585	107	6.8	976	157	16.1	2,561	61,9	264	10.3
+ CABG + aortic valve replacement	310	30	9.7	309	64	20.7	619	50,1	94	15.2
Total	7,343	272	3.7	5,063	639	12.6	12,406	59,2	911	7.3

^a57 procedures (not specified mitral valve + tricuspid valve surgery) were excluded; †: 21% (12/57).

Table V4 Isolated mitral valve procedures

Prosthesis/native valve	N	†	%
Repair	3,908	49	1.3
Xenograft	1,821	190	10.4
Mechanical prosthesis	473	26	5.5
Homograft	15	1	6.7
Total	6,217	266	4.3

Note: Transcatheter procedures are excluded.

Table V5 Multiple heart valve procedures

Combination	N	†	%
Mitral + tricuspid	1,665	142	8.5
Aortic + mitral	1,401	157	11.2
Aortic + mitral + tricuspid	407	58	14.3
Aortic + tricuspid	160	24	15.0
Aortic + pulmonary ^a	54	0	0.0
Tricuspid + pulmonary	18	0	0.0
Aortic + mitral + pulmonary	2	1	50.0
Total	3,707	382	10.3

Note: Transcatheter procedures excluded.

^aIncluding Ross procedures.

Table V7 Transcatheter heart valve procedures

	Without ECC		With ECC		All procedures		
	N	†	N	†	N	†	%
Aortic valve implantation	10,765	290	114	35	10,879	325	3
Transvascular	8,731	206	61	25	8,792	231	3
Transapical	2,034	84	53	10	2,087	94	5
Mitral valve	770	31	27	6	797	37	5
Repair	628	20	22	1	650	21	3
Implantation	142	11	5	5	147	16	11
Tricuspid valve repair	24	1	1	0	25	1	4
Repair	22	1	1	0	23	1	4
Implantation	2	0	0	0	2	0	0
Aortic + mitral valve implantation	15	2	0	0	15	2	13
Aortic valve implantation ^a + CABG	33	4	16	6	49	10	20
Mitral valve implantation ^b + CABG	0	0	3	1	3	1	33
Aortic + mitral valve + CABG	0	0	0	0	0	0	—
Total	11,607	328	161	48	11,768	376	3

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

Notes: Pulmonary valve implantation for the correction of congenital lesions is not included, No procedure was reported for adults without congenital lesion, 19% of transcatheter aortic valve implantation (TAVI) by transapical access; and 1% of TAVI under use of ECC.

^aFemoral, subclavian, or transaortic access.

^bTransvascular and transapical access.

Table C1 Isolated CABG and combined procedures with ECC

Procedures	N	†	%
Isolated CABG	37,614	1,080	2.9
+ aortic valve replacement	6,742	321	4.8
+ other	2,401	154	6.4
+ mitral valve repair	1,585	107	6.8
+ mitral valve replacement	976	157	16.1
+ aortic valve replacement + mitral valve repair	310	30	9.7
+ aortic + mitral valve replacement	309	64	20.7
+ aneurysm resection	125	9	7.2
+ transcatheter aortic valve implantation	49	10	20.4
Total	50,111	1,932	3.9

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

Table C2 Isolated CABG with/without ECC

Grafts (n)	With ECC			Without ECC			All		
	N	†	%	N	†	%	N	†	%
Single	1,013	59	5.8	1,488	45	3.0	2,501	104	4.2
Double	6,604	247	3.7	1,941	36	1.9	8,545	283	3.3
Triple	13,524	405	3.0	2,361	35	1.5	15,885	440	2.8
Quadruple	7,261	178	2.5	961	15	1.6	8,222	193	2.3
Quintuple + more	2,254	59	2.6	207	1	0.5	2,461	60	2.4
Total	30,656	948	3.1	6,958	132	1.9	37,614	1,080	2.9

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

Table Con1 Congenital heart surgery with/without ECC

Age (y)	N		†		%	
	With ECC	Without ECC	With ECC	Without ECC	With ECC	Without ECC
< 1	2,154	835	80	25	3.7	3.0
1–17	1,672	238	18	3	1.1	1.3
≥ 18	1,001	20	33	1	3.3	5.0
Total	2,673	258	51	4	1.9	1.6

Abbreviation: ECC, extracorporeal circulation.

Table Con2 Procedures for congenital heart disease with and without ECC

Lesion/procedure	Age < 1 y			Age 1–17 y			Age ≥ 18 y		
	N	†	%	N	†	%	N	†	%
ASD	35	0	0.0	245	0	0.0	272	4	1.5
Complete AV canal	213	5	2.3	75	1	1.3	13	0	0.0
VSD	295	0	0.0	110	0	0.0	20	0	0.0
Falot's tetralogy	188	3	1.6	52	0	0.0	5	0	0.0
DORV	56	2	3.6	15	0	0.0	1	0	0.0
TGA	171	1	0.6	3	0	0.0	0	0	–
TGA + VSD	54	3	5.6	5	0	0.0	0	0	–
Truncus arteriosus	35	2	5.7	8	0	0.0	1	0	0.0
Fontan	2	0	0.0	214	1	0.5	8	1	12.5
Norwood	183	30	16.4	2	1	50.0	0	0	–
Pulmonary valve	64	1	1.6	199	2	1.0	71	4	5.6
Transcatheter pulmonary valve implantation	0	–	–	6	0	0.0	3	0	0.0
Aortic valve	50	1	2.0	188	5	2.7	347	8	2.3
Ross procedure	9	0	0.0	29	0	0.0	29	0	0.0
Mitral valve	35	1	2.9	100	0	0.0	86	9	10.5
Tricuspid valve	68	3	4.4	58	2	3.4	45	3	6.7
PDA	214	8	3.7	28	0	0.0	1	0	0.0
Coarctation	208	1	0.5	38	0	0.0	3	0	0.0
Others	1,105	44	4.0	481	7	1.5	116	5	4.3
HTx	4	0	0.0	38	1	2.6	0	0	–
HLTx	0	–	–	2	0	0.0	0	0	–
LTx	0	–	–	14	1	7.1	0	0	–
Total	2,989	105	3.5	1,910	21	1.1	1,021	34	3.3

Abbreviations: ASD, atrial septal defect; AV, atrioventricular; DORV, double outlet right ventricle; ECC, extracorporeal circulation; HLTx, heart-lung transplantation; HTx, heart transplantation; LTx, lung transplantation; PDA, patent ductus arteriosus; TGA, transposition of the great arteries; VSD, ventricular septal defect.

Table Mis1 Ross procedures (autologous aortic and pulmonary valve replacement)

Age (y)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 18	34	42	54	43	40	36	33	37	28	38
≥ 18	261	207	175	184	134	117	107	90	64	72
Total	295	249	229	227	174	153	140	127	92	110

Abbreviation: AV, aortic valve.

Table Mis2 Heart and lung transplantation

Organ	With ECC			Without ECC		
	N	†	%	N	†	%
HTx	291	38	13.1			
HLTx	7	0	0.0			
LTx	53	10	18.9	247	14	5.7

Abbreviations: HTx, heart transplantation; HLTx, heart–lung transplantation; LTx, lung transplantation; Tx, transplantation.
 Notes: All pediatric transplantations (demonstrated in ► **Table Con2**) are included in this table, Eurotransplant report 2016: 287 HTx, 2 HTx + kidneyTx, 1 HTx + liverTx, 7 HLTx, 281 double lung transplantation, 38 single lung transplantation, 0 LTx + kidneyTx, and 2 LTx + liverTx.

Table Mis3 Aortic surgery

Replacement ^a	With ECC			Without ECC		
	N	†	%	N	†	%
Supracoronary replacement of ascending aorta	1,383	128	9.3			
Supracoronary ascending + aortic valve replacement	1,325	69	5.2			
Infracoronary ascending						
Mechanical valve conduits	441	33	7.5			
Biological valve conduits	999	110	11.0			
David procedure	537	15	2.8			
Yacoub procedure	120	5	4.2			
Other	286	21	7.3			
Aortic arch replacement ^b	2,117	246	11.6			
Replacement of descending aorta	43	20	46.5	7	1	14.3
Thoracoabdominal aortic replacement	101	16	15.8	24	5	20.8
Endostent descending aorta	17	0	0.0	719	46	6.4
Total	7,369	663	9.0	750	52	6.9

Abbreviation: ECC, extracorporeal circulation.
 Notes: All procedures involving aortic surgery are included in this table, isolated aortic surgery as well as all possible combined procedures (e.g., additional coronary artery bypass grafting) are summarized in this category.
^aProcedures for abdominal aortic diseases excluded: 449 abdominal procedures and 734 endovascular abdominal stents.
^bAll possible combined procedures included, the only common denominator is aortic arch surgery.

Table Mis4 Pacemaker and ICD procedures

Device/category				With ECC		Without ECC	
	N	†	%	N	†	N	†
Pacemaker	13,882	118	0.9	25	4	13,857	114
Implantation	8,968	71	0.8	8	1	8,960	70
Battery exchange	1,907	2	0.1	2	0	1,905	2
Revision procedures	3,007	45	1.5	15	3	2,992	42
ICD	9,368	85	0.9	17	2	9,351	83
Implantation	4,140	21	0.5	2	1	4,138	20
Battery exchange	2,019	3	0.1	0	0	2,019	3
Revision procedures	3,209	61	1.9	15	1	3,194	60
Miscellaneous	1,430	11	0.8	0	0	1,430	11
Total	24,680	214	0.9	42	6	24,638	208

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

Table Mis5 Surgical ablation procedures for tachyarrhythmia

Energy source	Total	Endocardiac	Epicardiac
		N	N
Unipolar radiofrequency	200	65	135
Unipolar cryo-radiofrequency	241	109	132
Bipolar radiofrequency	2,210	223	1,987
Cryotherapy	1,523	1,307	216
Microwave	13	3	10
Focused ultrasound	89	22	67
Laser	0	0	0
Other	29	14	15
Total	4,305	1,743	2,562

Note: 419 procedures are not specified with regard to endocardiac/epicardiac ablation.

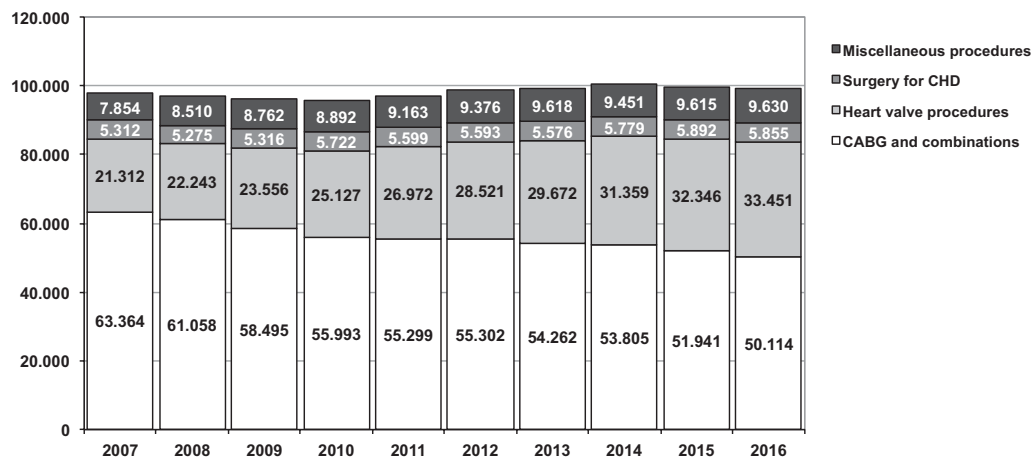


Fig. 1 Selected heart surgical categories (2007–2016). (1) CABG and combined procedures: all types of coronary surgery. (2) Heart valve procedures: combination with aortic surgery summarized under miscellaneous procedures. (3) Congenital heart surgery: ASD repairs in adults or in combination with CABG or heart valve procedures are summarized in the CABG or heart valve procedure groups. (4) Miscellaneous procedures: all other types of procedures with ECC. ASD, atrial septal defect; CABG, coronary artery bypass grafting; ECC, extracorporeal circulation.

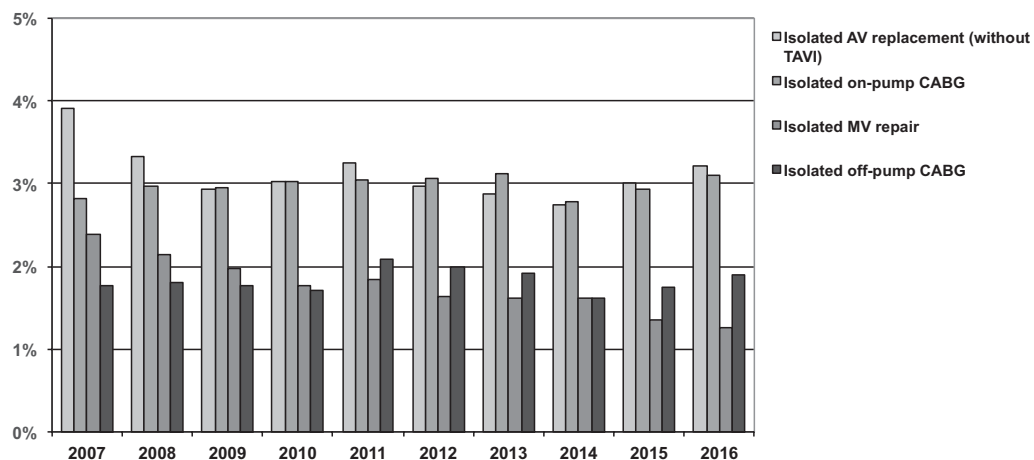


Fig. 2 Unadjusted mortality for selected procedures (2007–2016). AV, aortic valve; CABG, coronary artery bypass grafting; MV, mitral valve; TAVI, transcatheter heart valve intervention.

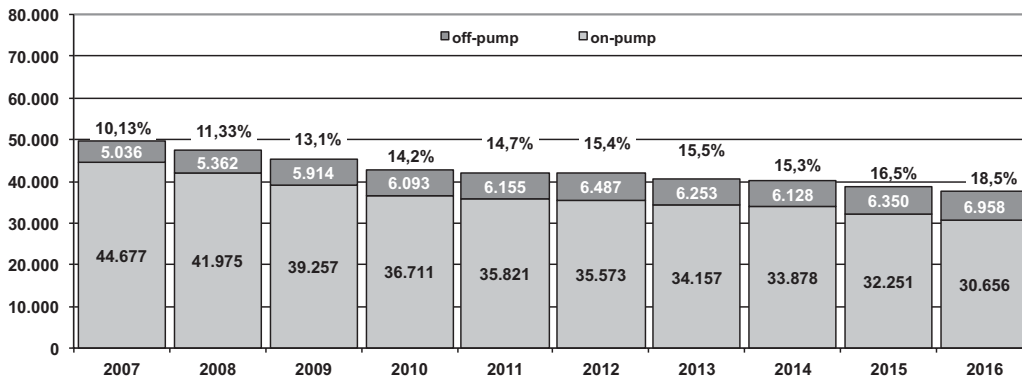


Fig. 3 Isolated coronary artery bypass grafting (2007–2016).

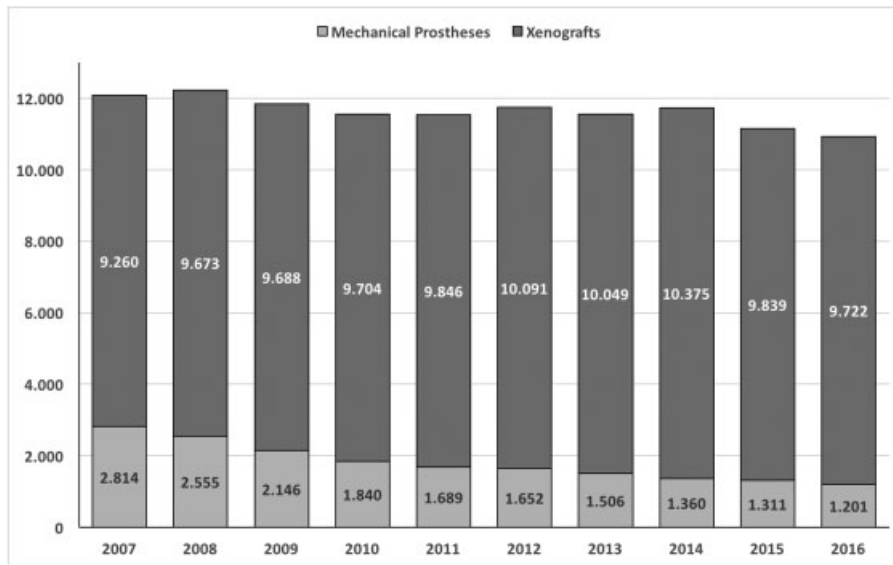


Fig. 4 Isolated aortic valve replacement (2007–2016). Notes: Ross procedures, homograft implantations, and transcatheter heart valve intervention excluded.

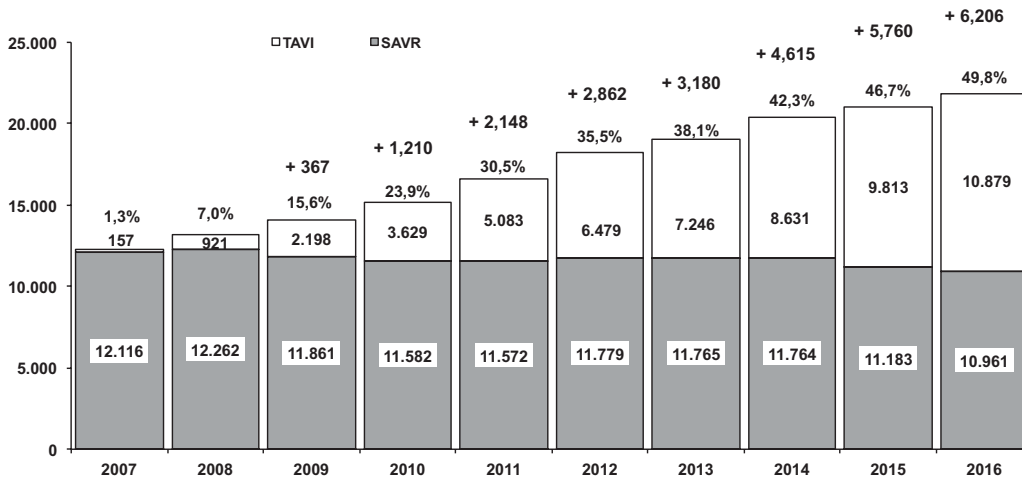


Fig. 5 Isolated aortic valve replacement and transcatheter aortic valve implantation (TAVI) The annual count of TAVI submitted to the voluntary registry of German Society for Thoracic and Cardiovascular Surgery does not represent all TAVI procedures performed in Germany in 2016. †Additional TAVI procedures calculated from the German legal quality assurance program, § 137 SGB V.

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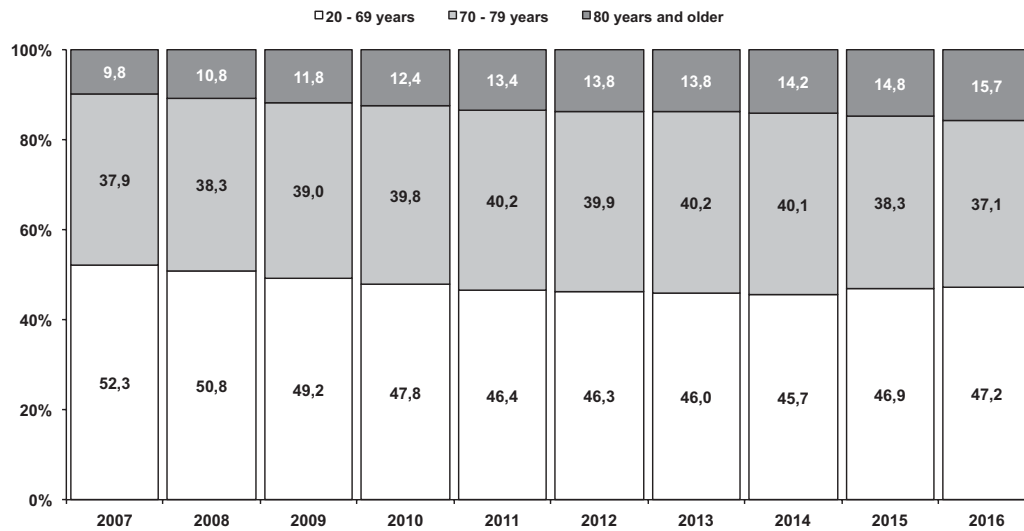


Fig. 6 Age distribution of cardiac procedures (2007–2016). Notes: Patients < 20 years and pacemaker/implantable cardioverter defibrillator procedures were excluded.

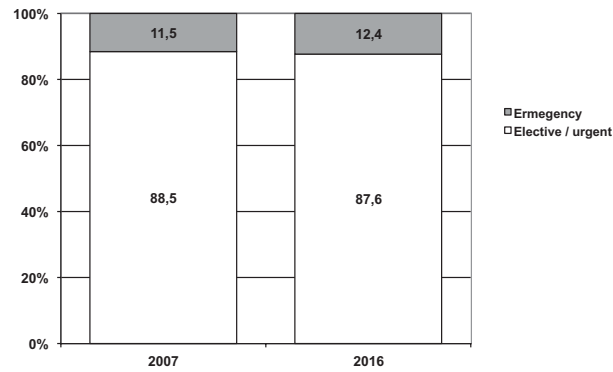


Fig. 7 Urgency categories (2007 vs. 2016) Emergency = acutely life-threatening cardiac/vascular disease.

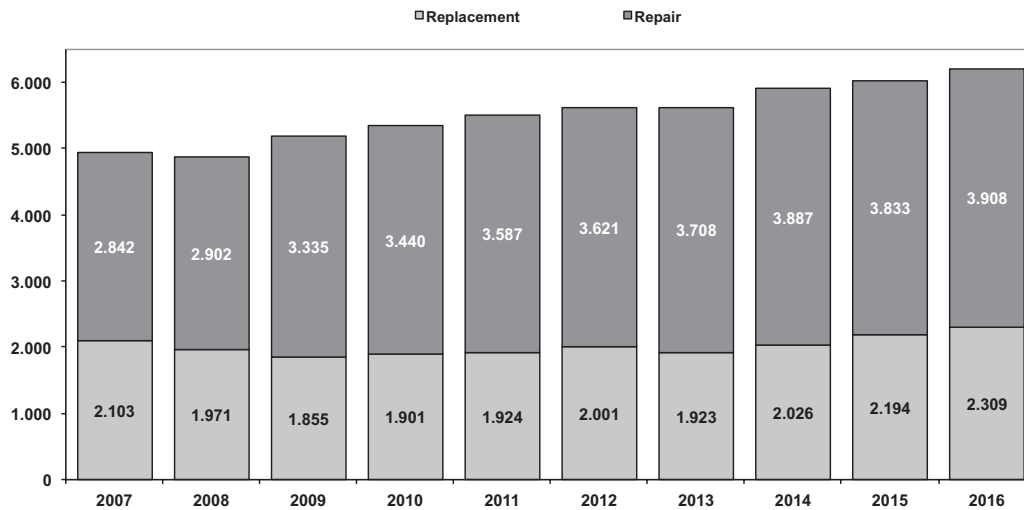


Fig. 8 Isolated mitral valve surgery (2007–2016).

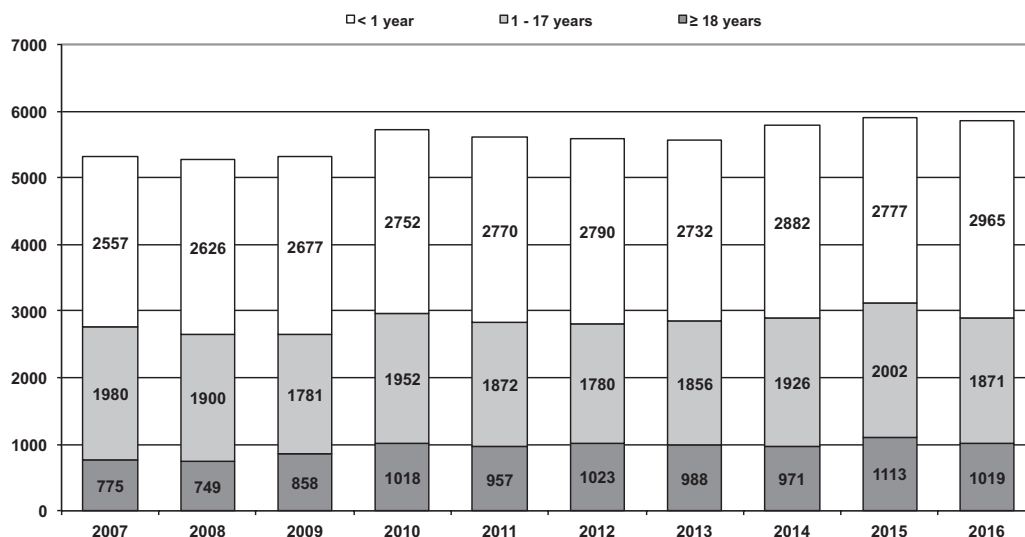


Fig. 9 Age distribution for CHD (2007–2016). Notes: Bias possible due to the fact that not all relevant procedures can be allocated exactly to CHD category in patients older than 18 years (e.g., aortic valve disease). CHD, congenital heart disease.

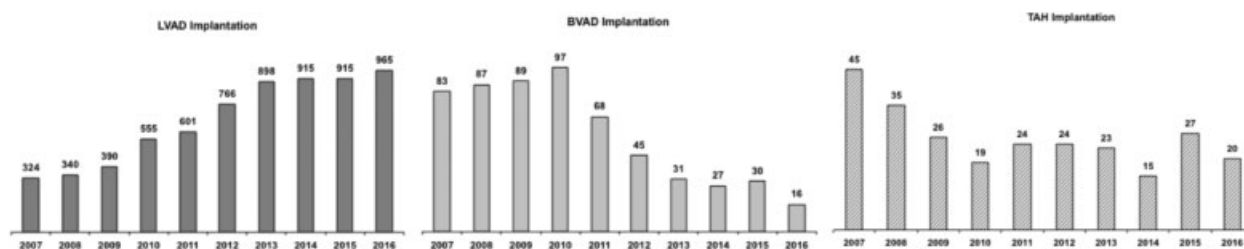


Fig. 10 Development of mechanical circulatory support (2007–2016). BVAD, biventricular assist device; LVAD, left ventricular assist device; TAH, total artificial heart.

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