

# German Heart Surgery Report 2015: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery

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## Abstract

On the basis of a long-standing voluntary registry, which was founded by the German Society for Thoracic and Cardiovascular Surgery (GSTCVS), well-defined data of all heart, thoracic, and vascular surgery procedures performed in 78 German heart surgery departments during 2015 are analyzed. In 2015, a total of 103,967 heart surgery procedures (implantable cardioverter defibrillator, pacemaker, and extracardiac procedures without ECC excluded) were submitted to the database. Approximately 14.8% of the patients were at least 80 years old, resulting in an increase of 0.6% compared with the data of 2014. For 38,601 isolated coronary artery bypass grafting procedures (relationship on-/off-pump: 5:1), the unadjusted inhospital mortality was 2.7%. Concerning the 32,346 isolated heart valve procedures (including 10,606 catheter-based implantations) an unadjusted inhospital mortality of 4.4% was observed.

## Keywords

- ▶ heart surgery
- ▶ outcome
- ▶ registry
- ▶ quality assurance
- ▶ congenital heart disease
- ▶ aortic surgery
- ▶ transplantation

This annual updated registry of the GSTCVS represents voluntary public reporting by accumulating actual information for nearly all heart surgical procedures in Germany, demonstrates advancements in heart medicine, and enables internal/external quality assurance for all participants. In addition, the registry demonstrates that the provision of heart surgery in Germany is appropriate and patients are treated nationwide in a round-the-clock service.

## Introduction

Legitimate demands for a sophisticated quality management in medicine—by authorities, scientific organizations, health insurance companies, and patients all over the world—have stimulated 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 annual database of all cardiac surgical procedures in terms of a voluntary registry. Since 1989, the

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data are annually updated, summarized in a registry format, and published in the scientific journal of the GSTCVS.<sup>1–26</sup> The aims of this registry are to gather developments and current trends in cardiac surgery in Germany, to compile various results for nearly all cardiac surgical procedures, to enable each participating department for cardiac surgery comparing its own results to the nationwide achievements, and to facilitate an evaluation on an international level for the society.

In order to monitor actual conditions as well as developments in cardiac medicine, the registry covers all relevant techniques as well as innovative technologies including minimally invasive cardiac surgery and all kinds of heart valve operations 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 and may be evaluated under different aspects.

Data and results presented in this report comprehend assorted data of 2015.

## Material and Methods

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

All participating institutions were requested to complete the structured questionnaire, asking for all performed procedures and associated inhospital mortality, by January 24, 2016. The recommended path for data export is 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 2015 registry were all cardiac surgical procedures performed on patients between January 1, 2015, and December 31, 2015, unrelated to the date of admission or discharge as compared with other registries. Like in all previous years, the number of procedures was counted rather than individual patients. For example, if during one admission a patient required coronary bypass grafting due to a complication following initial mitral valve reconstruction, one count in the “mitral valve reconstruction” category and another in the “coronary surgery” category are enumerated. Thus, the registry contains a higher number of procedures than the real number of patients operated on.

Death of patients was defined as inhospital 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 of coronary artery bypass grafting (CABG) would only be attributed to the coronary procedure. The denominator in the calculation of mortality rates is getting

falsely higher with the assignment of complication procedures resulting in a marginal underestimation of mortality rates (calculus estimate: <0.1%).

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 getting not only the count of treated patients but also detailed information about all performed procedures. Last but not least, the process of data acquisition had to be standardized and feasible for all participating cardiac surgery departments in Germany, thus enabling the submission of a complete dataset, regardless of the locally existing hard- and software used for data management.

In 2015, a total of 78 institutions performed heart surgery in Germany. Fortunately, all units answered the questionnaire and delivered a complete dataset for 2015 including hospital mortality rates.

## Registry Data 2015

► **Table 1** gives an overview of heart surgical procedures by distribution between the 16 German states. In the table, the range of heart operations per 100,000 inhabitants shows a minimum of 101.8 (Baden-Württemberg) and a maximum of 168.9 (Sachsen-Anhalt), resulting in a nationwide mean value of 126.6. Analyzing the heart operations for department dimension, 59% performed from 590 to 1,460 procedures (► **Table 2**). Summarizing the departments by various heart surgical procedures, it can be ascertained that heart operations in patients for congenital heart disease (<1 year, with extracorporeal circulation [ECC]) are conducted in 23 and heart transplantations in 22 institutions (► **Table 3**). ► **Table 4** illustrates the number of procedures using ECC from 2006 to 2015 in Germany. Over the past decade, the number of heart operations using ECC shows a diminution by 9,530 procedures, certainly an achievement of establishing innovations and minimally invasive therapies in heart surgery.

Overall, 185,270 procedures were reported to the registry in 2015, a decrease of 1.1% compared to 2014 (187,392 procedures). A total of 103,967 heart surgical procedures (excluding implantable cardioverter defibrillator, pacemakers, and miscellaneous procedures without ECC) in 2015 displays nearly the same quantity with a difference of just 0.5% ( $n = 517$ ) compared to 2014 (104,484 procedures; ► **Table 5**). ► **Tables 6 and 7, V1 to V7, C1 to C2, ►Table Con1 and Con2, and ►Table Mis 1 to Mis 5 and ►Figs. 1–9** demonstrate some compiled registry data of 2015 under different aspects and for various categories.

Compared to previous years' data, several important developments continued to be almost unchanged in 2015. The age distribution of patients (► **Fig. 6**) shows again the shift to an elderly patient population, with presently 53.1% of the cardiac procedures performed in patients aged at least 70 years and 14.8% in patients aged 80 years or older. However, mortality remained on the same low level over the represented decade (► **Fig. 2**). The rate of CABG procedures decreased over the past years, whereas the relative

number of off-pump CABG procedures reached a level of 16.5% in 2015 as compared to 15.3% in 2014 (→ Fig. 3).

Since 2004, more than 50% of isolated mitral valve procedures have been reconstructions. In 2015, mitral valve reconstruction could be achieved in 63.6% of the procedures (→ Fig. 8). Based on the fact that without exception all isolated mitral valve procedures are included, 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 by Gammie et al.,<sup>27</sup> patients with mitral valve stenosis, endocarditis, and emergency procedures were 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 increasing relevance of mechanical circulatory support.

Again, a remarkable trend is the still ongoing increase of TAVI procedures in Germany (→ Fig. 5), whereas the count of isolated aortic valve replacement procedures showed a slight decrease of 4.9%. Starting in 2006 with just 78 implantations (0.67% of isolated aortic valve procedures), in 2015, 9,813 (46.7%) TAVI were 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. It is known that some additional institutions in Germany perform TAVI procedures under different infrastructure conditions and various external co-operations. This practice does not correlate to the recommendations of the European guideline on the management of valvular heart disease (version 2012).<sup>28</sup> In July 2015, the first version of the quality assurance directive for “minimally invasive heart valve interventions (TAVI, mitral clip reconstruction),” in which obligatory structures, defined processes, and qualified personnel are exactly specified, was released by the German Federal Joint Committee (G-BA).

In addition to the registry data, the short-, mid-, and long-term results of the German Aortic Valve Registry (GARY)<sup>29–33</sup> and the annual analyses of the legal quality assurance (§137 SGB V) are of outstanding importance concerning the judgement of developments and quality - and thus for patient benefit.

## Discussion

The registry of the GSTCVS enables a comprehensive overview of all heart surgical procedures performed in Germany in 2015. 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.<sup>34</sup> In continuation with previous years, it can be concluded that heart surgery in Germany is performed on a constantly high level with very high inhospital survival rates of patients compared with international registries. In addition, the registry data demonstrate that the provision of heart surgery in Germany is appropriate and nationwide patient treatment is guaranteed in a round-the-clock service (24/7/365). These conclusions 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 resulting in higher preoperative risk profiles.

Compared to 2014, the number of cardiac surgery procedures remains on nearly the same level due to the still increasing number 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 in 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 adduce evidence for high quality of heart surgery in Germany.

## Abbreviations

ASD	atrial septal defect
CABG	coronary artery bypass grafting
CHD	congenital heart disease
DLTx	double lung transplantation
DORV	double outlet right ventricle
ECC	extracorporeal circulation
HLTx	heart-lung transplantation
HTx	heart transplantation
ICD	implantable cardioverter defibrillator
PDA	patent ductus arteriosus
SLTx	single lung transplantation
TAVI	transcatheter aortic valve implantation
TGA	transposition of the great arteries
TMLR	transmyocardial laser revascularisation
Tx	Organ transplantation
VSD	ventricular septal defect

## Acknowledgments

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**Tables and Figures**

**Table 1** Heart operations in German states

German states	Quantity <sup>a</sup>	Population <sup>b</sup>	Heart procedures/ 100,000 inhabitants
Baden-Württemberg	10,907	10,716,644	101.8
Bayern	14,542	12,691,568	114.6
Berlin	3,800	3,469,849	109.5
Brandenburg	3,194	2,457,872	129.9
Bremen	812	661,888	122.7
Hamburg	2,168	1,762,791	123.0
Hessen	7,875	6,093,888	129.2
Mecklenburg-Vorpommern	2,134	1,599,138	133.4
Niedersachsen	10,848	7,826,739	138.6
Nordrhein-Westfalen	23,164	17,638,098	131.3
Rheinland-Pfalz	5,637	4,011,582	140.5
Saarland	1,644	989,035	166.2
Sachsen	5,271	4,055,274	130.0
Sachsen-Anhalt	3,776	2,235,548	168.9
Schleswig-Holstein	4,180	2,830,864	147.7
Thüringen	2,843	2,156,759	131.8
Total	102,795	81,197,537	126.6

<sup>a</sup>1,172 foreign residents excluded.

<sup>b</sup>Federal Offices for Statistics of German Population; due date December 31, 2014.

**Table 2** Departments sorted by quantity (n = 103.967)

Procedures (quantity)	<500	500–999	1,000–1,499	1,500–1,999	2,000–5,000
Departments (no.)	7	21	25	12	13
Average	346	814	1,198	1,663	2,658
Range	233–445	590–992	1,032–1,460	1,508–1,966	2,021–4,102

Note: Pacemaker/ implantable cardioverter defibrillator and extracardiac surgery without extracorporeal circulation excluded.

**Table 3** Departments summarized by heart surgery procedures in 2015

Procedures	N
Coronary artery bypass grafting	77
Heart valve surgery	77
Surgery for CHD patients < 1 yr with ECC	23 <sup>a</sup>
HTx	22 <sup>b</sup>
HLTx	2

<sup>a</sup>N = 2,041: 3–17 procedures in 4 units, 22–46 procedures in 5 units, 65–89 procedures in 5 units, and 110–265 procedures in 9 units.

<sup>b</sup>N = 283: 23–75 Tx in 4 units, 11–17 Tx in 5 units, 5–8 Tx in 8 units, and 2–4 Tx in 5 units.

**Table 4** Open heart procedures using extracorporeal circulation (2006–2015)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Departments	80	80	79	80	79	78	79	79	78	78
Procedures	91,057	91,618	89,773	86,916	84,686	84,402	84,388	84,040	83,787	81,527
Average	1,138	1,145	1,136	1,086	1,072	1,082	1,068	1,064	1,074	1,045

**Table 5** Heart surgery categories 2015

Category	with ECC	without ECC	Total	Diff. 2014 (%)
Coronary artery bypass grafting	45,107	6,834	51,941	-3.5
Heart valve procedures	21,892	10,454	32,346	+3.1
Surgery of thoracic aorta	7,265	657	7,922	+2.2
Surgery for CHD	4,913	979	5,892	+2.0
Cardiac surgery and others	1,173	1,206	2,379	-3.8
Assist device procedures	765	2,310	3,075	+5.7
Extracardiac surgery	358	54,785	55,143	-3.4
Pacemaker and ICD procedures	54	26,518	26,572	+1.2
Total	81,527	103,743	185,270	-1.1

**Table 6** Additional data for heart surgery procedures with ECC in 2015 versus 2014

Procedures	2015		2014	
	N	%	N	%
Emergency	12,843	12.4%	12,583	12.0%
Redo	8,994	8.7%	8,809	8.4%

**Table 7** Gender distribution

	Female (%)	Male (%)
Heart valve procedures	44	56
Coronary procedures	22	78
Surgery for CHD	44	56
Surgery of thoracic aorta	33	67
Cardiac surgery, other	52	48
Assist Devices	29	71
Pacemaker and ICD	35	65
Extracardiac surgery	34	66
Total	33	67

**Table V1** Isolated heart valve procedures

Procedures	N	†	%
Single	17,986	649	3.6
Double	3,280	305	9.3
Triple	358	47	13.1
Transcatheter access(single valve)	10,581	405	3.8
Transcatheter access(double valve)	25	2	8.0
Not specified	116	6	5.2
Total	32,346	1,414	4.4

Transcatheter heart valve procedures: 9,813 aortic valve implantations; 111 mitral valve implantations; 632 mitral valve repairs; 1 tricuspid valve implantation; 24 tricuspidal valve repairs; 25 combined aortic and mitral valve procedures; no pulmonary valve implantation.

**Table V2** Single heart valve procedures: access type

Heart valve/access	N	†	%
Aortic valve	21,120	715	3.4
Sternotomy	8,291	292	3.5
Part. sternotomy	3,016	49	1.6
Transvascular	7,311	218	3.0
Transapical	2,502	156	6.2
Mitral valve	6,770	283	4.2
Sternotomy	3,099	205	6.6
Minimally invasive	2,928	49	1.7
Transcatheter	743	29	3.9
Tricuspidal valve	617	53	8.6
Sternotomy	444	45	10.1
Minimally invasive	148	6	4.1
Transcatheter	25	2	8.0
Pulmonary valve	56	3	5.4
Sternotomy	56	3	5.4
Minimally invasive	0	0	-
Transcatheter	0	0	-
Total	28,563	1,054	3.7

Note: Apical aortic conduits procedures ( $n = 4$ ) excluded.

**Table V3** Isolated aortic valve procedures

Prosthesis/repair	N	†	%
Xenograft	9,839	311	3.2
Mechanical prosthesis	1,311	23	1.8
Repair	124	5	4.0
Homograft	33	2	6.1
Total	11,307	341	3.0

**Table V4** Isolated mitral valve procedures

Prosthesis/repair	N	†	%
Repair	3,833	52	1.4
Xenograft	1,680	165	9.8
Mechanical prosthesis	505	35	6.9
Homograft	9	2	22.2
Total	6,027	254	4.2

**Table V5** Multiple heart valve procedures

	N	†	%
Mitral + tricuspid	1,685	118	7.0
Aortic + mitral	1,372	170	12.4
Aortic + mitral + tricuspid	357	47	13.2
Aortic + tricuspid	174	15	8.6
Aortic + pulmonary <sup>a</sup>	39	1	2.6
Tricuspid + pulmonary	10	1	10.0
Aortic + mitral + pulmonary	1	0	0.0
Total	3,638	352	9.7

Note: Transcatheter procedures excluded.

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

**Table V6** Isolated/combined mitral valve procedures: implantation/replacement vs. repair

Mitral valve surgery	Repair			Implantation/replacement			All procedures			
	N	†	%	N	†	%	N	% repair	†	%
Isolated	3,833	52	1.4	2,194	202	9.2	6,027	63.6	254	4.2
+ Aortic valve	603	38	6.3	769	132	17.2	1,372	44.0	170	12.4
+ Tricuspid valve repair <sup>a</sup>	1,025	44	4.3	611	66	10.8	1,636	62.7	110	6.7
+ CABG	1,711	132	7.7	918	134	14.6	2,629	65.1	266	10.1
+ CABG + aortic valve replacement	318	40	12.6	286	59	20.6	604	52.6	99	16.4
Total	7,490	306	4.1	4,778	593	12.4	12,268	61.1	899	7.3

<sup>a</sup>A total of 49 procedures (not specified mitral valve + tricuspid valve surgery) excluded; †: (8/49) 16%.

**Table V7** Transcatheter heart valve procedures

	without ECC		with ECC		All procedures		
	N	†	N	†	N	†	%
Aortic valve implantation	9,675	330	138	44	9,813	374	4
Transvascular	7,236	192	75	26	7,311	218	3
Transapical	2,439	138	63	18	2,502	156	6
Mitral valve procedure	731	26	12	3	743	29	4
Repair	625	20	7	1	632	21	3
Implantation	106	6	5	2	111	8	7
Tricuspidal valve procedure	23	1	2	1	25	2	8
Repair	22	1	2	1	24	2	8
Implantation	1	0	0	0	1	0	0
Aortic + mitral valve implantation	25	2	0	0	25	2	8
Aortic valve implantation <sup>a</sup> + CABG	37	2	13	8	50	10	20
Mitral valve implantation <sup>b</sup> + CABG	1	0	1	1	2	1	50
Aortic + mitral valve + CABG	2	0	0	0	2	0	0
Total	10,494	361	166	57	10,660	418	4

Note: Pulmonary valve implantations for the correction of congenital lesions are not included; No procedure was reported for adults without congenital lesion. 25% of TAVI by transapical access; 1.5% of TAVI under use of ECC.

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

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

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**Table C1** Isolated/combined CABG with ECC

	N	†	%
Isolated CABG	38,601	1,057	2.7
+ Aortic valve replacement	7,214	396	5.5
+ Other	2,705	156	5.8
+ Mitral valve repair	1,711	132	7.7
+ Mitral valve replacement	918	134	14.6
+ Aortic valve replacement + mitral valve repair	318	40	12.6
+ Aortic + mitral valve replacement	286	59	20.6
+ Aneurysm resection	133	7	5.3
+ Transcatheter aortic valve implantation	50	10	20.0
+ TMLR	1	0	0.0
Total	51,937	1,991	3.8

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

Grafts (N)	with ECC			without ECC			All		
	N	†	%	N	†	%	N	†	%
Single	1,009	56	5.6	1,359	32	2.4	2,368	88	3.7
Double	6,840	236	3.5	1,755	33	1.9	8,595	269	3.1
Triple	14,353	388	2.7	2,185	38	1.7	16,538	426	2.6
Quadruple	7,776	206	2.6	847	7	0.8	8,623	213	2.5
Quintuple + more	2,273	60	2.6	204	1	0.5	2,477	61	2.5
Total	32,251	946	2.9	6,350	111	1.7	38,601	1,057	2.7

**Table Con1** Congenital heart surgery with/without ECC

Age (yrs)	N		†		%	
	with ECC	without ECC	with ECC	without ECC	with ECC	without ECC
<1	2,041	736	63	13	3.1	1.8
1–17	1,796	206	9	1	0.5	0.5
≥18	1,076	37	24	1	2.2	2.7
Total	4,913	979	96	15	2.0	1.5

**Table Con2** Lesions/procedures for CHD with and without ECC

Lesion/procedures	Age < 1 yr			Age 1–17 yrs			Age ≥ 18 yrs		
	N	†	%	N	†	%	N	†	%
ASD	33	0	0.0	254	1	0.4	246	4	1.6
Complete AV canal	183	2	1.1	88	1	1.1	10	1	10.0
VSD	305	0	0.0	86	0	0.0	25	2	8.0
Fallot's tetralogy	205	3	1.5	49	0	0.0	2	0	0.0
DORV	48	0	0.0	21	1	4.8	1	0	0.0
TGA	160	2	1.3	10	0	0.0	2	0	0.0
TGA + VSD	63	2	3.2	10	0	0.0	0	0	–

**Table Con2** (Continued)

Lesion/procedures	Age < 1 yr			Age 1–17 yrs			Age ≥ 18 yrs		
	N	†	%	N	†	%	N	†	%
Truncus arteriosus	38	3	7.9	7	0	0.0	0	0	–
Fontan	1	0	0.0	253	3	1.2	6	1	16.7
Norwood	146	20	13.7	1	0	0.0	0	0	–
Pulmonary valve	73	2	2.7	240	1	0.4	75	0	0.0
Transcatheter pulmonary valve implantation	0	–	–	4	0	0.0	17	0	0.0
Aortic valve	61	2	3.3	246	0	0.0	394	5	1.3
Ross procedure	7	1	14.3	21	0	0.0	29	0	0.0
Mitral valve	46	4	8.7	88	0	0.0	108	8	7.4
Tricuspid valve	95	1	1.1	59	0	0.0	62	2	3.2
PDA	225	3	1.3	26	1	3.8	2	0	0.0
Coarctation	218	4	1.8	39	0	0.0	7	0	0.0
Others	890	28	3.1	479	3	0.6	119	2	1.7
HTx	7	0	0.0	42	0	0.0	0	0	–
HLTx	0	–	–	0	0	–	0	0	–
LTx	0	–	–	9	0	0.0	0	0	–
Total	2,804	77	2.7	2,032	11	0.5	1,105	25	2.3

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

Age (y)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
<18	50	34	42	54	43	40	36	33	37	28
≥18	228	261	207	175	184	134	117	107	90	64
Total	278	295	249	229	227	174	153	140	127	92

**Table Mis2** Heart and lung transplantation

	with ECC			without ECC		
	N	†	%	N	†	%
HTx	283	38	13,4			
HLTx	2	0	0,0			
LTx	57	13	22,8	206	13	6,3

Eurotransplant (ET) report for 2015: 283 HTx, 1 HTx + kidneyTx, 0 HTx + liverTx, 2 HLTx, 262 DLTx, 27 SLTx, 0 LTx + kidneyTx and 4 LTx + liverTx.

**Table Mis3** Aortic surgery

Replacement <sup>a</sup>	with ECC			without ECC		
	N	†	%	N	†	%
Supracoronary replacement of ascending aorta	1,433	127	8.9			
Supracoronary ascending + aortic valve replacement	1,329	63	4.7			
Infracoronary ascending			–			
Mechanical valve conduits	508	36	7.1			
Biological valve conduits	989	109	11.0			
David procedure	514	8	1.6			

(Continued)



**Table Mis3** (Continued)

Replacement <sup>a</sup>	with ECC			without ECC		
	N	†	%	N	†	%
Yacoub procedure	89	3	3.4			
Other	279	23	8.2			
Aortic arch replacement <sup>b</sup>	1,977	271	13.7			
Replacement of descending aorta	56	4	7.1	8	0	0.0
Thoracoabdominal aortic replacement	86	10	11.6	24	4	16.7
Endostent descending aorta	5	0	0.0	625	53	8.5
Total	7,265	654	9.0	657	57	8.7

<sup>a</sup>Procedures for abdominal aortic diseases excluded: 549 abdominal procedures and 609 endovascular abdominal stents.

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

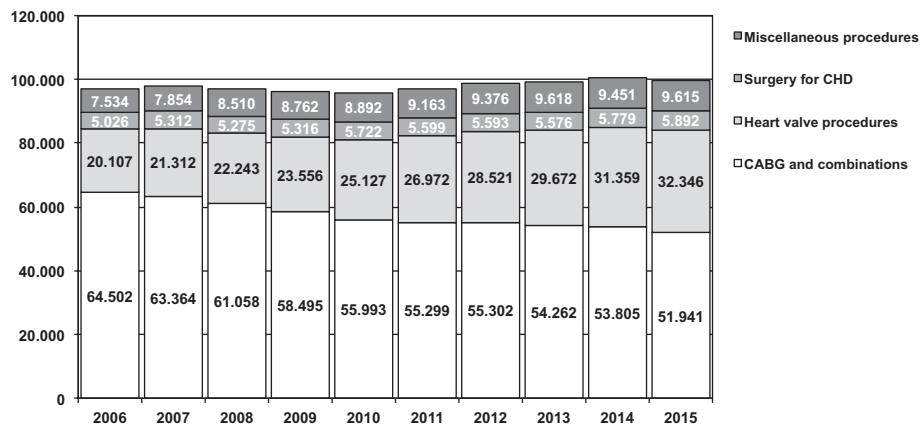
**Table Mis4** Pacemaker and ICD procedures

Device/category	N	†	%	with ECC		without ECC	
				N	†	N	†
Pacemaker	14,295	98	0.7	27	1	14,268	97
Implantation	9,337	68	0.7	8	1	9,329	67
Battery exchange	1,935	0	0.0	0	0	1,935	0
Revision	3,023	30	1.0	19	0	3,004	30
ICD	10,104	83	0.8	26	5	10,078	78
Implantation	4,673	19	0.4	0	0	4,673	19
Battery exchange	2,048	3	0.1	0	0	2,048	3
Revision	3,383	61	1.8	26	5	3,357	56
Miscellaneous	2,173	13	0.6	1	0	2,172	13
Total	26,572	194	0.7	54	6	26,518	188

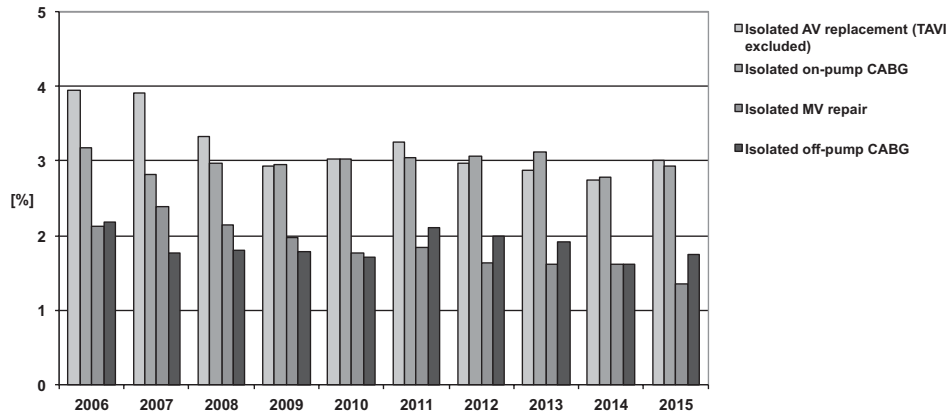
**Table Mis5** Surgical ablation therapy

Energy source	Total	Endocardiac	Epicardiac
		N	N
Unipolar radiofrequency	229	77	152
Unipolar cryoradiofrequency	254	122	132
Bipolar radiofrequency	2,306	309	1,997
Cryotherapy	1,606	1,340	266
Microwave	13	3	10
Focused ultrasound	66	7	59
Laser	9	1	8
Other	23	4	19
Total	4,506	1,863	2,643

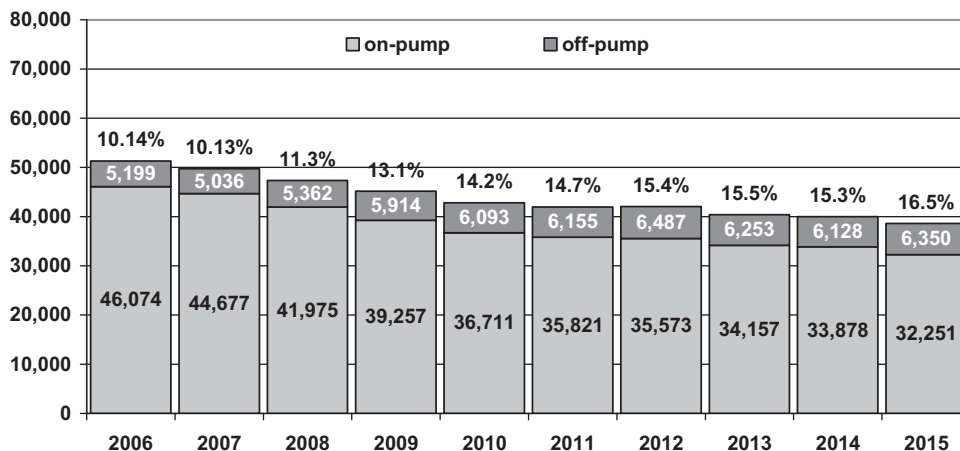
Note: 496 procedures unspecified with regard to endocardiac/epicardiac ablation.



**Fig. 1** Cardiac surgery in Germany (2006–2015). (1) Coronary artery bypass grafting (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: atrial septal defect repair 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 extracorporeal circulation.

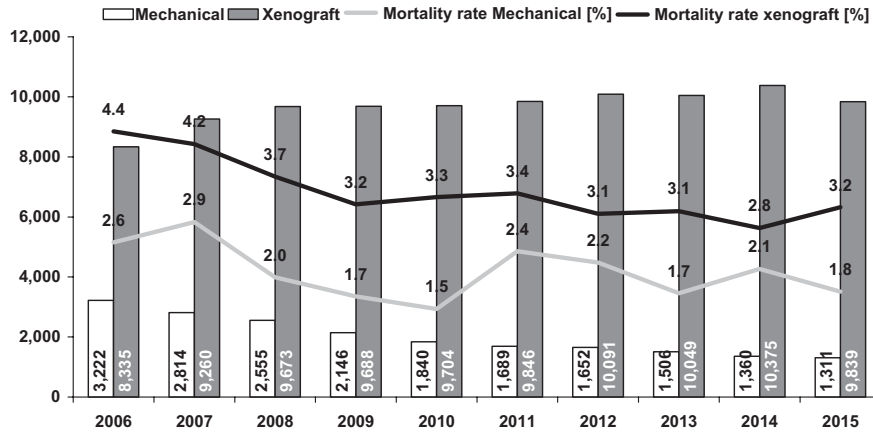


**Fig. 2** Unadjusted mortality for selected procedures (2006–2015).

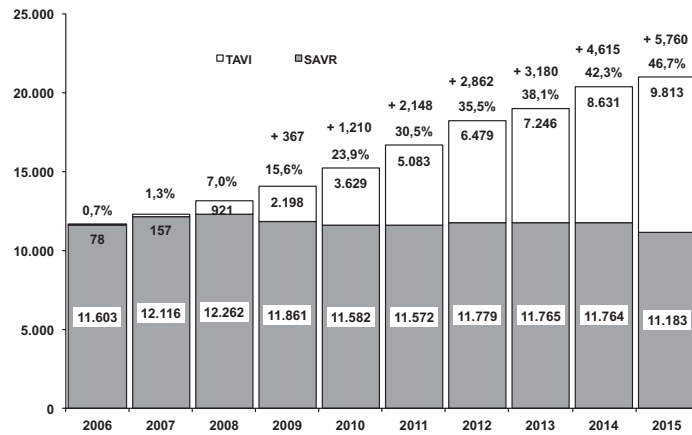


**Fig. 3** Isolated coronary artery bypass grafting (2006–2015).

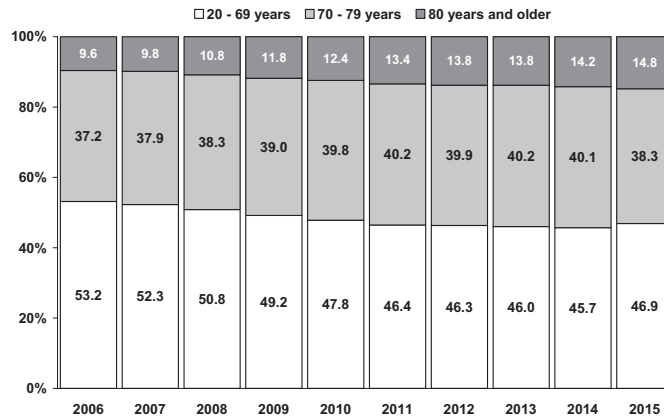
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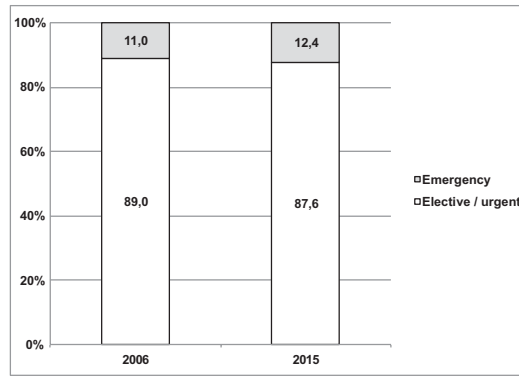
**Fig. 4** Isolated aortic valve replacement (2006–2015). Ross procedures, homograft implantations, and transcatheter aortic valve implantation excluded.



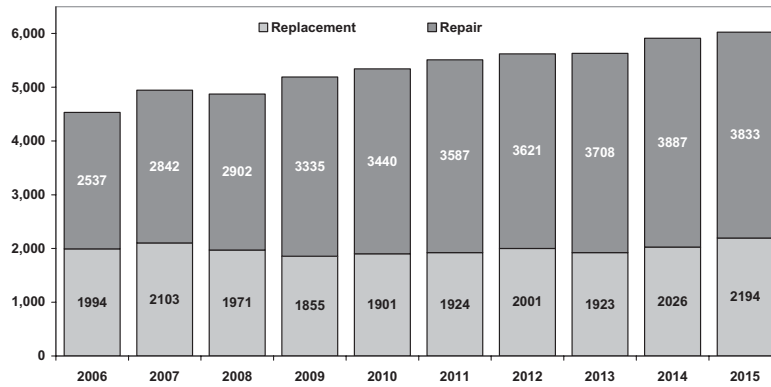
**Fig. 5** Isolated aortic valve replacement and transcatheter aortic valve implantation (TAVI). + Additional TAVI procedures calculated from the German legal quality assurance program (§137 SGB V).



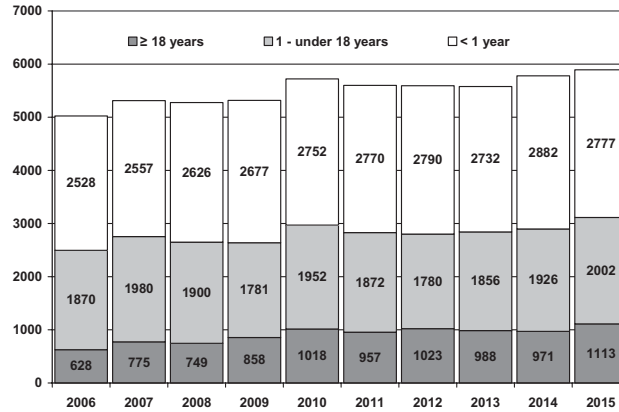
**Fig. 6** Age distribution of cardiac procedures (2006–2015). Patients < 20 years and pacemaker/implantable cardioverter defibrillator procedures excluded.



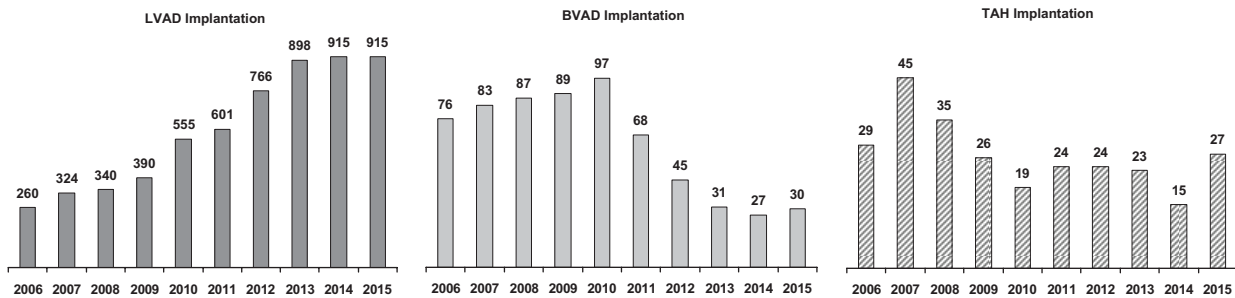
**Fig. 7** Urgency categories (2006 vs. 2015).  
Emergency = acutely life-threatening cardiac/vascular disease.



**Fig. 8** Isolated mitral valve surgery (2006–2015).



**Fig. 9** Age distribution for congenital heart surgery (2006–2015). Bias possible due to the fact that not all relevant procedures can be allocated exactly to the congenital heart disease category in patients older than 18 years (e.g., aortic valve disease).



**Fig. 10** Development of mechanical circulatory support (2006–2015).

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