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Original Article

The Incidence of Perioperative Stroke: Estimate Using State and National Databases and Systematic Review

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Background and Purpose Perioperative stroke remains a devastating complication after surgical procedures, due to hemodynamic and inflammatory changes that increase the risk of strokes within 30 days following surgery. We aimed to assess the incidence of perioperative strokes in patients undergoing various surgical procedures and reach a national estimate.

Methods A retrospective cohort study was conducted using California State Inpatient Databases, State Emergency Department Databases, State Ambulatory Surgery and Services Databases, and the National Inpatient Sample (NIS) during the period 2008 to 2011 from the Healthcare Cost and Utilization Project. A systematic review was conducted using PubMed, Embase, and Web of Science databases to obtain published articles that reported the incidence of perioperative stroke in various surgical procedures.

Results Analysis of 3,694,410 surgical encounters from the state of California (mean±standard deviation age: 52.4±21.1 years) yielded an overall rate of perioperative stroke of 0.32% (n=11,759). The incidence of perioperative strokes was highest following neurological (1.25%), vascular (1.07%), and cardiac (0.98%) surgeries. The NIS database contained a total of 48,672,974 weighted hospitalizations and yielded a rate of perioperative stroke of 0.42% (n=204,549). The systematic review completed yielded 187 articles, which had an overall sample size of 184,922 and an incidence of perioperative stroke ranging from 0% to 13.86%. It is estimated that in any given year, there would be approximately 40,000 to 55,000 (0.33% to 0.46%) perioperative strokes nationally.

Conclusions Our findings support further strategies to identify and stratify patients undergoing surgical procedures with a high incidence of perioperative strokes to improve patient counseling and a future potential treatment plan.

Keywords Stroke; Postoperative complications; Incidence; Surgery; Perioperative period

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Introduction

Perioperative stroke, a new neurological deficit that occurs during or within 30 days of surgery,[1] is a devastating complication because it is associated with significant clinical burden and mortality.[1-3] The vast majority of these strokes are ischemic, and about 1% to 4% are hemorrhagic.[2,4,5] The majority of the strokes (50%) occur within the first postoperative day.[3,6]

The incidence of perioperative stroke varies among different types of surgical procedures, as it ranges approximately from 1.9% to 9.7% in high-risk cardiovascular surgeries, e.g., coronary artery bypass grafting (CABG) surgeries have a perioperative stroke rate of 3% to 5%[7] compared to 0.1% to 1.9% in non-cardiovascular, non-neurological and minor vascular surgeries.[1,3,8] This variation in incidence is attributed to the surgical procedure itself as well as the associated risk factors and comorbidities.[2] The incidence of perioperative stroke has not changed over the past two decades despite an improvement in medical and surgical care.[2,9]

The primary objective of the present study was to estimate the national incidence of perioperative strokes in patients undergoing various surgical procedures. We achieved this objective through analysis of a state-wide database and stratifying included patients according to their comorbidities and demographic variables, including age, sex, and ethnicity. We further estimated the incidence of perioperative stroke with results from the National Inpatient Sample (NIS) database. Finally, we performed a systematic review for all published studies reporting the incidence of perioperative stroke following various surgical procedures; this review has helped to solidify the calculated estimate we have reached using our databases. We expect the results of the study to improve the recognition and diagnosis of perioperative stroke and patient safety, which will help us estimate the financial cost and burden of perioperative stroke, as well as, pave the road for optimizing therapeutic and preventive measures that could be implemented to minimize the incidence of perioperative stroke.

Methods

Data source

Informed consent was not required by the The Institutional Review Board (IRB) at our institution for this retrospectic cohory analysis. Data were obtained from the Healthcare Cost and Utilization Project (HCUP) including State Inpatient Databases (SID), State Emergency Department Databases (SEDD), and State Ambulatory Surgery and Services Databases (SASD) for the state of California, and NIS during the 2008 to 2011 period. The SID, SEDD, and SASD contain the universe of the inpatient, emergency department (ED) and outpatient unit discharge abstracts and a set of clinical and nonclinical information on about 97% of patients discharged from different medical facilities in California. We chose the California state databases as they contain present on admission (POA) indicator; which is defined as the conditions present when the inpatient admission occurs.[10] The POA indicator helps to differentiate strokes occurring in patients as a complication following surgery from those presented on admission with a stroke or history of stroke. The NIS contains data from all-payer inpatient health care in the United States, yielding national estimates of hospital inpatient stays.

Patient and surgical procedure selection

Patients in this study were those who underwent any surgical procedure from 2008 to 2011; this period was chosen because 2008 was one of the first years where the SID adopted using the POA indicators. The years 2010 and 2011 were chosen in Table 1 because claims databases tend to be very granular and improve yearly; therefore, presenting the most 2 recent years seemed most suited. Most patients undergoing any surgical procedure that did not require intubation and general anesthesia were excluded. Patients were identified according to their primary diagnosis, surgical procedure and comorbid risk factors using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) and the Clinical Classification Software (CCS) which is a uniform and standardized coding system, that collapses the vast multitude of codes found in the ICD-9 into a smaller number of clinically meaningful categories.

Each specific surgical subcategory in Table 2 reflects one ICD-9 code for one or more surgical procedure and intervention, the specific surgical procedure(s) for each subcategory are shown in Supplementary Table 1. The ICD-9 codes for the five subcategories were selected according to the combined highest procedure frequency, stroke number, and stroke incidence. Supplementary Tables 2-4 show the highest 100 surgical subcategories according to procedure frequency, stroke number, and stroke incidence respectively. Any results showing single digit number of cases were replaced by "*" to maintain patient privacy.

Covariates

The patients were identified into different categories according to hospital-level covariables, including age, sex, ethnicity, and specific comorbidities. Surgical procedures were stratified into 15 surgical categories according to the system involved. The age sub-groups were separated starting from 0 to 17 years, and from 18 to 25 years and every 5 years after that. Patients who suffered from perioperative stroke were identified according to the presence of at least one ICD-9 codes shown in Supplementary Table 5.

Table 1. The incidence of perioperative stroke during 2010 to 2011 for both genders according to different age groups and races

Variable	Male		Female		Overall (n=2,537,251) (2008–2011)	NIS (n=48,672,974) (2008–2011)
	2010	2011	2010	2011		
Age group (yr)						
0–17	24 (0.20)	23 (0.21)	20 (0.23)	14 (0.17)	196 (0.15)	3,479 (0.06)
18–25	12 (0.13)	18 (0.19)	13 (0.13)	11 (0.11)	121 (0.04)	1,845 (0.04)
26–30	14 (0.19)	* (0.112)	16 (0.19)	15 (0.18)	127 (0.05)	1,672 (0.05)
31–35	19 (0.23)	17 (0.20)	* (0.09)	10 (0.11)	122 (0.04)	2,082 (0.06)
36–40	27 (0.25)	23 (0.225)	20 (0.17)	13 (0.11)	180 (0.08)	3,184 (0.12)
41–45	43 (0.28)	36 (0.24)	30 (0.20)	49 (0.33)	322 (0.16)	4,725 (0.22)
46–50	71 (0.31)	75 (0.33)	66 (0.30)	51 (0.24)	489 (0.19)	8,020 (0.29)
51–55	95 (0.32)	85 (0.28)	77 (0.28)	91 (0.33)	717 (0.27)	11,730 (0.36)
56–60	147 (0.43)	127 (0.36)	121 (0.39)	106 (0.34)	975 (0.34)	15,541 (0.44)
61–65	171 (0.48)	157 (0.43)	128 (0.37)	142 (0.40)	1,167 (0.39)	19,856 (0.53)
66–70	200 (0.58)	170 (0.48)	173 (0.49)	177 (0.49)	1,390 (0.47)	21,832 (0.58)
71–75	201 (0.66)	196 (0.64)	193 (0.59)	191 (0.58)	1,501 (0.56)	22,723 (0.69)
76–80	195 (0.74)	218 (0.83)	210 (0.69)	220 (0.73)	1,681 (0.68)	23,068 (0.79)
81–85	150 (0.75)	173 (0.88)	203 (0.76)	202 (0.79)	1,455 (0.75)	19,372 (0.87)
86–90	109 (0.84)	107 (0.82)	157 (0.82)	176 (0.91)	1,067 (0.82)	11,272 (0.89)
91–95	20 (0.95)	20 (0.86)	39 (0.82)	37 (0.75)	220 (0.79)	3,328 (0.89)
96–100	* (1.92)	* (0.47)	* (0.94)	* (0.66)	25 (0.68)	495 (0.68)
Total†	1,502 (0.48)	1,454 (0.46)	1,481 (0.45)	1,510 (0.46)	11,755 (0.32)	174,287 (0.35)
Race						
White	874 (0.46)	827 (0.44)	881 (0.44)	883 (0.45)	6,889 (0.35)	107,795 (0.38)
Black	98 (0.52)	90 (0.47)	101 (0.45)	118 (0.51)	813 (0.35)	20,008 (0.39)
Hispanic	296 (0.47)	272 (0.42)	264 (0.41)	282 (0.42)	2,162 (0.26)	11,417 (0.24)
Asian or Pacific Islander	155 (0.83)	173 (0.89)	161 (0.76)	148 (0.69)	1,181 (0.45)	3,922 (0.34)
Native American	0 (0)	0 (0)	0 (0)	* (1.04)	* (0.23)	864 (0.31)
Other	33 (0.58)	44 (0.68)	25 (0.48)	42 (0.68)	275 (0.38)	4,763 (0.32)
Total†	1,456 (0.49)	1,406 (0.47)	1,432 (0.45)	1,475 (0.47)	11,327 (0.33)	148,768 (0.36)

Values are presented as number (%). The overall incidence during 2008 to 2011 for the same age groups and races for California state (State Inpatient Databases [SID], State Emergency Department Databases [SEDD], and State Ambulatory Surgery and Services Databases [SASD] databases; n=2,537,251) and National Inpatient Sample (NIS) databases (n=48,672,974).
*Any results showing numbers less than 10 patients to maintain patient privacy; †In the data obtained, some patients had the age and race information reported as missing, which resulted in different totals in both categories.

Outcomes

The primary outcome of the present study is strokes that occurred within 30 days of surgical procedures that require intubation and general anesthesia.

Systematic review

A systematic review was conducted on the incidence of perioperative stroke after surgical procedures. It complied with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The search criteria, inclusion and exclusion criteria, detailed data extraction information, and PRISMA flowchart, are found in Supplementary Material, Supplementary Table 6, and Supplementary Figure 1.

PubMed, EMBASE, and Web of Science were used as the search databases for relevant literature. Two researchers (R.A. and E.J.) independently conducted the study search, and a third researcher (K.A.) settled any disagreements.

Statistical analysis

Dataset construction and analysis were done using the SAS program version 9.4 (SAS Institute Inc., Cary, NC, USA). Data in each year from 2008 to 2011 were merged into a shared database. Patient records were linked and tracked using VisitLink and DaysToEvents variables provided by HCUP. For patients

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Table 2. The incidence of perioperative stroke for the state of California in different surgical categories

Surgical category	Male		Female		Overall (2008–2011)
	2010	2011	2010	2011	
Neurosurgery	225 (1.34)	216 (1.31)	190 (1.42)	188 (1.50)	1,594 (1.25)
Ventricular shunt to extracranial site	* (1.85)	* (2.99)	* (8.00)	* (10.91)	23 (5.65)
Craniotomy and craniectomy; reopening of craniotomy site	* (6.25)	* (4.65)	* (12.82)	0 (0)	18 (5.49)
Other incision of brain	14 (4.08)	29 (7.32)	14 (5.74)	14 (5.24)	138 (5.25)
Other craniectomy	* (4.55)	12 (8.05)	* (6.20)	* (2.13)	46 (4.56)
Incision of cerebral meninges	65 (3.62)	47 (2.60)	34 (3.90)	36 (4.12)	357 (3.27)
Cardiac	446 (0.90)	434 (0.92)	292 (1.24)	320 (1.43)	2,871 (0.98)
Insertion of implantable heart assist system	* (4.44)	* (3.45)	* (11.11)	* (11.76)	27 (5.7)
Open heart valvuloplasty of aortic valve without replacement	* (3.97)	* (4.67)	* (8.00)	* (6.41)	31 (4.22)
Open and other replacement of aortic valve with tissue graft	65 (2.49)	60 (2.21)	41 (2.79)	46 (3.03)	416 (2.61)
Implant of pulsation balloon	24 (1.98)	29 (2.25)	14 (2.55)	* (1.33)	151 (2.18)
(Aorto)coronary bypass of three coronary arteries	47 (1.83)	43 (1.75)	17 (2.32)	16 (2.25)	238 (1.78)
Vascular	369 (0.91)	367 (0.91)	443 (1.28)	431 (1.26)	3,170 (1.07)
Endovascular removal of obstruction from head and neck vessel(s)	27 (17.88)	25 (18.25)	34 (26.56)	36 (24.49)	171 (18.47)
Extracranial-intracranial vascular bypass	* (20.69)	* (0.09)	* (15.00)	10 (15.87)	60 (13.82)
Clipping of aneurysm	17 (8.37)	21 (11.23)	51 (10.30)	47 (9.44)	294 (10.29)
Endarterectomy; other vessels of head and neck	56 (1.45)	59 (1.59)	49 (1.86)	57 (2.31)	433 (1.59)
Percutaneous transluminal coronary angioplasty	111 (0.39)	109 (0.41)	81 (0.63)	103 (0.86)	761 (0.46)
Organ transplant	10 (1.72)	10 (1.63)	* (2.56)	11 (2.94)	74 (1.90)
Heart transplantation	* (3.47)	* (4.29)	* (1.79)	* (7.94)	31 (3.51)
Combined heart-lung transplantation	0 (0)	0 (0)	0 (0)	0 (0)	* (3.3)
Bilateral lung transplantation	* (1.82)	* (1.69)	* (4.17)	* (1.82)	* (1.58)
Other transplant of liver	* (1.25)	* (0.60)	* (3.19)	* (1.97)	31 (1.48)
Pancreatic transplant, not otherwise specified	0 (0)	0 (0)	0 (0)	0 (0)	* (1.79)
Respiratory/Thoracic	61 (0.43)	48 (0.33)	54 (0.42)	68 (0.52)	428 (0.39)
Reopening of recent thoracotomy site	0 (0)	0 (0)	* (13.33)	* (7.14)	* (2.78)
Other and unspecified pneumonectomy	* (3.03)	0 (0)	* (2.99)	* (3.92)	* (1.55)
Other lobectomy of lung	* (0.55)	* (0.45)	* (0.75)	* (0.38)	37 (0.57)
Decortication of lung	* (0.39)	* (0.39)	* (0.44)	* (0.48)	15 (0.48)
Thoracoscopic excision of lesion or tissue of lung	* (0.44)	* (0.27)	* (0.36)	* (0.54)	31 (0.37)
Endocrine	12 (0.45)	13 (0.52)	22 (0.29)	14 (0.20)	109 (0.25)
Partial excision of pituitary gland, transfrontal approach	* (12.50)	* (6.06)	* (21.43)	* (9.52)	25 (10.16)
Partial excision of pineal gland	0 (0)	* (33.33)	* (16.67)	0 (0)	* (3.13)
Division of thyroid isthmus	0 (0)	0 (0)	* (33.33)	0 (0)	* (3.77)
Unilateral adrenalectomy	* (0.57)	0 (0)	* (0.40)	* (0.38)	* (0.33)
Complete thyroidectomy	* (0.14)	0 (0)	* (0.03)	* (0.04)	* (0.04)
Gastrointestinal	153 (0.23)	119 (0.18)	168 (0.20)	178 (0.21)	1,193 (0.19)
Open total intra-abdominal colectomy	* (0.40)	* (0.36)	* (1.44)	* (0.77)	17 (0.98)
Open and other left hemicolectomy	* (0.56)	* (1.11)	* (1.03)	* (0.79)	56 (0.83)
Exploratory laparotomy	* (0.35)	* (0.38)	* (0.81)	* (0.98)	28 (0.64)
Other partial resection of small intestine	13 (0.56)	14 (0.61)	16 (0.58)	21 (0.73)	121 (0.61)
Cholecystectomy	13 (0.61)	* (0.34)	* (0.29)	* (0.15)	57 (0.32)

Table 2. Continued

Surgical category	Male		Female		Overall (2008–2011)
	2010	2011	2010	2011	
Ophthalmic	* (25)	* (0.09)	* (0.13)	0 (0)	12 (0.15)
Other removal or destruction of corneal lesion	* (100.00)	0 (0)	0 (0)	0 (0)	* (9.9)
Other extracapsular extraction of lens	0 (0)	(0)	0 (0)	0 (0)	* (4.17)
Other repair of retinal detachment	* (10.00)	(0)	0 (0)	0 (0)	* (2.78)
Other operations on vitreous	0 (0)	(0)	0 (0)	0 (0)	* (1.67)
Suture of corneal laceration	0 (0)	(0)	0 (0)	0 (0)	* (0.36)
Blood/Lymphatic	* (0.24)	* (0.26)	11 (0.17)	16 (0.27)	88 (0.24)
Total splenectomy	* (0.19)	* (0.56)	* (0.96)	* (0.68)	23 (0.56)
Radical excision of periaortic lymph nodes	0 (0)	0 (0)	* (0.64)	(0)	* (0.55)
Biopsy of lymphatic structure	* (0.031)	* (0.20)	* (0.24)	* (0.38)	36 (0.34)
Radical neck dissection, unilateral	* (0.45)	* (0.15)	0 (0)	* (0.61)	10 (0.24)
Excision of axillary lymph node	0 (0)	0 (0)	0 (0)	* (0.05)	* (0.02)
Musculoskeletal	180 (0.19)	185 (0.19)	257 (0.22)	248 (0.21)	1,719 (0.20)
Amputation above knee	* (0.60)	* (0.58)	* (1.50)	* (1.29)	53 (1.06)
Atlas-axis spinal fusion	* (1.37)	* (0.78)	* (0.60)	* (0.61)	11 (0.92)
Other amputation below knee	* (0.50)	13 (0.87)	11 (1.72)	* (0.92)	66 (0.75)
Partial hip replacement	21 (0.77)	22 (0.82)	51 (0.80)	36 (0.57)	250 (0.68)
Open reduction of fracture with internal fixation; femur	19 (0.45)	28 (0.66)	39 (0.47)	38 (0.46)	275 (0.54)
Urology	24 (0.18)	38 (0.29)	22 (0.20)	17 (0.16)	214 (0.22)
Nephroureterectomy	* (0.24)	* (0.30)	* (0.35)	* (0.25)	45 (0.27)
Percutaneous nephrostomy without fragmentation	* (0.25)	* (0.40)	* (0.37)	* (0.33)	41 (0.41)
Radical cystectomy	* (0.46)	* (0.47)	* (0.92)	0 (0)	14 (0.45)
Other transurethral excision or destruction of lesion or tissue of bladder	* (0.16)	* (0.22)	* (0.65)	0 (0)	28 (0.28)
Control of (postoperative) hemorrhage of bladder	* (0.82)	* (3.57)	0 (0)	0 (0)	* (0.96)
Reproductive male	12 (0.06)	22 (0.10)	0 (0)	0 (0)	66 (0.08)
Other transurethral prostatectomy	* (0.08)	11 (20)	0 (0)	0 (0)	33 (0.13)
Control of (postoperative) hemorrhage of prostate	* (1.69)	* (0.81)	0 (0)	0 (0)	* (0.89)
Radical prostatectomy	* (0.05)	* (0.07)	0 (0)	0 (0)	12 (0.04)
Unilateral orchiectomy	0 (0)	* (0.31)	0 (0)	0 (0)	* (0.7)
Removal of both testes at same operative episode	0 (0)	0 (0)	0 (0)	0 (0)	* (0.56)
OBGYN	0 (0)	0 (0)	30 (0.01)	21 (0.01)	110 (0.01)
Low cervical cesarean section	0 (0)	0 (0)	11 (0.01)	10 (0.01)	41 (0.01)
Other and unspecified total abdominal hysterectomy	0 (0)	0 (0)	* (0.06)	* (0.02)	27 (0.04)
Other removal of both ovaries and tubes at same operative episode	0 (0)	0 (0)	(0)	* (0.13)	* (0.11)
Laparoscopic total abdominal hysterectomy	0 (0)	0 (0)	* (0.03)	* (0.04)	* (0.03)
Classical cesarean section	0 (0)	0 (0)	* (0.12)	0 (0)	* (0.6)
Breast and skin	* (0.019)	* (0.19)	* (0.05)	11 (0.10)	52 (0.08)
Fat graft of skin and subcutaneous tissue	0 (0)	* (3.23)	0 (0)	* (2.17)	* (2.06)
Bilateral simple mastectomy	0 (0)	0 (0)	0 (0)	* (0.34)	* (0.8)
Removal of implant of breast	0 (0)	0 (0)	0 (0)	0 (0)	* (0.8)
Other free skin graft to other sites	* (0.27)	* (0.17)	* (0.47)	* (0.15)	15 (0.21)
Homograft to skin	* (0.56)	0 (0)	0 (0)	0 (0)	* (0.34)

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Table 2. Continued

Surgical category	Male		Female		Overall (2008–2011)
	2010	2011	2010	2011	
ENT	* (0.12)	* (0.18)	* (0.17)	* (0.22)	59 (0.15)
Sphenoidectomy	0 (0)	* (5.00)	* (3.85)	0 (0)	* (4.37)
Incision of multiple nasal sinuses	0 (0)	* (25.00)	0 (0)	0 (0)	* (4.35)
Sphenoidotomy	0 (0)	0 (0)	0 (0)	0 (0)	* (3.31)
Control of epistaxis by ligation of ethmoidal arteries	0 (0)	0 (0)	0 (0)	0 (0)	* (2.7)
Ethmoidectomy	* (1.37)	0 (0)	0 (0)	* (1.54)	* (0.62)

Values are presented as number (%). The incidence of perioperative stroke for the state of California in different surgical categories with five subcategories that had the combined highest procedure frequency, stroke number, and stroke incidence according to their International Classification of Diseases, Ninth Revision (ICD-9) codes in 2010 and 2011 for both sexes, as well as their incidence during 2008 to 2011.
OBGYN, obstetrics and gynecology; ENT, ear, nose, throat.
*Any results showing numbers less than 10 patients to maintain patient privacy.

with multiple admissions and surgeries, only the first record was considered for analysis. The cases that were lacking values for age, gender, and race were not excluded in our final dataset as they composed a sizable portion of the data. Descriptive data characteristics were presented as mean±standard deviation or as a number of cases with their percentages.

CCS codes available on the HCUP website were used to group surgical procedures into different categories. ICD-9 procedural codes were used for surgical subgroup analysis. We created an array that searches through every record's diagnoses variable 2 to 25 with negative POA variable. The negative POA variable helps us differentiate between cases of stroke developing during the inpatient hospital stay and cases of stroke that was present at the time of admission, and therefore, eliminating the latter. We performed univariate analyses using an unpaired t-test for continuous variables and Pearson's chi-square test for categorical variables.

The HCUP uses databases as samples used to represent a larger universe. To generate a national estimate using the NIS database, a process called data weighting must be performed on the discharge or hospital weights from unweighted counts,[11] which was performed and stratified using the strata variable provided by HCUP. NIS databases do not contain the POA variable, which made it impossible to identify cases of stroke that happened before the studied surgical admission.

Results

Patient characteristics

California state database

A total of 3,694,410 patients who underwent various surgical procedures during 2008 to 2011 were identified from the SID, SASD, and SEDD. In the present dataset, 63.21% of the cases were females (n=2,267,321) with cases missing values for gender (n=107,537, 2.91%), the largest age and racial groups were those between 61 to 65 years of age 8.21% (n=300,779) and white 58.44% (n=1,991,270) with cases missing values for age (n=31,294, 0.85%) and race (n=287,191, 7.77%).

Patients who suffered from a perioperative stroke were older (67.6±16.7 years vs. 52.4±21.1 years) and more likely to be females (50.9%, P<0.01). However, the incidence of perioperative stroke was higher in males (0.44% vs. 0.26%) because of the high number of obstetrics and gynecology (OBGYN) surgeries that had a low total incidence of perioperative stroke (Table 2). The most prevalent comorbidities in patients from this dataset were hypertension (n=1,445,794, 39.13%), iron deficiency anemia (n=571,964, 15.48%), and uncomplicated diabetes (n=457,844, 12.39%).

NIS database

From the NIS database, a total of 48,672,974 weighted hospitalizations were obtained during 2008 to 2011, 58.0% of the cases were females (n=27,984,592), and the largest age and racial groups were those between 0 to 17 years of age 11.71% (n=5,701,621) and white 69.1% (n=28,643,738), while cases missing values for race comprised a proportion of the cohort, we were not able to obtain the number of those missing cases after data weighting. The patients who suffered from a perioperative stroke were older (65.1±17.5 years vs. 47.4±24.9 years), and the incidence of perioperative stroke was higher in males (0.43% vs. 0.31%).

Systematic review

The systematic review performed, without a meta-analysis, yielded 187 papers, with a total cohort of 184,922 patients. The highest three countries that had the most published papers

in our search were United State (58 papers, 75,456 patients), Italy (23 papers, 15,703 patients), and Germany (21 papers, 11,814 patients). From the 58 papers published in the United States, there were 57 papers on cardiovascular procedures and one paper on noncardiovascular procedures.

Incidence of perioperative stroke

California state database results

The 30-day stroke incidence was 0.32% (n=11,759) in all surgical procedures in this database. The majority of patients suffered from perioperative stroke during the same surgical hospitalization (86.38%, n=10,157), while the rest (13.62%, n =1,602) occurred as a readmission within the 30-day postoperative period after discharge, or as a visit to the ED or as a visit to an observation unit in an outpatient setting.

The incidence of perioperative stroke in the state of California during 2010 to 2011 for each gender according to different age groups and races, as well as the overall incidence through 2008 to 2011 for age and race using the dataset for the state of California and the NIS are shown in Table 1. For incidence calculation and comparison between the two genders in Table 1, OBGYN and male reproductive surgeries were excluded, resulting in 2,537,251 patients in 2008 to 2011. The incidence of perioperative stroke rises significantly after the age of 40 in both genders (Table 1). However, the incidence was markedly higher in patients younger than 17 years old—compared to the following older age groups—in both genders in 2010 to 2011 with an incidence of 0.15% (n=196) in that age group. Among race groups, perioperative stroke was highest among Asian and Pacific Islander in both genders in 2010 to 2011 with an incidence of 0.45% (n=1,181).

Surgical procedures with the highest incidence of perioperative strokes in the state of California for different age groups during 2008 to 2011 are shown in Figure 1. It shows that neurosurgical and cardiac procedures have the highest perioperative stroke incidence in age groups between 65 to 95 years old, neurosurgery peaking at 2.19% in the age group of 86 to 90 years and cardiac surgery peaking at 2.5% in the age group of 91 to 95 years. Meanwhile, organ transplant procedures were the highest in almost all age groups younger than 65 years, peaking at 4.17% in the age group of 36 to 40 years. The incidence of perioperative stroke in all surgical procedures peaked at 0.82% in the age group of 86 to 90 years, while it had an apparent increase starting at the age of 40.

The incidence of perioperative stroke in the state of California during 2010 to 2011 according to the surgical procedure for each gender, as well as the overall incidence during 2008 to 2011, are shown in Table 2. The surgical categories with the highest overall incidence of perioperative stroke were organ transplant surgeries 1.9% (n=74) followed by neurosurgeries 1.25% (n=1,594) and vascular surgeries 1.07% (n=3,170).

The incidence of perioperative stroke in patients with different comorbidities in the state of California during 2008 to 2011, as

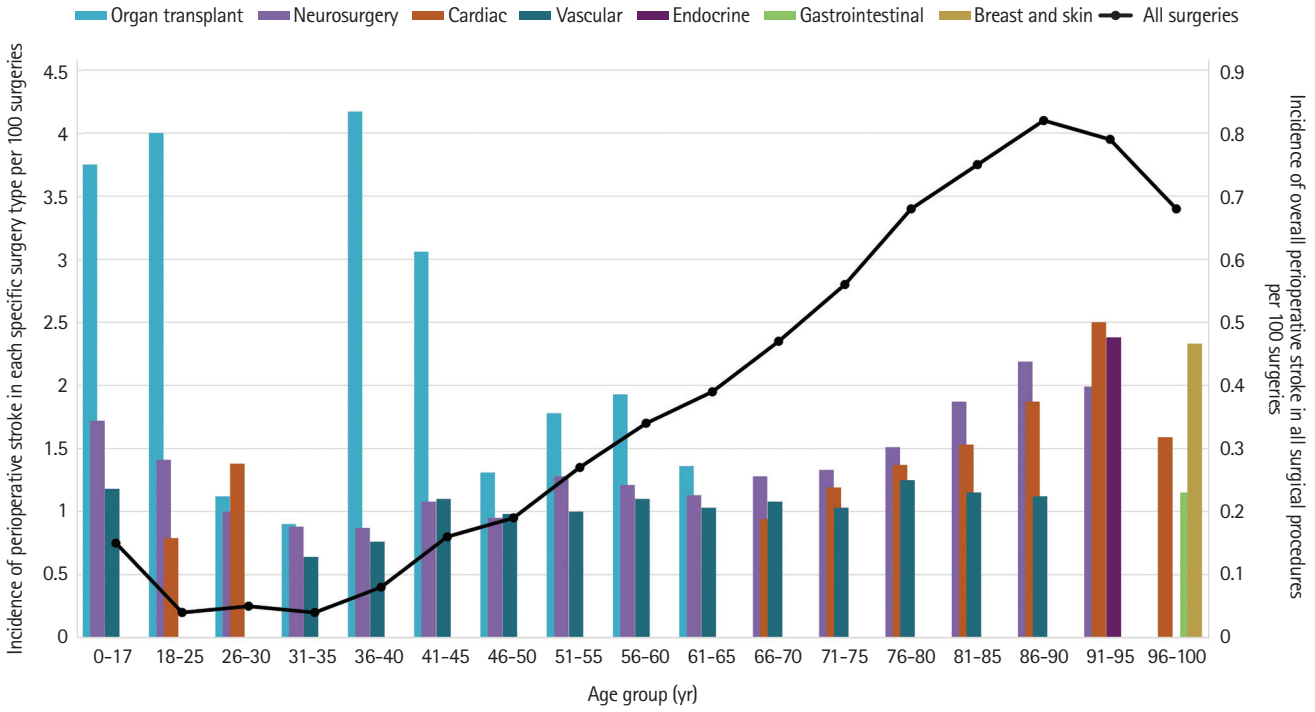

Figure 1. The overall Incidence of perioperative stroke according to different age groups and the highest three surgical categories in each age group.

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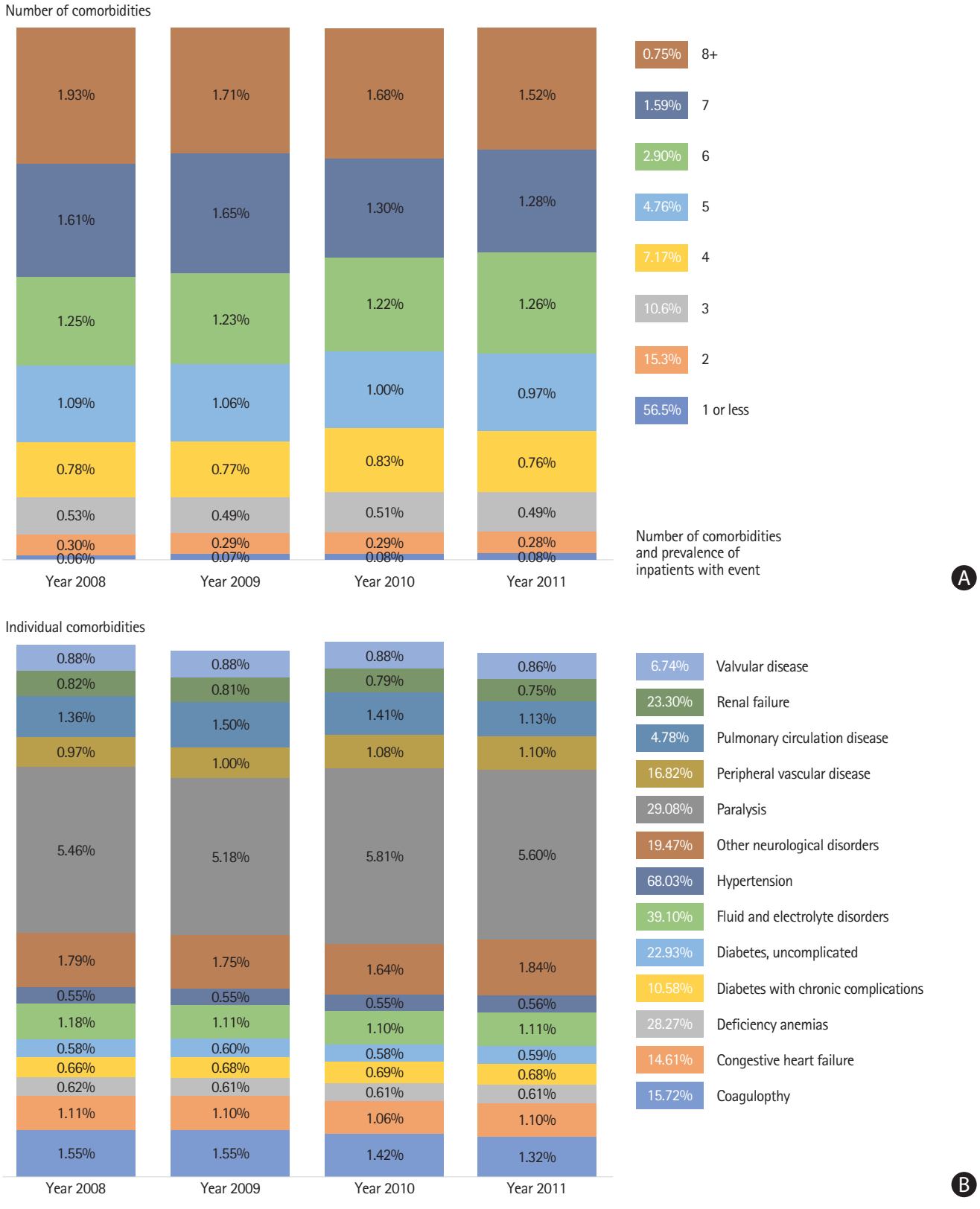

Figure 2. Associated comorbidities in patients who suffered from a perioperative stroke in the state of California during 2008 to 2011. (A) The association between the number of comorbidities and the incidence of perioperative stroke, as well as the prevalence of the count of comorbidities in patients who suffered from a perioperative stroke. (B) The incidence of perioperative stroke with different comorbidities and the prevalence of those comorbidities in patients who suffered from a perioperative stroke.

well as the prevalence of those comorbidities in patients who suffered from a perioperative stroke, are shown in Figure 2. Correlation between the number of comorbidities and the incidence of perioperative stroke is shown in Figure 2A, as patients who had increasing numbers of comorbidities, had a higher incidence of perioperative stroke. It also shows that 56.5% of patients who suffered from perioperative stroke had one comorbidity or less. Specific comorbidities shown in Figure 2B, demonstrate that patients who had paralysis or other neurologic disorders had the highest incidence of perioperative stroke that ranges between 5.18% to 5.81% and 1.64% to 1.84% respectively. It also shows that hypertension (68.03%, n=8,000), fluid and electrolyte disorders (39.10%, n=4,598), and paralysis (29.08%, n=3,419) were the most prevalent comorbidities in patients who suffered from a perioperative stroke.

NIS database results

The overall incidence of inpatient perioperative stroke from the NIS is 0.42% (n=204,549), results from the NIS in Table 1 shows a similar pattern to the California state database with slightly higher incidences in age groups older than 40. However, the youngest age group (0 to 17 years) did not show a significantly higher perioperative stroke incidence compared to the older age groups.

Systematic review

From our systematic review, 187 articles were qualified for data extraction and yielded an overall cohort sample size of 184,922 as shown in Table 3, detailed information about the search results can be found in Supplementary Material and Supplementary Table 6.

Studies that provided information about perioperative strokes occurring in cardiovascular and non-cardiovascular procedures, comprised a cohort of 145,714 and 39,208 patients and the perioperative stroke incidence and stroke number ranged from 0% to 13.86% (n=0–214; total=2,342) and 0% to 1.05% (n=0–123; total=233), respectively.

Table 3. Characteristics of systematic review results according to surgical procedure type

Surgery	Sample size	No. of studies	No. of strokes
Non-cardiovascular*	39,208	10	233
Cardiovascular	145,714	178	2,342
Cardiac surgeries	78,233	82	1,555
CABG	56,414	49	1,035
Valvular heart surgery	4,100	12	86
Surgical ablation for atrial fibrillation	1,814	6	14
Other cardiac surgery	15,905	15	420
Carotid surgeries	64,879	87	756
Carotid artery stenting	3,984	12	76
CEA	59,528	70	651
Other carotid surgeries	1,367	5	22
Aortic surgeries	787	6	22
Other peripheral vascular surgeries	1,815	3	9
All surgeries	184,922	188	2,575

CABG, coronary artery bypass grafting; CEA, carotid endarterectomy.
*Detailed list can be found in Supplementary Table 6.

Estimation

In the state of California during the year 2011, our databases showed that there had been 911,126 surgical procedures performed, and had an incidence of perioperative stroke of 0.33%. Nationally during the same year, the NIS showed that there had been 11,934,162 surgical procedures performed, and had a 0.46% incidence of perioperative stroke. Using our databases from the state of California and the NIS, it can be estimated that in any given year there would be approximately 40,000 to 55,000 perioperative strokes nationally, and its incidence would be close to 0.33% to 0.46% and that constitutes of approximately 6.25% of all strokes that happen in the USA every year.[12]

In the state of California during the year 2011 as well, our databases showed that there had been 11,534 CABG and 6,301 carotid endarterectomies (CEAs) performed and had an incidence of perioperative stroke of 1.53% and 1.56%, respectively. Nationally during the same year, the NIS showed that there had been 163,864 CABG and 98,626 CEA surgeries performed and had an incidence of perioperative stroke of 1.76% and 3.04% respectively. In the systematic review performed, studies that reported the incidence of perioperative stroke in CABG and CEA in the United States ranged from 0% to 7.69% in 14 papers (cohort=27,173 patients) and 0% to 4.16% in 22 papers (cohort=32,116) respectively. It can be estimated that in any given year, there would be approximately 2,500 to 3,000 and 1,000 to 3000 perioperative strokes nationally that result from CABG and CEA, respectively.

Discussion

Our study identifies the incidence of perioperative stroke according to the surgical procedure performed as well as gender, age, and race of patients using various databases from the HCUP from 2008 to 2011. A systematic review of the literature was also performed to identify the incidences of perioperative stroke in the United States and other countries published between the years 1980 to 2017. Most perioperative strokes from

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the HCUP in the present study (86.3%) occurred during the same surgical hospitalization in agreement with other studies that reported the occurrence of perioperative stroke during the first postoperative week.[6] The NIS database during 2008 to 2011 included 48,672,974 weighted hospitalizations, resulted in an overall incidence of perioperative stroke of 0.42%. Results from the state of California and NIS showed similar results according to the incidence of perioperative stroke. There have been no noticeable trends over the incidence of perioperative stroke during the years our data was obtained from, although the incidence of stroke in the general population has been decreasing over the past 20 years due to improvement in blood pressure control and a decrease in smoking prevalence.[13]

The results reported from the analysis of our data are consistent with other previous studies, which reported that the overall incidence of perioperative stroke in various surgical procedures ranged between 0.2% and 0.7%.[14-17] Female gender and advanced age have been consistently reported as a risk factor for perioperative stroke; as our California population cohort showed that patients who suffered from perioperative stroke were older (67.6±16.7 years vs. 52.4±21.1 years).[2,17] The overall incidence of perioperative stroke started increasing after the 4th decade significantly (Figure 1). However, the higher incidence of perioperative stroke in the age group of 0 to 17 years can be explained by the increased rates of certain surgical procedures in pediatrics. Congenital defects that involve the heart and central nervous system would put this age group under surgical procedures that have an increased risk for perioperative stroke.[18,19]

Our systematic review showed that the incidence and number of perioperative stroke to be higher in Cardiovascular procedures than non-cardiovascular procedures ranging from 0% to 13.86% (n=0–214; 177 papers) and 0% to 1.05% (n=0–123; 10 papers), respectively. In cardiovascular procedures, most literature had a focus on CEA, CABG, and valvular procedures, with no specific trend or change in the incidence of perioperative stroke in the United States in these or any other surgical procedures over time. Somatosensory evoked potential is mainly used in CEAs to detect and diagnose perioperative strokes.[20] Many studies reported that the incidence of perioperative stroke in procedures like CABG and valvular heart surgeries had higher incidences than carotid surgeries, this could mean that intraoperative monitoring might need to be broadened to include further surgical procedures in order to prevent and manage perioperative strokes.

The different incidences in each surgical procedures can be accounted for various pathophysiologic pathways. Surgical procedures can cause hemodynamic and inflammatory changes that increase the risk of stroke.[3,8] It has been estimated that embolic events cause more than 60% of perioperative strokes, followed by unknown causes (13.9%), a synergistic effect from hypotension, hypoperfusion and formation of microemboli together (10%), hypoperfusion (9%), hemorrhagic strokes (1%), and the remaining 20% is distributed between other minor and unknown causes.[3,6,21] Surgery also has been known to amplify the inflammatory pathways which can initiate or exacerbate cerebral ischemic injury.[3,9] Perioperative hemorrhagic strokes have been linked to sudden surges of cerebral perfusion; revascularization procedures; for example, can lead to cerebral hyperperfusion syndrome that causes acute neurological deficits.[21] Solid organ transplant surgeries have been previously reported to be associated with different neurological complications; stroke specifically was found to be the most common neurologic complication within the first 30 days after transplant, especially in liver, heart, and lung transplant surgeries.[22-24] Zierer et al.[24] explained that there are fundamental factors that contribute to the high incidence of perioperative stroke after heart transplant surgeries, which include prolonged cardiopulmonary bypass and metabolic changes secondary to hepatic failure. Perioperative strokes that occur after neurosurgeries have been linked to local changes and alterations to the physiological regulation of brain vascular circulation, autoregulation, and vasomotricity. These changes vary according to the nature of different tumoral, vascular, infectious or traumatic conditions, different localization, and different surgical technique used in the procedure.[25]

Strengths and limitations

This study was conducted using claims databases obtained from the HCUP, as they allow the analysis of a large number of patients and facilitates multi-state and national analysis and comparison. A major strength of this study is its large cohort size, with sufficient cases in each sex, age, and race groups to allow generalizability and population analysis. Furthermore, the usage of POA enables us to differentiate between strokes that occurred as a postoperative complication and patients presenting with strokes.

However, some of the limitations of using claims databases from HCUP include that it depends on proper ICD-9 coding for each diagnosis, as well as its inconsistency and overlapping of the codes of specific procedures that could affect the analysis and results. Although the usage of the POA indicator helps us differentiate between strokes that occurred before the time of admission, there is a possibility that some of the strokes might have happened after admission and before the surgical procedure. Furthermore, the lack of POA in the NIS database can attribute to the slightly higher incidences of perioperative stroke

than in the state of California (Table 1) as some of those strokes may have happened at the time of admission and before surgery. The presence of paralysis and other neurologic disorders as the most prevalent comorbidities (Figure 2B) might also indicate that those patients had these comorbidities from a previous medical condition such as a previous stroke. Some limitations of our systematic review include that the incidence of perioperative stroke may have varied in various studies, which may be caused by different diagnostic protocols for strokes in each hospital or healthcare facility. Comorbidities that increase the risk of perioperative strokes such as hypertension, diabetes, and older age may have been more prevalent in some studies more than others and affected the variance of the systematic review.

Conclusions

Further prospective studies are needed in surgical procedures with a relatively high incidence of perioperative stroke to identify further strategies and stratify patients at high risk before the surgical procedures to improve patient counseling and a future potential treatment plan. Perioperative stroke is an underrecognized complication that accounts for about 6% for all strokes that happen in the United States annually.

Supplementary materials

Supplementary materials related to this article can be found online at https://doi.org/10.5853/jos.2019.00304.

Disclosure

The authors have no financial conflicts of interest.

References

1. Sanders RD, Grocott HP. Perioperative stroke: time to redefine the impact of age? *Stroke* 2012;43:3-5.
2. Vlisides P, Mashour GA. Perioperative stroke. *Can J Anaesth* 2016;63:193-204.
3. Ng JL, Chan MT, Gelb AW. Perioperative stroke in noncardiac, nonneurosurgical surgery. *Anesthesiology* 2011;115:879-890.
4. McDonagh DL, Mathew JP. Perioperative stroke: where do we go from here? *Anesthesiology* 2011;114:1263-1264.
5. Chiao SS. Zuo ZY. Approach to risk management of perioperative stroke. *J Anesth Perioper Med* 2015;2:268-276.
6. Selim M. Perioperative stroke. *N Engl J Med* 2007;356:706-713.
7. Cheng H, Udesh R, Mehta A, Thirumala PD. Perioperative strokes after coronary artery bypass grafting with staged carotid endarterectomy: a nationwide perspective. *J Clin Anesth* 2017;39:25-30.
8. Kikura M, Bateman BT, Tanaka KA. Perioperative ischemic stroke in non-cardiovascular surgery patients. *J Anesth* 2010;24:733-738.
9. Dong TT, Gelb AW. Perioperative stroke remains an underappreciated cause of morbidity and mortality. *J Anesth Perioper Med* 2014;1:57-59.
10. Garrett G. Present on admission. Where we are now. *J AHIMA* 2009;80:22-26.
11. Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality. https://www.ahrq.gov/data/hcup/index.html. 2013. Accessed August 27, 2019.
12. Benjamin EJ, Virani SS, Callaway CW, Chamberlain AM, Chang AR, Cheng S, et al. Heart disease and stroke statistics-2018 update: a report from the American Heart Association. *Circulation* 2018;137:e67-e492.
13. Vangen-Lønne AM, Wilsgaard T, Johnsen SH, Løchen ML, Njølstad I, Mathiesen EB. Declining incidence of ischemic stroke: what is the impact of changing risk factors? The Tromsø Study 1995 to 2012. *Stroke* 2017;48:544-550.
14. Larsen SF, Zaric D, Boysen G. Postoperative cerebrovascular accidents in general surgery. *Acta Anaesthesiol Scand* 1988;32:698-701.
15. Kam PC, Calcroft RM. Peri-operative stroke in general surgical patients. *Anaesthesia* 1997;52:879-883.
16. Knapp RB, Topkins MJ, Artusio JF Jr. The cerebrovascular accident and coronary occlusion in anesthesia. *JAMA* 1962;182:332-334.
17. Kaatz S, Douketis JD, Zhou H, Gage BF, White RH. Risk of stroke after surgery in patients with and without chronic atrial fibrillation. *J Thromb Haemost* 2010;8:884-890.
18. Chen J, Zimmerman RA, Jarvik GP, Nord AS, Clancy RR, Wernovsky G, et al. Perioperative stroke in infants undergoing open heart operations for congenital heart disease. *Ann Thorac Surg* 2009;88:823-829.
19. Ng PY, Ng AK, Subramaniam B, Burns SM, Herisson F, Timm FP, et al. Association of preoperatively diagnosed patent foramen ovale with perioperative ischemic stroke. *JAMA* 2018;319:452-462.
20. Reddy RP, Brahme IS, Karnati T, Balzer JR, Crammond DJ, Anetakis KM, et al. Diagnostic value of somatosensory evoked potential changes during carotid endarterectomy for 30-day perioperative stroke. *Clin Neurophysiol* 2018;129:1819-1831.
21. Ko SB. Perioperative stroke: pathophysiology and management. *Korean J Anesthesiol* 2018;71:3-11.
22. Patchell RA. Neurological complications of organ transplan-

tation. *Ann Neurol* 1994;36:688-703.

23. Pruitt AA, Graus F, Rosenfeld MR. Neurological complications of solid organ transplantation. *Neurohospitalist* 2013;3:152-166.
24. Zierer A, Melby SJ, Voeller RK, Guthrie TJ, Al-Dadah AS, Meyers BF, et al. Significance of neurologic complications in the modern era of cardiac transplantation. *Ann Thorac Surg* 2007;83:1684-1690.
25. Landriel F, Ajler P, Yampolsky C. Postoperative stroke in neurosurgery. In: Qureshi AI, Tsiskaridze A, Lindgren A. Treatment-Related Stroke: Including Iatrogenic and In-Hospital Strokes. Cambridge, UK: Cambridge University Press, 2016:23-32.

Supplementary Material

Search criteria and strategy

An electronic search of PubMed, Embase, and Web of Science was performed to retrieve published articles related to postoperative s that were published from January 1970 through December 2017. The search was completed by combining keywords for stroke (stroke OR Cerebrovascular accident OR CVA OR Cerebral ischemia OR Brain ischemia) with surgery-specific key terms (postoperative OR perioperative OR post-operative OR peri-operative OR postprocedural OR post-procedural OR postsurgical OR post-surgical OR postoperative care OR post-operative care OR surgical patient OR postoperative complication OR post-operative complication). For Pubmed, the terms (prospective studies[mesh:noexp] OR prospective[TIAB]) were used to specify prospective studies only. The search criteria and inclusion/exclusion criteria were created in a way to minimize bias commonly encountered in observational studies. The Quality Assessment of Diagnostic Accuracy Studies, version 2, was performed to evaluate for bias and to determine whether the chosen studies were relevant to the review question.

Inclusion & exclusion criteria for study selection

The inclusion criteria included the following: (1) all prospective studies, (2) incident postoperative stroke that was identified using criteria for the study, (3) studies inclusive of postoperative neurological outcomes within 30 days postoperative, (4) reported quantitative data, (5) studies published in English, (6) studies that included an abstract, and (7) studies done on 100 patients or more.

Data extraction

Two authors (R.A. and E.J.) independently reviewed all the titles and abstracts of the articles from the electronic search to identify those that satisfied all the inclusion criteria, and a third researcher (K.A.) settled any disagreements. Simultaneously, an Excel spreadsheet was constructed by each author outlining the articles to be excluded—the reason why a study was eliminated was indicated by a number corresponding to the inclusion criteria that was not met. A third author reconciled inclusion/exclusion disagreements and assembled a final list of studies for this review. The following data were extracted from each study: author name and year, sample size, the incidence of perioperative stroke, number of strokes.

Search results

A search was conducted on December 18, 2017 using the terms mentioned and resulted with total 4,035 references, 870 duplicates were removed from the three databases using endnote, leaving 3,166 potential references. Looking further into the abstracts of the references, 2,830 articles were excluded after title/abstract screening; 484 were not prospective studies, 1,578 the incidence of perioperative stroke and neurologic outcome was not identified within 30 days, 335 had a sample size of fewer than 100 patients, six studies were not performed on humans and 427 were more duplicated studies found, leaving 336 articles.

After full-text screen, 187 articles were qualified for data extraction. The overall sample size is 184,922 patients that had an incidence of perioperative stroke ranging from 0% to 13.86%. Studies that provided information about perioperative strokes occurring in cardiovascular and non-cardiovascular procedures, comprised of a total cohort of 145,714 and 39,208. The highest three countries that had the most published papers in our search were United State (58 papers; 75,456 patients), Italy (23 papers; 15,703 patients), and Germany (21 papers; 11,814 patients). From the 58 papers published in the United States, there were 57 papers on cardiovascular procedures and one paper on noncardiovascular procedures.

Supplementary Table 1. Surgical subcategories used and the surgical procedures they include

Surgical subcategory	ICD-9 code	Surgical procedure(s)
Ventricular shunt to extracranial site	0231	Ventricle to nasopharynx shunt, ventriculomastoid anastomosis
Craniotomy and craniectomy; reopening of craniotomy site	0123	-
Other incision of brain	0139	Amygdalohippocampotomy, drainage of intracerebral hematoma, incision of brain NOS Excludes: division of cortical adhesions
Other craniectomy	0124	Cranial (decompression. exploration, trephination), craniotomy NOS, craniotomy with removal of (epidural abscess, extradural hematoma, foreign body of skull) Excludes: removal of foreign body with incision into brain
Incision of cerebral meninges	0131	Drainage of (intracranial hygroma, subarachnoid abscess (cerebral), subdural empyema)
Insertion of implantable heart assist system	3766	Axial flow heart assist system, diagonal pump heart assist system, left ventricular assist device, pulsatile heart assist system, right ventricular assist device, rotary pump heart assist system, transportable implantable heart assist system, ventricular assist device not otherwise specified Excludes: implant of pulsation balloon, implantation of total internal biventricular heart replacement system (artificial heart), insertion of percutaneous external heart assist device
Open heart valvuloplasty of aortic valve without replacement	3511	-
Open and other replacement of aortic valve with tissue graft	3521	Repair of aortic valve with tissue graft (autograft, heterograft, homograft)
Implant of pulsation balloon	3761	-
(Aorto)coronary bypass of three coronary arteries	3613	-
Endovascular removal of obstruction from head and neck vessel(s)	3974	Endovascular embolectomy, endovascular thrombectomy of pre-cerebral and cerebral vessels, mechanical embolectomy or thrombectomy Excludes: endarterectomy of intracranial vessels and other vessels of head and neck, occlusive endovascular repair of head or neck vessels, open embolectomy or thrombectomy
Extracranial-intracranial vascular bypass	3928	-
Clipping of aneurysm	3951	Excludes: clipping of arteriovenous fistula
Endarterectomy; other vessels of head and neck	3812	Extirpation of matter from: right/left common carotid artery, right/left internal carotid artery, right/left external carotid artery, right/left vertebral artery, facial artery, right/left temporal artery, right/left thyroid artery
Percutaneous transluminal coronary angioplasty	0066	Balloon angioplasty of coronary artery, coronary atherectomy, percutaneous coronary angioplasty NOS
Heart transplantation	3751	-
Combined heart-lung transplantation	336	-
Bilateral lung transplantation	3352	Double-lung transplantation, *en bloc* transplantation
Other transplant of liver	5059	Exclude: auxiliary hepatic transplantation leaving patient's own liver *in situ*
Pancreatic transplant NOS	5280	-
Reopening of recent thoracotomy site	3403	-
Other and unspecified pneumonectomy	3259	Excludes: thoracoscopic pneumonectomy
Other lobectomy of lung	3249	Excludes: thoracoscopic lobectomy of lung
Decortication of lung	3451	Excludes: thoracoscopic decortication of lung
Thoracoscopic excision of lesion or tissue of lung	3220	Thoracoscopic wedge resection
Partial excision of pituitary gland, transfrontal approach	0761	Cryohypophysectomy, partial transfrontal approach, division of hypophyseal stalk transfrontal approach, excision of lesion of pituitary (hypophysis) transfrontal approach, hypophysectomy subtotal transfrontal approach, infundibulectomy hypophyseal transfrontal approach Excludes: biopsy of pituitary gland transfrontal approach
Partial excision of pineal gland	0753	Excludes: biopsy of pineal gland
Division of thyroid isthmus	0691	Transection of thyroid isthmus
Unilateral adrenalectomy	0722	Adrenalectomy NOS Excludes: excision of remaining adrenal gland

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Supplementary Table 1. Continued

Surgical subcategory	ICD-9 code	Surgical procedure(s)
Complete thyroidectomy	064	Excludes: complete substernal thyroidectomy
Open total intra-abdominal colectomy	4582	-
Open and other left hemicolectomy	4575	Excludes: proctosigmoidectomy, second stage Mikulicz operation
Exploratory laparotomy	5411	Excludes: exploration incidental to intra-abdominal surgery
Other partial resection of small intestine	4562	Duodenectomy, ileectomy, jejunectomy Excludes: duodenectomy with synchronous pancreatectomy, resection of cecum and terminal ileum
Cholecystectomy	5122	Excludes: laparoscopic cholecystectomy
Other removal or destruction of corneal lesion	1149	Excision of cornea NOS Excludes: biopsy of cornea
Other extracapsular extraction of lens	1359	Exclude: extracapsular extraction of lens by temporal inferior route
Other repair of retinal detachment	1459	Exclude: repair of retinal detachment with diathermy, cryotherapy, xenon arc photocoagulation, laser photocoagulation, photocoagulation of unspecified type
Other operations on vitreous	1479	Exclude: open sky technique, removal of vitreous, anterior approach, aspiration of vitreous by posterior sclerotomy, mechanical vitrectomy by anterior/posterior approach, injection of vitreous substitute
Suture of corneal laceration	1151	-
Total splenectomy	415	Splenectomy NOS
Radical excision of periaortic lymph nodes	4052	-
Biopsy of lymphatic structure	4011	-
Radical neck dissection, unilateral	4041	-
Excision of axillary lymph node	4023	-
Amputation above knee	8417	Amputation of leg through femur, amputation of thigh, conversion of below-knee amputation into above-knee amputation, supracondylar above-knee amputation
Atlas-axis spinal fusion	8101	Craniocervical fusion by (anterior, transoral, or posterior technique), C1-C2 fusion by (anterior, transoral, or posterior technique), occiput C2 fusion by (anterior, transoral, or posterior technique)
Other amputation below knee	8415	Amputation of leg through tibia and fibula NOS
Partial hip replacement	8152	Bipolar endoprosthesis
Open reduction of fracture with internal fixation; femur	7935	Excludes: that for separation of epiphysis
Nephroureterectomy	5551	Nephroureterectomy with bladder cuff, total nephrectomy (unilateral) Excludes: removal of transplanted kidney
Percutaneous nephrostomy without fragmentation	5503	Nephrostolithotomy (nephroscopic), percutaneous removal of kidney stone(s) by: (basket extraction, forceps extraction [nephroscopic]), pyelostolithotomy (nephroscopic), with placement of catheter down ureter Excludes: percutaneous removal by fragmentation, repeat nephroscopic removal during current episode
Radical cystectomy	5771	Pelvic exenteration in male, removal of (bladder, prostate, seminal vesicles, and fat), removal of (bladder, urethra, and fat in a female) Excludes: that as part of pelvic exenteration in female
Other transurethral excision or destruction of lesion or tissue of bladder	5749	Endoscopic resection of bladder lesion Excludes: transurethral biopsy of bladder, transurethral fistulectomy
Control of (postoperative) hemorrhage of bladder	5793	-
Other transurethral prostatectomy	6029	Excision of median bar by transurethral approach, transurethral electrovaporization of prostrate, transurethral enucleative procedure, transurethral prostatectomy NOS, transurethral resection of prostate
Control of (postoperative) hemorrhage of prostate	6094	Coagulation of prostatic bed, cystoscopy for control of prostatic hemorrhage
Radical prostatectomy	605	Prostatovesiculectomy, radical prostatectomy by any approach Excludes: cystoprostatectomy
Unilateral orchiectomy	623	Orchidectomy (with epididymectomy) NOS

Supplementary Table 1. Continued

Surgical subcategory	ICD-9 code	Surgical procedure(s)
Removal of both testes at same operative episode	6241	Bilateral orchidectomy NOS
Low cervical cesarean section	741	Lower uterine segment cesarean section
Other and unspecified total abdominal hysterectomy	6849	-
Other removal of both ovaries and tubes at same operative episode	6561	Excludes: that by laparoscope
Laparoscopic total abdominal hysterectomy	6841	Total laparoscopic hysterectomy
Classical cesarean section	740	Transperitoneal classical cesarean section
Fat graft of skin and subcutaneous tissue	8687	Replacement of subcutaneous tissue and fascia for (scalp, face, neck, chest, back, buttock, abdomen, perineum, pelvic region, arms, hands, legs, feet) with autologous tissue substitute percutaneous approach, extraction of subcutaneous tissue and fascia for (scalp, face, neck, chest, back, buttock, abdomen, perineum, pelvic region, arms, hands, legs, feet) percutaneous approach
Bilateral simple mastectomy	8542	Bilateral complete mastectomy
Removal of implant of breast	8594	-
Other free skin graft to other sites	8669	Excludes: heterograft, homograft
Homograft to skin	8666	Graft to skin of amnionic membrane from donor skin from donor
Sphenoidectomy	2264	-
Incision of multiple nasal sinuses	2253	-
Sphenoidotomy	2252	-
Control of epistaxis by ligation of ethmoidal arteries	2104	-
Ethmoidectomy	2263	-

ICD-9, International Classification of Diseases, 9th revision; NOS, not otherwise specified.

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Supplementary Table 2. 100 surgeries that were most frequently performed

Procedure name	ICD-9 code	Procedure frequency	No. of stroke	Incidence of stroke (%)
Low cervical cesarean section	741	516,134	41	0.01
Total knee replacement	8154	191,443	173	0.09
Percutaneous transluminal coronary angioplasty	0066	165,698	761	0.46
Laparoscopic cholecystectomy	5123	141,814	117	0.08
Hemodialysis	3995	115,663	454	0.39
Total hip replacement	8151	98,769	111	0.11
Laparoscopic appendectomy	4701	92,255	22	0.02
Other and unspecified total abdominal hysterectomy	6849	691,39	27	0.04
Open reduction of fracture with internal fixation; femur	7935	51,207	275	0.54
Percutaneous abdominal drainage	5491	46,708	93	0.2
Episiotomy	736	45,878	*	0.01
Thoracentesis	3491	45,733	175	0.38
Other cervical fusion of the anterior column, anterior technique	8102	41,651	45	0.11
Open reduction of fracture with internal fixation; tibia and fibula	7936	41,571	42	0.1
Other exploration and decompression of spinal canal	0309	37,627	77	0.2
Excision of intervertebral disc	8051	37,514	18	0.05
Partial hip replacement	8152	36,879	250	0.68
Other and unspecified vaginal hysterectomy	6859	33,798	*	0.02
Angioplasty of other non-coronary vessel(s)	3950	32,919	157	0.48
Other appendectomy	4709	32,117	13	0.04
Lumbar and lumbosacral fusion of the anterior column, posterior technique	8108	31,922	53	0.17
Radical prostatectomy	605	27,682	12	0.04
Endarterectomy; other vessels of head and neck	3812	27,172	433	1.59
Other transurethral prostatectomy	6029	25,617	33	0.13
Interruption of the vena cava	387	22,439	288	1.28
Closed reduction of fracture with internal fixation; femur	7915	22,214	114	0.51
Laparoscopically assisted vaginal hysterectomy	6851	20,672	*	0.01
Excision or destruction of other lesion or tissue of heart, endovascular approach	3734	20,145	62	0.31
Open and other right hemicolectomy	4573	20,075	117	0.58
Other partial resection of small intestine	4562	19,867	121	0.61
Lumbar and lumbosacral fusion of the anterior column, anterior technique	8106	18,861	23	0.12
Other lysis of peritoneal adhesions	5459	18,711	48	0.26
Open and other sigmoidectomy	4576	18,441	90	0.49
Cholecystectomy	5122	17,557	57	0.32
Nephroureterectomy	5551	16,516	45	0.27
Insertion of intercostal catheter for drainage	3404	16,069	52	0.32
Open and other replacement of aortic valve with tissue graft	3521	15,928	416	2.61
Complete thyroidectomy	064	15,238	*	0.04
Circumcision	640	15,138	*	0.01
Amputation of toe	8411	15,130	29	0.19
(Aorto)coronary bypass of two coronary arteries	3612	14,793	216	1.46
Other and unspecified subtotal abdominal hysterectomy	6839	14,602	*	0.01
Other excision or destruction of lesion or tissue of brain	0159	14,476	468	3.23
Lumbar and lumbosacral fusion of the posterior column, posterior technique	8107	14,067	29	0.21

Supplementary Table 2. Continued

Procedure name	ICD-9 code	Procedure frequency	No. of stroke	Incidence of stroke (%)
Open reduction of fracture with internal fixation; radius and ulna	7932	13,718	10	0.07
(Aorto)coronary bypass of three coronary arteries	3613	13,380	238	1.78
Other open incisional hernia repair with graft or prosthesis	5361	13,063	*	0.04
Laparoscopic total abdominal hysterectomy	6841	12,607	*	0.03
Open reduction of fracture with internal fixation; humerus	7931	12,565	10	0.08
Other (peripheral) vascular shunt or bypass	3929	12,302	57	0.46
Unilateral extended simple mastectomy	8543	12,087	*	0.02
Arteriovenostomy for renal dialysis	3927	11,559	70	0.61
Transurethral removal of obstruction from ureter and renal pelvis	560	11,027	10	0.09
Incision of cerebral meninges	0131	10,929	357	3.27
Biopsy of lymphatic structure	4011	10,455	36	0.34
Internal fixation of bone without fracture reduction; femur	7855	10,171	40	0.39
Other transurethral excision or destruction of lesion or tissue of bladder	5749	10,151	28	0.28
Laparoscopic right hemicolectomy	1733	10,009	24	0.24
Percutaneous nephrostomy without fragmentation	5503	9,998	41	0.41
Laparoscopic lysis of peritoneal adhesions	5451	9,655	11	0.11
Arthroplasty; other total shoulder replacement	8180	9,130	11	0.12
Other amputation below knee	8415	8,776	66	0.75
Unilateral thyroid lobectomy	062	8,775	*	0
Open and other replacement of aortic valve	3522	8,633	205	2.37
Open and other partial gastrectomy	4389	8,582	*	0.08
Excision of axillary lymph node	4023	8,537	*	0.02
Laparoscopic sigmoidectomy	1736	8,432	12	0.14
Endovascular implantation of other graft in abdominal aorta	3971	8,414	37	0.44
Thoracoscopic excision of lesion or tissue of lung	3220	8,401	31	0.37
Revision of hip replacement, both acetabular and femoral components	0070	7,814	21	0.27
Excision of lesion of other soft tissue	8339	7,457	13	0.17
Other free skin graft to other sites	8669	7,308	15	0.21
Dorsal and dorsolumbar fusion of the posterior column, posterior technique	8105	7,204	18	0.25
Other unilateral salpingo-oophorectomy	6549	7,105	*	0.01
Other kidney transplantation	5569	7,093	*	0.13
Revision of knee replacement, total (all components)	0080	6,983	*	0.11
(Aorto)coronary bypass of four or more coronary arteries	3614	6,942	134	1.93
Implant of pulsation balloon	3761	6,913	151	2.18
Open and other left hemicolectomy	4575	6,733	56	0.83
Other removal of both ovaries and tubes at same operative episode	6561	6,644	*	0.11
Other endovascular procedures on other vessels	3979	6,577	76	1.16
Other lobectomy of lung	3249	6,539	37	0.57
Other revision of vascular procedure	3949	6,309	35	0.55
Other repair of urinary stress incontinence	5979	6,230	*	0.03
Arthroplasty; partial shoulder replacement	8181	6,110	*	0.08
(Aorto)coronary bypass of one coronary artery	3611	6,108	79	1.29
Other cervical fusion of the posterior column, posterior technique	8103	5,539	20	0.36
Incision of perirectal tissue	4881	5,520	*	0.04

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Supplementary Table 2. Continued

Procedure name	ICD-9 code	Procedure frequency	No. of stroke	Incidence of stroke (%)
Other anterior resection of rectum	4863	5,506	15	0.27
Other myectomy	8345	5,416	21	0.39
Unilateral simple mastectomy	8541	5,286	*	0.02
Single internal mammary-coronary artery bypass	3615	5,282	69	1.31
Attachment of pedicle or flap graft to other sites	8674	5,254	*	0.11
Partial nephrectomy	554	5,180	*	0.15
Other and unspecified hysterectomy	689	5,129	*	0.06
Amputation above knee	8417	5,021	53	1.06
Percutaneous vertebral augmentation	8166	4,749	*	0.19
Laparoscopy	5421	4,724	*	0.11
Amputation through foot	8412	4,686	20	0.43
Open heart valvuloplasty of mitral valve without replacement	3512	4,597	79	1.72

ICD-9, International Classification of Diseases, 9th revision.
*Any results showing numbers less than 10 patients to maintain patient privacy.

Supplementary Table 3. One hundred surgeries that had the highest number of strokes

Procedure name	ICD-9 code	No. of stroke	Procedure frequency	Incidence of stroke (%)
Percutaneous transluminal coronary angioplasty	0066	761	165,698	0.46
Other excision or destruction of lesion or tissue of brain	0159	468	14,476	3.23
Hemodialysis	3995	454	115,663	0.39
Endarterectomy; other vessels of head and neck	3812	433	27,172	1.59
Open and other replacement of aortic valve with tissue graft	3521	416	15,928	2.61
Incision of cerebral meninges	0131	357	10,929	3.27
Clipping of aneurysm	3951	294	2,856	10.29
Interruption of the vena cava	387	288	22,439	1.28
Open reduction of fracture with internal fixation; femur	7935	275	51,207	0.54
Endovascular (total) embolization or occlusion of head and neck vessels	3972	252	4,174	6.4
Partial hip replacement	8152	250	36,879	0.68
(Aorto)coronary bypass of three coronary arteries	3613	238	13,380	1.78
(Aorto)coronary bypass of two coronary arteries	3612	216	14,793	1.46
Open and other replacement of aortic valve	3522	205	8,633	2.37
Excision of lesion or tissue of cerebral meninges	0151	193	4,549	4.24
Thoracentesis	3491	175	45,733	0.38
Total knee replacement	8154	173	191,443	0.09
Endovascular removal of obstruction from head and neck vessel(s)	3974	171	926	18.47
Angioplasty of other non-coronary vessel(s)	3950	157	32,919	0.48
Implant of pulsation balloon	3761	151	6,913	2.18
Other incision of brain	0139	138	2,628	5.25
(Aorto)coronary bypass of four or more coronary arteries	3614	134	6,942	1.93
Other partial resection of small intestine	4562	121	19,867	0.61
Laparoscopic cholecystectomy	5123	117	141,814	0.08
Open and other right hemicolectomy	4573	117	20,075	0.58
Closed reduction of fracture with internal fixation; femur	7915	114	22,214	0.51
Total hip replacement	8151	111	98,769	0.11
Percutaneous angioplasty of extracranial vessel(s)	0061	110	4,312	2.55
Other craniotomy	124	104	3,030	3.43
Resection of vessel with replacement; thoracic vessels	3845	98	1,499	6.54
Open and other replacement of mitral valve with tissue graft	3523	95	2,783	3.41
Percutaneous abdominal drainage	5491	93	46,708	0.2
Endovascular embolization or occlusion of vessel(s) of head or neck using bare coils	3975	91	1,166	7.8
Open and other sigmoidectomy	4576	90	18,441	0.49
(Aorto)coronary bypass of one coronary artery	3611	79	6,108	1.29
Open heart valvuloplasty of mitral valve without replacement	3512	79	4,597	1.72
Other exploration and decompression of spinal canal	0309	77	37,627	0.2
Other endovascular procedures on other vessels	3979	76	6,577	1.16
Arteriovenostomy for renal dialysis	3927	70	11,559	0.61
Single internal mammary-coronary artery bypass	3615	69	5,282	1.31
Other amputation below knee	8415	66	8,776	0.75
Open and other replacement of mitral valve	3524	64	2,639	2.43

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Supplementary Table 3. Continued

Procedure name	ICD-9 code	No. of stroke	Procedure frequency	Incidence of stroke (%)
Excision or destruction of other lesion or tissue of heart, endovascular approach	3734	62	20,145	0.31
Extracranial-intracranial vascular bypass	3928	60	434	13.82
Ventricular shunt to abdominal cavity and organs	234	59	4,201	1.4
Cholecystectomy	5122	57	17,557	0.32
Other (peripheral) vascular shunt or bypass	3929	57	12,302	0.46
Open and other left hemicolectomy	4575	56	6,733	0.83
Lumbar and lumbosacral fusion of the anterior column, posterior technique	8108	53	31,922	0.17
Amputation above knee	8417	53	5,021	1.06
Insertion of intercostal catheter for drainage	3404	52	16,069	0.32
Other lysis of peritoneal adhesions	5459	48	18,711	0.26
Other craniectomy	0125	46	1,008	4.56
Other cervical fusion of the anterior column, anterior technique	8102	45	41,651	0.11
Nephroureterectomy	5551	45	16,516	0.27
Endovascular implantation of graft in thoracic aorta	3973	45	1,216	3.7
Open reduction of fracture with internal fixation; tibia and fibula	7936	42	41,571	0.1
Resection of vessel with replacement; aorta, abdominal	3844	42	2,570	1.63
Low cervical cesarean section	741	41	516,134	0.01
Percutaneous nephrostomy without fragmentation	5503	41	9,998	0.41
Internal fixation of bone without fracture reduction; femur	7855	40	10,171	0.39
Incision of vessel; lower limb arteries	3808	39	1,783	2.19
Endovascular implantation of other graft in abdominal aorta	3971	37	8,414	0.44
Other lobectomy of lung	3249	37	6,539	0.57
Biopsy of lymphatic structure	4011	36	10,455	0.34
Other revision of vascular procedure	3949	35	6,309	0.55
Replacement of ventricular shunt	0242	35	3,278	1.07
Extracorporeal membrane oxygenation	3965	34	389	8.74
Other transurethral prostatectomy	6029	33	25,617	0.13
Annuloplasty	3533	32	1,465	2.18
Thoracoscopic excision of lesion or tissue of lung	3220	31	8,401	0.37
Pericardiotomy	3712	31	3,094	1
Other transplant of liver	5059	31	2,095	1.48
Incision of vessel; upper limb vessels	3803	31	942	3.29
Heart transplantation	3751	31	882	3.51
Open heart valvuloplasty of aortic valve without replacement	3511	31	735	4.22
Percutaneous angioplasty of intracranial vessel(s)	0062	31	359	8.64
Partial excision of pituitary gland, transsphenoidal approach	0762	30	3,337	0.9
Amputation of toe	8411	29	15,130	0.19
Lumbar and lumbosacral fusion of the posterior column, posterior technique	8107	29	14,067	0.21
Other transurethral excision or destruction of lesion or tissue of bladder	5749	28	10,151	0.28
Exploratory laparotomy	5411	28	4,374	0.64
Aorta-iliac-femoral bypass	3925	28	2,399	1.17
Excision or destruction of other lesion or tissue of heart, open approach	3733	28	1,529	1.83
Other and unspecified total abdominal hysterectomy	6849	27	69,139	0.04

Supplementary Table 3. Continued

Procedure name	ICD-9 code	No. of stroke	Procedure frequency	Incidence of stroke (%)
Insertion of implantable heart assist system	3766	27	474	5.7
Partial excision of pituitary gland, transfrontal approach	0761	25	246	10.16
Laparoscopic right hemicolectomy	1733	24	10,009	0.24
Other repair of aneurysm	3952	24	1,581	1.52
Lumbar and lumbosacral fusion of the anterior column, anterior technique	8106	23	18,861	0.12
Total splenectomy	415	23	4,123	0.56
Percutaneous balloon valvuloplasty	3596	23	1,095	2.1
Lobectomy of brain	0153	23	585	3.93
Ventricular shunt to extracranial site NEC	239	23	407	5.65
Laparoscopic appendectomy	4701	22	92,255	0.02
Revision of hip replacement, both acetabular and femoral components	0070	21	7,814	0.27
Other myectomy	8345	21	5,416	0.39
Revision of arteriovenous shunt for renal dialysis	3942	21	4,469	0.47
Other cervical fusion of the posterior column, posterior technique	8103	20	5,539	0.36
Amputation through foot	8412	20	4,686	0.43

ICD-9, International Classification of Diseases, 9th revision; NEC, not otherwise specified.

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Supplementary Table 4. One hundred surgeries that had the highest incidence of perioperative stroke, with procedure frequency ≥10

Procedure name	ICD-9 code	Incidence of stroke (%)	Procedure frequency
Implantation or insertion of biventricular external heart assist system	3760	20	15
Endovascular removal of obstruction from head and neck vessel(s)	3974	18.47	926
Incision of vessel; intracranial vessels	3801	18.18	11
Other excision of vessel; intracranial vessels	3861	17.5	40
Percutaneous insertion of intracranial vascular stent(s)	0065	16.67	12
Extracranial-intracranial vascular bypass	3928	13.82	434
Lobotomy and tractotomy	132	11.43	35
Clipping of aneurysm	3951	10.29	2,856
Partial excision of pituitary gland, transfrontal approach	0761	10.16	246
Other removal or destruction of corneal lesion	1149	9.9	11
Extracorporeal membrane oxygenation	3965	8.74	389
Percutaneous angioplasty of intracranial vessel(s)	0062	8.64	359
Incision of vessel; abdominal veins	3807	8	25
Endovascular embolization or occlusion of vessel(s) of head or neck using bare coils	3975	7.8	1,166
Partial excision of pituitary gland, unspecified approach	0763	7.55	53
Resection of vessel with anastomosis; intracranial vessels	3831	7.14	28
Other operations on pancreas	5299	6.67	15
Excision of uvula	2772	6.67	15
Insertion of temporary non-implantable extracorporeal circulatory assist device	3762	6.6	33
Resection of vessel with replacement; thoracic vessels	3845	6.54	1,499
Endovascular (total) embolization or occlusion of head and neck vessels	3972	6.4	4,174
Adjunct vascular system; procedure on single vessel	0040	6.25	32
Insertion of percutaneous external heart assist device	3764	6.25	16
Incision of vessel; aorta	3804	6.15	65
Endovascular embolization or occlusion of vessel(s) of head or neck using bioactive coils	3976	5.9	305
Insertion of implantable heart assist system	3766	5.7	474
Ventricular shunt to extracranial site NEC	0239	5.65	407
Transapical replacement of aortic valve	3506	5.56	18
Craniotomy and craniectomy; reopening of craniotomy site	0123	5.49	328
Excision, destruction, or exclusion of left atrial appendage	3736	5.41	37
Other incision of brain	0139	5.25	2,628
Incision of vessel; other thoracic vessels	3805	4.9	102
Total excision of pituitary gland, transfrontal approach	0764	4.76	21
Other craniectomy	0125	4.56	1,008
Sphenoidectomy	2264	4.37	183
Other excision of vessel; other thoracic vessels	3865	4.35	23
Incision of multiple nasal sinuses	2253	4.35	23
Excision of lesion or tissue of cerebral meninges	0151	4.24	4,549
Open heart valvuloplasty of aortic valve without replacement	3511	4.22	735
Other extracapsular extraction of lens	1359	4.17	24
Aorta-subclavian-carotid bypass	3922	4.12	437
Lobectomy of brain	0153	3.93	585
Division of thyroid isthmus	0691	3.77	53
Cardiotomy	3711	3.74	107

Supplementary Table 4. Continued

Procedure name	ICD-9 code	Incidence of stroke (%)	Procedure frequency
Endovascular implantation of graft in thoracic aorta	3973	3.7	1,216
Placement of intracerebral catheter(s) via burr hole(s)	0128	3.63	248
Heart transplantation	3751	3.51	882
Other intra-abdominal vascular shunt or bypass	3926	3.49	172
Intraoperative cardiac pacemaker	3964	3.45	29
Other craniotomy	0124	3.43	3,030
Open and other replacement of mitral valve with tissue graft	3523	3.41	2,783
Sphenoidotomy	2252	3.31	121
Combined heart-lung transplantation	336	3.3	33
Incision of vessel; upper limb vessels	3803	3.29	942
Operations on carotid body, carotid sinus and other vascular bodies	398	3.28	122
Incision of cerebral meninges	0131	3.27	10,929
Other excision or destruction of lesion or tissue of brain	0159	3.23	14,476
Partial excision of pineal gland	0753	3.13	64
Excision of accessory spleen	4193	3.13	32
Endovascular replacement of aortic valve	3505	2.94	68
Total correction of transposition of great vessels, not elsewhere classified	3584	2.94	34
Incision of vessel; abdominal arteries	3806	2.93	273
Percutaneous insertion of carotid artery stent(s)	0063	2.91	103
Incision of vessel; other vessels of head and neck	3802	2.91	103
Other surgical occlusion of vessels; other vessels of head and neck	3882	2.85	281
Reopening of recent thoracotomy site	3403	2.78	144
Transluminal coronary atherectomy	1755	2.78	36
Ligation of thoracic duct	4064	2.78	36
Other repair of retinal detachment	1459	2.78	36
Other surgical occlusion of vessels; intracranial vessels	3881	2.73	110
Control of epistaxis by ligation of ethmoidal arteries	2104	2.7	37
Repair of endocardial cushion defect with tissue graft	3563	2.63	114
Total ostectomy of other facial bone with synchronous reconstruction	7644	2.63	38
Open ablation of renal lesion or tissue	5532	2.63	38
Open and other replacement of aortic valve with tissue graft	3521	2.61	15,928
Ventricular shunt to circulatory system	232	2.6	77
Percutaneous angioplasty of extracranial vessel(s)	0061	2.55	4,312
Trocar cholecystostomy	5102	2.53	79
Soave submucosal resection of rectum	4841	2.5	40
Other operations on heart and pericardium	3799	2.44	41
Open and other replacement of mitral valve	3524	2.43	2,639
Open and other replacement of pulmonary valve with tissue graft	3527	2.41	166
Suture of peritoneum	5464	2.38	84
Other dental restoration	2349	2.38	42
Percutaneous mitral valve repair with implant	3597	2.38	42
Open and other replacement of aortic valve	3522	2.37	8,633
Creation of conduit between right ventricle and pulmonary artery	3592	2.34	128
Other and unspecified repair of atrial septal defect	3571	2.32	518

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Supplementary Table 4. Continued

Procedure name	ICD-9 code	Incidence of stroke (%)	Procedure frequency
Aorta-renal bypass	3924	2.27	44
Systemic to pulmonary artery shunt	390	2.26	177
Isolation of segment of small intestine	4551	2.25	89
Closed (aspiration, percutaneous) biopsy of spleen	4132	2.22	45
Incision of vessel; lower limb arteries	3808	2.19	1,783
Implant of pulsation balloon	3761	2.18	6,913
Annuloplasty	3533	2.18	1,465
Other excision of vessel; other vessels of head and neck	3862	2.17	46
Percutaneous balloon valvuloplasty	3596	2.1	1,095
Incision of pituitary gland	0772	2.08	48
Fat graft of skin and subcutaneous tissue	8687	2.06	97
Other division of bone; scapula, clavicle, and thorax (ribs and sternum)	7731	2.04	49

ICD-9, International Classification of Diseases, 9th revision; NEC, not otherwise specified.

Supplementary Table 5. ICD-9 codes used in identifying perioperative strokes

Type of stroke	Diagnostic ICD-9 code
Ischemic stroke	43301, 43311, 43321, 43331, 43381, 43391, 43401, 43411, 43491, 436
Iatrogenic stroke	99702
Hemorrhagic stroke	430, 431, 4329

ICD-9, International Classification of Diseases, 9th revision.

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Supplementary Table 6. Full list of the systematic review

Author	Year	Surgical procedure	Country	Sample size	Stroke no.	Stroke incidence (%)
Abbas et al.[1]	2015	CABG	Pakistan	115	7	6.0
Aboyans et al.[2]	2008	CABG	France	1,022	37	3.60
Abraham et al.[3]	2002	Abdominal aortic aneurysm repair	United States	116	1	0.90
AbuRahma et al.[4]	1996	CEA	United States	399	7	1.75
AbuRahma[5]	2004	CEA	United States	357	10	2.80
AbuRahma et al.[6]	2008	CAS	United States	100	2	2.0
AbuRahma et al.[7]	2010	CEA	United States	200	2	1.0
AbuRahma et al.[8]	2010	CEA and CAS	United States	192	3	1.56
AbuRahma et al.[9]	2005	CEA	United States	187	3	1.50
AbuRahma et al.[10]	2001	CEA	United States	144	6	4.16
AbuRahma et al.[11]	2007	CEA	United States	200	6	3.0
AbuRahma et al.[12]	2002	CEA	United States	200	7	3.50
Ackerstaff et al.[13]	1996	CEA	Netherlands	301	13	4.31
Ad et al.[14]	2011	Cox-Maze procedure	United States	124	1	0.8
Ad et al.[15]	2015	Mitral valve surgery	United States	387	3	0.76
Ad et al.[16]	2013	Cox-Maze procedure	United States	232	4	1.70
Ad et al.[17]	2017	Cox-Maze procedure	United States	709	4	0.56
Alcantara et al.[18]	2014	CEA	United States	181	0	0
Alnasser et al.[19]	2017	Transcatheter valve-in-valve implantation	Canada	162	2	1.23
Alonso-Coello et al.[20]	2017	Noncardiac surgeries	Multiple	8,346	60	0.72
Amato et al.[21]	2015	CEA	Italy	202	3	1.49
Ambrosii et al.[22]	2016	Musculoskeletal system or abdominal cavity surgeries	Moldova	400	2	0.50
Ansel et al.[23]	2010	CAS	United States	257	5	1.90
Antunes et al.[24]	1999	CABG	Portugal	107	3	2.8
Anzola et al.[25]	2004	Patent foramen ovale transcatheter closure	Italy	140	0	0
Arnaoutoglou et al.[26]	2017	Endovascular repair of abdominal aortic aneurysm	Greece	153	3	1.96
Aronson[27]	2009	Cardiac surgery	United States	1,405	20	1.42
Ascher et al.[28]	2002	CEA	United States	226	3	1.30
Ascione et al.[29]	2004	CABG	United Kingdom	686	5	0.73
Ascione et al.[30]	2005	CABG	United Kingdom	470	6	1.27
Ascione et al.[31]	2001	CABG	United Kingdom	253	14	5.53
Ascione et al.[32]	2002	CABG	United Kingdom	4,077	45	1.10
Asimakopoulos et al.[33]	2006	Off pump CABG	United Kingdom	251	2	0.80
Assadian et al.[34]	2008	CEA	Austria	338	2	0.60
Assadian et al.[35]	2007	Carotid eversion endarterectomy	Austria	363	5	1.38
Assadian et al.[36]	2005	CEA	Austria	1,210	30	2.48
Asteriou et al.[37]	2013	CABG	Greece	200	6	3.0
Avinee et al.[38]	2016	TAVI	France	368	14	3.80
Axisa et al.[39]	2002	Peripheral angioplasty	United Kingdom	1,377	6	0.44
Ayad[40]	2016	Percutaneous coronary intervention	Egypt	160	0	0
Baklanov et al.[41]	2006	Coronary stenting	United States	197	0	0
Ballotta et al.[42]	2008	CEA	Italy	102	0	0
Ballotta et al.[43]	2005	Carotid coiling or kinking	Italy	129	0	0
Ballotta et al.[44]	2008	CEA	Italy	374	0	0

Supplementary Table 6 . Continued

Author	Year	Surgical procedure	Country	Sample size	Stroke no.	Stroke incidence (%)
Ballotta et al.[45]	2004	CEA	Italy	363	3	0.77
Ballotta et al.[46]	2003	CEA	Italy	624	4	0.64
Ballotta et al.[47]	1999	CEA	Italy	336	5	1.49
Ballotta et al.[48]	2001	CEA	Italy	547	5	0.91
Ballotta et al.[49]	2014	CEA	Italy	1,773	8	0.39
Banach et al.[50]	2008	Open heart surgery	Poland	260	5	1.92
Baracchini et al.[51]	2012	eCEA	Italy	1,294	8	0.55
Bardia et al.[52]	2017	Isolated cardiac surgery	United States	763	23	3.01
Baribeau et al.[53]	2002	Open heart surgery	United States	228	16	7.01
Barnes et al.[54]	1981	Coronary or peripheral arterial revascularization	United States	314	1	0.32
Barnes et al.[55]	1981	Coronary or peripheral arterial revascularization	United States	449	5	1.11
Basic et al.[56]	2016	CEA	Austria	485	6	1.24
Bastounis et al.[57]	2001	CEA	Greece	337	0	0
Batchelder et al.[58]	2015	CEA	United Kingdom	100	1	1.0
Bechtel et al.[59]	2000	CEA and abdominal aortic surgery	Germany	201	1	0.50
Becquemin et al.[60]	2003	Carotid stenting and carotid surgery	France	455	9	1.98
Bellomo et al.[61]	2002	All patients undergoing surgeries with a hospital stay more than 48 hr	Australia	1,125	16	1.20
Bellomo et al.[62]	2004	Various surgical procedures with a hospital stay more than 48 hr	Australia	2,183	23	1.05
Berens et al.[63]	1992	Cardiac surgery	United States	1,087	22	2.02
Bernhardt et al.[64]	2015	Orthotopic liver transplant	Germany	134	1	0.70
Bertolini et al.[65]	1997	Myocardial revascularization	Italy	100	3	3.0
Berwanger et al.[66]	2016	Patients undergoing noncardiac surgeries in patients >45 with an overnight hospital stay	Multiple	22,815	123	0.54
Bilecen et al.[67]	2013	Complex cardiac surgery	Netherlands	1,075	31	2.88
Bilfinger et al.[68]	2000	Complex cardiac surgery	United States	1,987	38	1.8
Binder et al.[69]	2015	TAVI	Switzerland	598	18	3.01
Birincioglu et al.[70]	1999	CABG	Turkey	722	13	1.80
Bishu et al.[71]	2014	TAVR	United States	277	2	0.72
Boehm et al.[72]	2007	CABG	Germany	1,447	35	2.41
Börgermann et al.[73]	2013	Aortic valve replacement	Germany	808	9	1.11
Borst et al.[74]	2007	CEA	Netherlands	102	1	0.98
Borst et al.[75]	2001	CEA	Netherlands	599	20	3.34
Borstad et al.[76]	1992	Patients undergoing major gynecological surgery, laparotomy, vaginal repair, colposuspension. In procedures lasting more than a 30-min.	Norway	141	1	0.71
Boudriot et al.[77]	2011	CABG and sirolimus-eluting stenting	Germany	201	2	0.99
Bourke et al.[78]	2002	CEA	Australia	146	0	0
Braun et al.[79]	2002	Transcatheter closure of patent foramen ovale	Germany	276	0	0
Breuer et al.[80]	1983	CABG	United States	421	22	5.22
Brittenden et al.[81]	2000	CEA	Scotland	226	6	2.65
Broască et al.[82]	2013	lower limb revascularization	Romania	231	0	0
Brosig et al.[83]	2008	CEA	Germany	164	12	7.31
Budera et al.[84]	2012	Valve and/or coronary surgery	Czech Republic	224	6	2.68

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Supplementary Table 6 . Continued

Author	Year	Surgical procedure	Country	Sample size	Stroke no.	Stroke incidence (%)
Bull et al.[85]	1993	CABG	Canada	245	5	2.04
Camous et al.[86]	2014	Pulmonary endartectomy	France	207	3	1.45
Canaud et al.[87]	2011	Thoracic endovascular aortic repair	France	186	0	0
Cao et al.[88]	1997	CEA	Italy	469	15	2.91
Cao et al.[89]	2000	CEA	Italy	1,353	28	2.07
Carrier et al.[90]	1997	CABG	Canada	224	3	1.34
Castriota et al.[91]	2008	CAS with cardiopulmonary bypass	Italy	178	1	0.56
Chen et al.[92]	2009	Cardiac surgery with cardiopulmonary bypass	United States	122	6	4.92
Cieri et al.[93]	2008	CAS	Italy	223	7	3.14
Cimochowski et al.[94]	1997	CABG	United States	111	1	0.90
Cohen et al.[95]	1998	Valve and/or coronary surgery	Canada	115	2	1.74
Cooper et al.[96]	2013	Anaortic off-pump CABG	Australia	1,135	5	0.44
Coscas et al.[97]	2010	Open surgery for carotid stenosis	France	119	3	2.52
Crouch et al.[98]	2015	TAVI	Australia	114	3	2.63
Da Col et al.[99]	2008	Myocardial revascularization	Italy	257	1	0.39
Da Silva et al.[100]	1996	CEA	United Kingdom	108	4	3.70
Dake et al.[101]	1998	Endovascular repair of descending aortic aneurysm	United States	103	7	6.80
D'Angelo et al.[102]	2001	CEA	Italy	100	1	1
Darling et al.[103]	1998	CEA	United States	470	5	1.06
Darwazah et al.[104]	2010	Myocardial revascularization	Israel	350	0	0
M.Davies et al.[105]	1993	CEA	Australia	389	10	2.57
J.Davies et al.[106]	2016	SAVR or TAVR	United States	573	11	1.92
De Santis et al.[107]	2016	Carotid surgery	Italy	285	4	1.28
Debing et al.[108]	2007	CEA	Belgium	742	16	2.16
Debing et al.[109]	2011	CEA	Belgium	1,351	18	1.33
Deiwick et al.[110]	1997	Open heart surgery	Germany	101	14	13.86
Deng et al.[111]	2006	Coronary revascularization	China	179	1	0.60
Detter et al.[112]	2002	CABG	Germany	340	0	0
Devereaux et al.[113]	2011	Noncardiac surgeries in patients older than 45 yr	Multiple	432	1	0.23
Di Biase et al.[114]	2014	Catheter ablation of atrial fibrillation with radiofrequency	Multiple	428	2	0.47
Didier et al.[115]	2016	CEA	United States	25,626	86	0.34
Dinkel et al.[116]	1992	Carotid surgery	Germany	125	0	0
Donaldson et al.[117]	1993	CEA	United States	396	1	0.22
Dong et al.[118]	2016	CAS	China	154	9	5.84
Dong et al.[119]	2017	CAS	China	358	10	2.79
Dorigo et al.[120]	2009	CEA	Italy	3,324	19	0.47
Lam et al.[121]	2007	CAS	United States	133	4	2.96
Larsen et al.[122]	1988	Noncardiac noncarotid surgeries	Denmark	2,463	6	0.20
Lee et al.[123]	2013	CABG	Multiple	541	18	3.33
Lennard et al.[124]	1999	CEA	United Kingdom	252	4	1.59
Liapis et al.[125]	2001	CEA	Greece	308	7	2.07
Likosky et al.[126]	2003	CABG	United States	11,825	177	0.99
Linden et al.[127]	2007	Coronary revascularization	United States	611	39	6.38
Loponen et al.[128]	2003	CABG	Finland	1,318	34	2.58

Supplementary Table 6 . Continued

Author	Year	Surgical procedure	Country	Sample size	Stroke no.	Stroke incidence (%)
Love et al.[129]	2000	CEA	Australia	443	8	1.80
Lübke et al.[130]	2015	CEA	Germany	1,880	28	1.49
MacDonald et al.[131]	1998	CABG	Canada	100	6	6
Mandeville et al.[132]	2015	Bifurcation resection and interposition of a polytetrafluoroethylene graft and CEA	Belgium	153	4	2.61
Mattos et al.[133]	1992	CEA	United States	478	16	2.94
McCollum et al.[134]	1997	Carotid surgery	Multiple	709	15	2.11
McKhann et al.[135]	2002	CABG	United States	2,711	72	2.66
Mitchell et al.[136]	1999	Thoracic endovascular aortic repair	United States	103	7	6.80
Mukerji et al.[137]	2015	CEA	United Kingdom	728	17	2.33
Mullenix et al.[138]	2002	CEA	United States	267	6	2.24
Naylor et al.[139]	2000	CEA	United Kingdom	500	4	0.80
Newman et al.[140]	1996	CABG	United States	2,417	68	3.20
Nicholls et al.[141]	1985	CEA	United States	134	2	1.49
Nordanstig et al.[142]	2017	CEA	Sweeden	418	11	2.63
Ott et al.[143]	1980	CEA	United States	240	4	1.29
Pell et al.[144]	2004	CEA	Scotland	877	22	2.51
Radu et al.[145]	2013	CAS	Germany	279	6	2.15
Rafiq et al.[146]	2012	CABG	Denmark	194	10	3.09
Roach et al.[147]	1996	CABG	United States	2,108	63	2.99
Saini et al.[148]	2017	Minimally invasive surgical ablation for atrial fibrillation	United States	109	1	0.92
Salazar et al.[149]	2001	Cardiac surgery	United States	5,971	214	3.58
Salem et al.[150]	2011	CEA	United Kingdom	109	2	1.83
Samson et al.[151]	1998	CEA	United States	654	11	1.68
Sandison et al.[152]	2000	CEA	United Kingdom	333	8	2.40
Santo et al.[153]	2008	Cardiac surgery	Italy	925	9	0.97
Schmitz et al.[154]	2003	Cardiac surgery	Germany	582	8	1.37
Schneider et al.[155]	1997	CEA	United States	186	7	3.48
Schoenefeld et al.[156]	2012	CEA	Germany	540	19	3.52
Schoof et al.[157]	2007	CABG and/or valve surgery	Germany	2,797	67	2.40
Senay et al.[158]	2011	CABG	Turkey	3,248	32	0.99
Shapira et al.[159]	2006	CABG	United States	2,450	28	1.14
Shaw et al.[160]	1985	CABG	United Kingdom	312	15	4.81
Spes et al.[161]	2007	CAS	Germany	371	9	2.22
Stabile et al.[162]	2010	CAS	Italy	1,300	12	0.92
Subban et al.[163]	2016	TAVI	Australia	209	9	4.31
Suematsu et al.[164]	2000	CABG	Japan	179	6	3.35
Takach et al.[165]	1996	CEA	United States	248	2	0.75
Tatoulis et al.[166]	1999	Coronary revascularization	Australia	3,220	26	0.81
Trehan et al.[167]	1997	CABG	India	792	6	0.76
Trehan et al.[168]	2000	CABG	India	3,660	35	0.96
Verhoeven et al.[169]	2005	CEA	Netherlands	200	11	5.47
Veselka et al.[170]	2009	CAS	Czech Republic	176	2	0.93
Walker et al.[171]	1995	CEA	Multiple	825	15	1.82
Walkes et al.[172]	2002	CABG	United States	1,069	31	2.90

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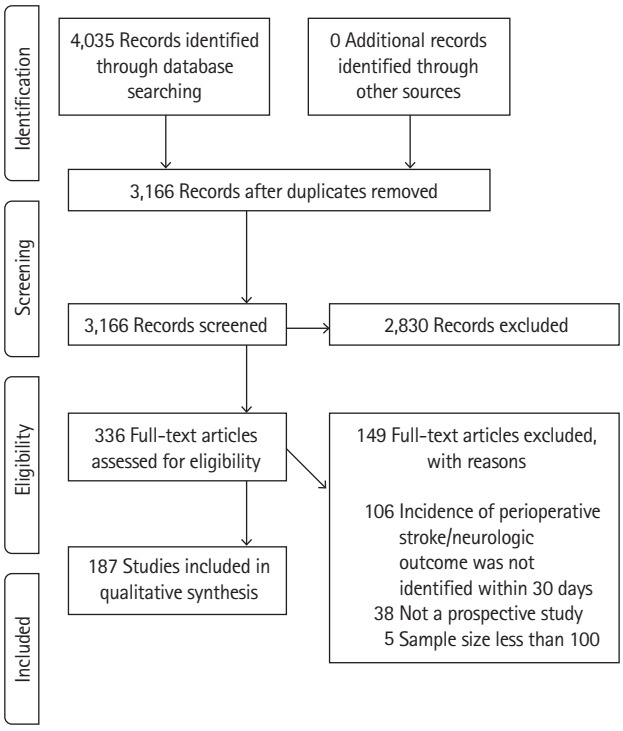
Supplementary Table 6 . Continued

Author	Year	Surgical procedure	Country	Sample size	Stroke no.	Stroke incidence (%)
Weimar et al.[173]	2012	Cox-Maze procedure	United States	212	2	0.94
Weinstein[174]	2001	CABG	United States	2,217	51	2.30
Wenaweser et al.[175]	2011	TAVI	Switzerland	256	9	3.52
Burns et al.[176]	1991	CEA	Australia	223	14	5.86
Wöhrle et al.[177]	2016	TAVI	Germany	235	5	2.13
Woelfle et al.[178]	2002	CEA	Germany	111	3	2.70
Wolman et al.[179]	1999	Cardiac and coronary surgery	United States	273	21	7.69
Wong et al.[180]	1999	CEA	Canada	184	8	4.35
Yadeau et al.[181]	2011	Ambulatory shoulder surgery	United States	1,169	0	0
Young et al.[182]	1996	CEA	United States	721	10	1.39
Zannetti et al.[183]	1999	CEA	Italy	1,305	13	1.00
Zarins et al.[184]	2009	CEA and CAS	United States	397	12	3.02
Zhang et al.[185]	2015	Aortic valve replacement	Germany	113	1	0.88
Ziemann et al.[186]	2017	Cardiac surgery	Germany	983	14	1.42
Zipfel et al.[187]	2008	Endovascular repair of abdominal aortic aneurysm	Germany	126	4	3.17

CABG, coronary artery bypass grafting; CEA, carotid endarterectomy; CAS, carotid artery stenting; eCEA, eversion carotid endarterectomy; TAVI, transcatheter aortic valve implantation; TAVR, transcatheter aortic valve replacement; SAVR, surgical aortic valve replacement.



Supplementary Figure 1. PRISMA 2009 flow diagram. Adapted from Moher et al.[188] PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

https://doi.org/10.5853/jos.2019.00304

Supplementary References

1. Abbas S, Riaz W, Khwaja IA, Iqbal M, Tufail Z, Waheed A. Mean arterial pressure and pulse pressure, influence on postoperative renal and neurological outcomes in elderly patients undergoing coronary revascularization. *Pak Heart J* 2015;48:194-199.
2. Aboyans V, Frank M, Nubret K, Lacroix P, Laskar M. Heart rate and pulse pressure at rest are major prognostic markers of early postoperative complications after coronary bypass surgery. *Eur J Cardiothorac Surg* 2008;33:971-976.
3. Abraham CZ, Chuter TA, Reilly LM, Okuhn SP, Pethan LK, Kerlan RB, et al. Abdominal aortic aneurysm repair with the Zenith stent graft: short to midterm results. *J Vasc Surg* 2002;36:217-225.
4. AbuRahma AF, Khan JH, Robinson PA, Saiedy S, Short YS, Boland JP, et al. Prospective randomized trial of carotid endarterectomy with primary closure and patch angioplasty with saphenous vein, jugular vein, and polytetrafluoroethylene: perioperative (30-day) results. *J Vasc Surg* 1996;24:998-1007.
5. Aburahma AF. Patch closure improves results with carotid endarterectomy. *Semin Vasc Surg* 2004;17:243-252.
6. AbuRahma AF, Bates MC, Eads K, Armistead L, Flaherty SK. Safety and efficacy of carotid angioplasty/stenting in 100 consecutive high surgical risk patients: immediate and long-term follow-up. *Vasc Endovascular Surg* 2008;42:433-439.
7. Aburahma AF, Stone PA, Hass SM, Dean LS, Habib J, Keiffer T, et al. Prospective randomized trial of routine versus selective shunting in carotid endarterectomy based on stump pressure. *J Vasc Surg* 2010;51:1133-1138.
8. AbuRahma AF, Abu-Halimah S, Hass SM, Nanjundappa A, Stone PA, Mousa A, et al. Carotid artery stenting outcomes are equivalent to carotid endarterectomy outcomes for patients with post-carotid endarterectomy stenosis. *J Vasc Surg* 2010;52:1180-1187.
9. AbuRahma AF, Stone PA, Welch CA, Hofeldt MJ, Hass SM, Perry W. Prospective study of carotid endarterectomy with modified polytetrafluoroethylene (ACUSEAL) patching: early and late results. *J Vasc Surg* 2005;41:789-793.
10. AbuRahma AF, Robinson PA, Hannay RS, Hudson J, Cutlip L. Prospective controlled study of carotid endarterectomy with hemashield patch: is it thrombogenic? *Vasc Surg* 2001;35:167-174.
11. AbuRahma AF, Stone PA, Flaherty SK, AbuRahma Z. Prospective randomized trial of ACUSEAL (Gore-Tex) versus Hemashield-Finesse patching during carotid endarterectomy: early results. *J Vasc Surg* 2007;45:881-884.
12. AbuRahma AF, Hannay RS, Khan JH, Robinson PA, Hudson JK, Davis EA. Prospective randomized study of carotid endarterectomy with polytetrafluoroethylene versus collagen-impregnated Dacron (Hemashield) patching: perioperative (30-day) results. *J Vasc Surg* 2002;35:125-130.
13. Aackerstaff RG, Jansen C, Moll FL. Carotid endarterectomy and intraoperative emboli detection: correlation of clinical, transcranial Doppler, and magnetic resonance findings. *Echocardiography* 1996;13:543-550.
14. Ad N, Henry L, Hunt S. The concomitant cryosurgical Cox-Maze procedure using Argon based cryoprobes: 12 month results. *J Cardiovasc Surg (Torino)* 2011;52:593-599.
15. Ad N, Holmes SD, Shuman DJ, Pritchard G, Massimiano PS. Minimally invasive mitral valve surgery without aortic cross-clamping and with femoral cannulation is not associated with increased risk of stroke compared with traditional mitral valve surgery: a propensity score-matched analysis. *Eur J Cardiothorac Surg* 2015;48:868-872.
16. 16. Ad N, Holmes SD, Massimiano PS, Pritchard G, Stone LE, Henry L. The effect of the Cox-maze procedure for atrial fibrillation concomitant to mitral and tricuspid valve surgery. *J Thorac Cardiovasc Surg* 2013;146:1426-1435.
17. 17. Ad N, Holmes SD, Rongione AJ, Massimiano PS, Fornaresio LM. Does surgical ablation energy source affect long-term success of the concomitant Cox Maze procedure? *Ann Thorac Surg* 2017;104:29-35.
18. Alcantara SD, Wuamett JC, Lantis JC 2nd, Ulkatan S, Bamberger P, Mendes D, et al. Outcomes of combined somatosensory evoked potential, motor evoked potential, and electroencephalography monitoring during carotid endarterectomy. *Ann Vasc Surg* 2014;28:665-672.
19. Alnasser S, Cheema AN, Simonato M, Barbanti M, Edwards J, Kornowski R, et al. Matched comparison of self-expanding transcatheter heart valves for the treatment of failed aortic surgical bioprosthesis: insights from the Valve-in-Valve International Data Registry (VIVID). *Circ Cardiovasc Interv* 2017;10:e004392.
20. Alonso-Coello P, Cook D, Xu SC, Sigamani A, Berwanger O, Sivakumaran S, et al. Predictors, prognosis, and management of new clinically important atrial fibrillation after noncardiac surgery: a prospective cohort study. *Anesth Analg* 2017;125:162-169.
21. Amato B, Compagna R, Amato M, Gallelli L, de Franciscis S, Serra R. Aterofisiol(®) in carotid plaque evolution. *Drug Des Devel Ther* 2015;9:3877-3884.
22. Ambrosii T, Şandru S, Belîi A. The prevalence of perioperative complications in patients with and without obstructive sleep apnoea: a prospective cohort study. *Rom J Anaesth Intensive Care* 2016;23:103-110.

23. Ansel GM, Hopkins LN, Jaff MR, Rubino P, Bacharach JM, Scheinert D, et al. Safety and effectiveness of the INVATEC MO.MA proximal cerebral protection device during carotid artery stenting: results from the ARMOUR pivotal trial. *Catheter Cardiovasc Interv* 2010;76:1-8.
24. Antunes PE, Ferrão de Oliveira J, Antunes MJ. Non-cardioplegic coronary surgery in patients with severe left ventricular dysfunction. *Eur J Cardiothorac Surg* 1999;16:331-336.
25. Anzola GP, Morandi E, Casilli F, Onorato E. Does transcatheter closure of patent foramen ovale really "shut the door?": a prospective study with transcranial Doppler. *Stroke* 2004;35:2140-2144.
26. Arnaoutoglou E, Kouvelos G, Tzimas P, Laou E, Bouris V, Papadopoulos G, et al. Relationship between normal preoperative white blood cell count and major adverse events after endovascular repair for abdominal aortic aneurysm: results of a pilot study. *J Clin Anesth* 2017;36:201-205.
27. Aronson S. Clevidipine in the treatment of perioperative hypertension: assessing safety events in the ECLIPSE trials. *Expert Rev Cardiovasc Ther* 2009;7:465-472.
28. Ascher E, Markevich N, Hingorani AP, Kallakuri S, Gunduz Y. Internal carotid artery flow volume measurement and other intraoperative duplex scanning parameters as predictors of stroke after carotid endarterectomy. *J Vasc Surg* 2002;35:439-444.
29. Ascione R, Reeves BC, Pano M, Angelini GD. Trainees operating on high-risk patients without cardiopulmonary bypass: a high-risk strategy? *Ann Thorac Surg* 2004;78:26-33.
30. Ascione R, Ghosh A, Rogers CA, Cohen A, Monk C, Angelini GD. In-hospital patients exposed to clopidogrel before coronary artery bypass graft surgery: a word of caution. *Ann Thorac Surg* 2005;79:1210-1216.
31. Ascione R, Nason G, Al-Ruzzeh S, Ko C, Ciulli F, Angelini GD. Coronary revascularization with or without cardiopulmonary bypass in patients with preoperative nondialysis-dependent renal insufficiency. *Ann Thorac Surg* 2001;72:2020-2025.
32. Ascione R, Reeves BC, Chamberlain MH, Ghosh AK, Lim KH, Angelini GD. Predictors of stroke in the modern era of coronary artery bypass grafting: a case control study. *Ann Thorac Surg* 2002;74:474-480.
33. Asimakopoulos G, Karagounis AP, Valencia O, Rose D, Niranjan G, Chandrasekaran V. How safe is it to train residents to perform off-pump coronary artery bypass surgery? *Ann Thorac Surg* 2006;81:568-572.
34. Assadian A, Knöbl P, Hübl W, Senekowitsch C, Klingler A, Pfaffelmeyer N, et al. Safety and efficacy of intravenous enoxaparin for carotid endarterectomy: a prospective randomized pilot trial. *J Vasc Surg* 2008;47:537-542.
35. Assadian A, Rotter R, Assadian O, Senekowitsch C, Hagmüller GW, Hübl W. Homocysteine and early re-stenosis after carotid eversion endarterectomy. *Eur J Vasc Endovasc Surg* 2007;33:144-148.
36. Assadian A, Senekowitsch C, Assadian O, Ptakovsky H, Hagmüller GW. Perioperative morbidity and mortality of carotid artery surgery under loco-regional anaesthesia. *Vasa* 2005;34:41-45.
37. Asteriou C, Antonitsis P, Argiriadou H, Deliopoulos A, Konstantinou D, Foroulis C, et al. Minimal extracorporeal circulation reduces the incidence of postoperative major adverse events after elective coronary artery bypass grafting in high-risk patients: a single-institutional prospective randomized study. *Perfusion* 2013;28:350-356.
38. Avinée G, Durand E, Elhatimi S, Bauer F, Glinel B, Dacher JN, et al. Trends over the past 4 years in population characteristics, 30-day outcomes and 1-year survival in patients treated with transcatheter aortic valve implantation. *Arch Cardiovasc Dis* 2016;109:457-464.
39. Axisa B, Fishwick G, Bolia A, Thompson MM, London NJ, Bell PR, et al. Complications following peripheral angioplasty. *Ann R Coll Surg Engl* 2002;84:39-42.
40. Ayad SW. Aspiration versus no aspiration during primary PCI for ST-segment elevation myocardial infarction. *Egypt Hear t J* 2016;68:147-152.
41. Baklanov DV, Marcu CB, Juhasz DF, Caracciolo EA, Chawarski MC, Donohue TJ. Coronary stenting is safe and effective in a high-risk octogenarian patient cohort. *Conn Med* 2006;70:15-19.
42. Ballotta E, Meneghetti G, Da Giau G, Manara R, Saladini M, Baracchini C. Carotid endarterectomy within 2 weeks of minor ischemic stroke: a prospective study. *J Vasc Surg* 2008;48:595-600.
43. Ballotta E, Thiene G, Baracchini C, Ermani M, Militello C, Da Giau G, et al. Surgical vs medical treatment for isolated internal carotid artery elongation with coiling or kinking in symptomatic patients: a prospective randomized clinical study. *J Vasc Surg* 2005;42:838-846.
44. Ballotta E, Manara R, Meneghetti G, Ermani M, Da Giau G, Baracchini C. Diabetes and asymptomatic carotid stenosis: does diabetic disease influence the outcome of carotid endarterectomy?: a 10-year single center experience. *Surgery* 2008;143:519-525.
45. Ballotta E, Da Giau G, Baracchini C, Manara R. Carotid endarterectomy in high-risk patients: a challenge for endovascular procedure protocols. *Surgery* 2004;135:74-80.
46. Ballotta E, Da Giau G. Selective shunting with eversion carotid endarterectomy. *J Vasc Surg* 2003;38:1045-1050.

https://doi.org/10.5853/jos.2019.00304

47. Ballotta E, Da Giau G, Saladini M, Abbruzzese E, Renon L, Toniato A. Carotid endarterectomy with patch closure versus carotid eversion endarterectomy and reimplantation: a prospective randomized study. *Surgery* 1999;125:271-279.
48. Ballotta E, Da Giau G, Renon L. Is diabetes mellitus a risk factor for carotid endarterectomy?: a prospective study. *Surgery* 2001;129:146-152.
49. Ballotta E, Toniato A, Da Giau G, Lorenzetti R, Da Roit A, Baracchini C. Durability of eversion carotid endarterectomy. *J Vasc Surg* 2014;59:1274-1281.
50. Banach M, Kazmierski J, Kowman M, Okonski PK, Sobow T, Kloszewska I, et al. Atrial fibrillation as a nonpsychiatric predictor of delirium after cardiac surgery: a pilot study. *Med Sci Monit* 2008;14:CR286-CR291.
51. Baracchini C, Saladini M, Lorenzetti R, Manara R, Da Giau G, Ballotta E. Gender-based outcomes after eversion carotid endarterectomy from 1998 to 2009. *J Vasc Surg* 2012;55:338-345.
52. Bardia A, Khabbaz K, Mueller A, Mathur P, Novack V, Talmor D, et al. The association between preoperative hemoglobin A1C and postoperative glycemic variability on 30-day major adverse outcomes following isolated cardiac valvular surgery. *Anesth Analg* 2017;124:16-22.
53. Baribeau Y, Westbrook BM, Charlesworth DC, Hearne MJ, Bradley WA, Maloney CT. Brachial gradient in cardiac surgical patients. *Circulation* 2002;106(12 Suppl 1):I11-I13.
54. Barnes RW, Marszalek PB. Asymptomatic carotid disease in the cardiovascular surgical patient: is prophylactic endarterectomy necessary? *Stroke* 1981;12:497-500.
55. Barnes RW, Liebman PR, Marszalek PB, Kirk CL, Goldman MH. The natural history of asymptomatic carotid disease in patients undergoing cardiovascular surgery. *Surgery* 1981;90:1075-1083.
56. Basic J, Assadian A, Strassegger J, Senekowitsch C, Wickenhauser G, Koulas S, et al. Degree of contralateral carotid stenosis improves preoperative risk stratification of patients with asymptomatic ipsilateral carotid stenosis. *J Vasc Surg* 2016;63:82-88.
57. Bastounis E, Filis K, Georgopoulos S, Klonaris C, Xeromeritis N, Papalambros E. Current practice: routine use of shunting in carotid endarterectomy: cost reduction and surgical training. *Int Angiol* 2001;20:218-224.
58. Batchelder A, Hunter J, Cairns V, Sandford R, Munshi A, Naylor AR. Dual antiplatelet therapy prior to expedited carotid surgery reduces recurrent events prior to surgery without significantly increasing peri-operative bleeding complications. *Eur J Vasc Endovasc Surg* 2015;50:412-419.
59. Bechtel JF, Bartels C, Hopstein S, Horsch S. Carotid endarterectomy prior to major abdominal aortic surgery. *J Cardiovasc Surg (Torino)* 2000;41:269-273.
60. Becquemin JP, Ben El Kadi H, Desgranges P, Kobeiter H. Carotid stenting versus carotid surgery: a prospective cohort study. *J Endovasc Ther* 2003;10:687-694.
61. Bellomo R, Goldsmith D, Russell S, Uchino S. Postoperative serious adverse events in a teaching hospital: a prospective study. *Med J Aust* 2002;176:216-218.
62. Bellomo R, Goldsmith D, Uchino S, Buckmaster J, Hart G, Opdam H, et al. Prospective controlled trial of effect of medical emergency team on postoperative morbidity and mortality rates. *Crit Care Med* 2004;32:916-921.
63. Berens ES, Kouchoukos NT, Murphy SF, Wareing TH. Preoperative carotid artery screening in elderly patients undergoing cardiac surgery. *J Vasc Surg* 1992;15:313-323.
64. Bernhardt M, Pflugrad H, Goldbecker A, Barg-Hock H, Knitsch W, Klempnauer J, et al. Central nervous system complications after liver transplantation: common but mostly transient phenomena. *Liver Transpl* 2015;21:224-232.
65. Bertolini P, Santini F, Montalbano G, Pessotto R, Mazzucco A. Single aortic cross-clamp technique in coronary surgery: a prospective randomized study. *Eur J Cardiothorac Surg* 1997;12:413-419.
66. Berwanger O, Le Manach Y, Suzumura EA, Biccard B, Srinathan SK, Szczeklik W, et al. Association between pre-operative statin use and major cardiovascular complications among patients undergoing non-cardiac surgery: the VISION study. *Eur Heart J* 2016;37:177-185.
67. Bilecen S, Peelen LM, Kalkman CJ, Spanjersberg AJ, Moons KG, Nierich AP. Fibrinogen concentrate therapy in complex cardiac surgery. *J Cardiothorac Vasc Anesth* 2013;27:12-17.
68. Bilfinger TV, Reda H, Giron F, Seifert FC, Ricotta JJ. Coronary and carotid operations under prospective standardized conditions: incidence and outcome. *Ann Thorac Surg* 2000;69:1792-1798.
69. Binder RK, Stortecky S, Heg D, Tueller D, Jeger R, Toggweiler S, et al. Procedural results and clinical outcomes of transcatheter aortic valve implantation in Switzerland: an observational cohort study of Sapien 3 versus Sapien XT Transcatheter Heart Valves. *Circ Cardiovasc Interv* 2015;8:e002653.
70. Birincioğlu CL, Bayazit M, Ulus AT, Bardakçi H, Küçüker SA, Taşdemir O. Carotid disease is a risk factor for stroke in coronary bypass operations. *J Card Surg* 1999;14:417-423.
71. Bishu K, Suri RM, Nkomo VT, Kane GC, Greason KL, Reeder GS, et al. Prognostic impact of pulmonary artery systolic pressure in patients undergoing transcatheter aortic valve replacement for aortic stenosis. *Am J Cardiol* 2014;114:1562-1567.

72. Boehm J, Grammer JB, Lehnert F, Dietrich W, Wagenpfeil S, Wildhirt SM, et al. Factor V Leiden does not affect bleeding in aprotinin recipients after cardiopulmonary bypass. *Anesthesiology* 2007;106:681-686.
73. Borgermann J, Furukawa N, Aboud A, Renner A, Benzinger M, Hakim-Meibodi K, et al. Minimally invasive versus standard approach aortic valve replacement: a propensity score analysis of 808 patients. 2003 Annual Scientific Meeting of Innovations: Technology and Techniques in Cardiothoracic and Vascular Surgery; 2003 Jun 12-15; Prague, CZ.
74. De Borst GJ, Hilgevoord AA, de Vries JP, van der Mee M, Moll FL, van de Pavoordt HD, et al. Influence of antiplatelet therapy on cerebral micro-emboli after carotid endarterectomy using postoperative transcranial Doppler monitoring. *Eur J Vasc Endovasc Surg* 2007;34:135-142.
75. de Borst GJ, Moll FL, van de Pavoordt HD, Mauser HW, Kelder JC, Ackerstaf RG. Stroke from carotid endarterectomy: when and how to reduce perioperative stroke rate? *Eur J Vasc Endovasc Surg* 2001;21:484-489.
76. Borstad E, Urdal K, Handeland G, Abildgaard U. Comparison of low molecular weight heparin vs. unfractionated heparin in gynecological surgery. II: reduced dose of low molecular weight heparin. *Acta Obstet Gynecol Scand* 1992;71:471-475.
77. Boudriot E, Thiele H, Walther T, Liebetrau C, Boeckstegers P, Pohl T, et al. Randomized comparison of percutaneous coronary intervention with sirolimus-eluting stents versus coronary artery bypass grafting in unprotected left main stem stenosis. *J Am Coll Cardiol* 2011;57:538-545.
78. Bourke BM, Crimmins DS. Early control of the distal internal carotid artery during endarterectomy: achievability and results. *J Vasc Surg* 2002;36:70-74.
79. Braun MU, Fassbender D, Schoen SP, Haass M, Schraeder R, Scholtz W, et al. Transcatheter closure of patent foramen ovale in patients with cerebral ischemia. *J Am Coll Cardiol* 2002;39:2019-2025.
80. Breuer AC, Furlan AJ, Hanson MR, Lederman RJ, Loop FD, Cosgrove DM, et al. Central nervous system complications of coronary artery bypass graft surgery: prospective analysis of 421 patients. *Stroke* 1983;14:682-687.
81. Brittenden J, Bradbury AW. Are we still performing inappropriate carotid endarterectomy? *Eur J Vasc Endovasc Surg* 2000;20:158-162.
82. Broască M, Nedelcu DE. Study on the chronic antithrombotic treatment after surgical revascularizations in the peripheral arterial disease. *Farmacia* 2013;61:492-502.
83. Brosig T, Hoinkes A, Seitz RJ, Sandmann W, Huber R, Siebler M. Ultrasound turbulence index during thromboendarterectomy predicts postoperative cerebral microembolism. *Cerebrovasc Dis* 2008;26:87-92.
84. Budera P, Straka Z, Osmančík P, Vaněk T, Jelínek Š, Hlavička J, et al. Comparison of cardiac surgery with left atrial surgical ablation vs. cardiac surgery without atrial ablation in patients with coronary and/or valvular heart disease plus atrial fibrillation: final results of the PRAGUE-12 randomized multicentre study. *Eur Heart J* 2012;33:2644-2652.
85. Bull DA, Neumayer LA, Hunter GC, Keksz J, Sethi GK, McIntyre KE, et al. Risk factors for stroke in patients undergoing coronary artery bypass grafting. *Cardiovasc Surg* 1993;1:182-185.
86. Camous J, Decrombecque T, Louvain-Quintard V, Doubine S, Dartevelle P, Stéphan F. Outcomes of patients with antiphospholipid syndrome after pulmonary endarterectomy. *Eur J Cardiothorac Surg* 2014;46:116-120.
87. Canaud L, Alric P, Gandet T, Albat B, Marty-Ané C, Berthet JP. Surgical conversion after thoracic endovascular aortic repair. *J Thorac Cardiovasc Surg* 2011;142:1027-1031.
88. Cao P, Giordano G, De Rango P, Caporali S, Lenti M, Ricci S, et al. Eversion versus conventional carotid endarterectomy: a prospective study. *Eur J Vasc Endovasc Surg* 1997;14:96-104.
89. Cao P, Giordano G, De Rango P, Zannetti S, Chiesa R, Coppi G, et al. Eversion versus conventional carotid endarterectomy: late results of a prospective multicenter randomized trial. *J Vasc Surg* 2000;31(1 Pt 1):19-30.
90. Carrier M, Pelletier LC, Searle NR. Does retrograde administration of blood cardioplegia improve myocardial protection during first operation for coronary artery bypass grafting? *Ann Thorac Surg* 1997;64:1256-1262.
91. Castriota F, de Campos Martins EC, Setacci C, Manetti R, Khamis H, Spagnolo B, et al. Cutting balloon angioplasty in percutaneous carotid interventions. *J Endovasc Ther* 2008;15:655-662.
92. Chen J, Zimmerman RA, Jarvik GP, Nord AS, Clancy RR, Wernovsky G, et al. Perioperative stroke in infants undergoing open heart operations for congenital heart disease. *Ann Thorac Surg* 2009;88:823-829.
93. Cieri E, De Rango P, Maccaroni MR, Spaccatini A, Caso V, Cao P. Is haemodynamic depression during carotid stenting a predictor of peri-procedural complications? *Eur J Vasc Endovasc Surg* 2008;35:399-404.
94. Cimochowski GE, Harostock MD, Foldes PJ. Minimal operative mortality in patients undergoing coronary artery bypass with significant left ventricular dysfunction by maximization of metabolic and mechanical support. *J Thorac Cardiovasc Surg* 1997;113:655-666.
95. Cohen G, Ivanov J, Weisel RD, Rao V, Mohabeer MK, Mickle

https://doi.org/10.5853/jos.2019.00304

DA. Aprotinin and dipyridamole for the safe reduction of postoperative blood loss. *Ann Thorac Surg* 1998;65:674-683.
96. Cooper EA, Edelman JJ, Black D, Brereton RJ, Ross DE, Bannon PG, et al. Anaortic off-pump coronary artery bypass grafting in the elderly and very elderly. *Heart Lung Circ* 2013;22:989-995.
97. Coscas R, Rhissassi B, Gruet-Coquet N, Couture T, de Tymowski C, Chiche L, et al. Open surgery remains a valid option for the treatment of recurrent carotid stenosis. *J Vasc Surg* 2010;51:1124-1132.
98. Crouch G, Sinhal A, Rice G, Baker R, Bennetts J. Long term outcomes of an Australian TAVI program: better than PARTNER? *Heart Lung Circ* 2015;24 Suppl 1:e16.
99. Da Col U, Di Bella I, Pasquino S, Ramoni E, Paris M, Stracci F, et al. Off-pump technique: a systematic alternative for myocardial revascularization? *J Cardiovasc Med (Hagerstown)* 2008;9:899-904.
100. Da Silva AF, McCollum P, Szymanska T, de Cossart L. Prospective study of carotid endarterectomy and contralateral carotid occlusion. *Br J Surg* 1996;83:1370-1372.
101. Dake MD, Miller DC, Mitchell RS, Semba CP, Moore KA, Sakai T. The "first generation" of endovascular stent-grafts for patients with aneurysms of the descending thoracic aorta. *J Thorac Cardiovasc Surg* 1998;116:689-704.
102. D'Angelo V, Catapano G, Bozzini V, Catapano D, De Vivo P, Del Gaudio A, et al. Propofol EEG burst suppression in carotid endarterectomy. *J Neurosurg Sci* 2001;45:157-162.
103. Darling RC 3rd, Dylewski M, Chang BB, Paty PS, Kreienberg PB, Lloyd WE, et al. Combined carotid endarterectomy and coronary artery bypass grafting does not increase the risk of perioperative stroke. *Cardiovasc Surg* 1998;6:448-452.
104. Darwazah AK, Osman M, Sharabati B. Use of off-pump coronary artery bypass surgery among patients with malignant disease. *J Card Surg* 2010;25:1-4.
105. Davies MJ, Mooney PH, Scott DA, Silbert BS, Cook RJ. Neurologic changes during carotid endarterectomy under cervical block predict a high risk of postoperative stroke. *Anesthesiology* 1993;78:829-833.
106. Davies JE Jr, McAlexander WW, Sasse MF, Leesar MA, Melby SJ, Singh SP, et al. Impact of transcatheter aortic valve replacement on surgical volumes and outcomes in a tertiary academic cardiac surgical practice. *J Am Coll Surg* 2016;222:645-655.
107. De Santis F, Chaves Brait CM, Pattaro C, Cesareo V, Di Cintio V. A prospective nonrandomized study on carotid surgery performed under general anesthesia without intraoperative cerebral monitoring. *J Stroke Cerebrovasc Dis* 2016;25:136-143.
108. Debing E, Van den Brande P. Carotid endarterectomy in the elderly: are the patient characteristics, the early outcome, and the predictors the same as those in younger patients? *Surg Neurol* 2007;67:467-471.
109. Debing E, Aerden D, van den Brande P. Diabetes mellitus is a predictor for early adverse outcome after carotid endarterectomy. *Vasc Endovascular Surg* 2011;45:28-32.
110. Deiwick M, Tandler R, Möllhoff T, Kerber S, Rötker J, Roeder N, et al. Heart surgery in patients aged eighty years and above: determinants of morbidity and mortality. *Thorac Cardiovasc Surg* 1997;45:119-126.
111. Deng Y, Sun Z, Paterson HS. Total arterial revascularisation in left ventricular dysfunction. *J Huazhong Univ Sci Technolog Med Sci* 2006;26:82-85.
112. Detter C, Reichenspurner H, Boehm DH, Thalhammer M, Raptis P, Schütz A, et al. Minimally invasive direct coronary artery bypass grafting (MIDCAB) and off-pump coronary artery bypass grafting (OPCAB): two techniques for beating heart surgery. *Heart Surg Forum* 2002;5:157-162.
113. VISION Pilot Study Investigators, Devereaux PJ, Bradley D, Chan MT, Walsh M, Villar JC, et al. An international prospective cohort study evaluating major vascular complications among patients undergoing noncardiac surgery: the VISION Pilot Study. *Open Med* 2011;5:e193-e200.
114. Di Biase L, Gaita F, Toso E, Santangeli P, Mohanty P, Rutledge N, et al. Does periprocedural anticoagulation management of atrial fibrillation affect the prevalence of silent thromboembolic lesion detected by diffusion cerebral magnetic resonance imaging in patients undergoing radiofrequency atrial fibrillation ablation with open irrigated catheters?: results from a prospective multicenter study. *Heart Rhythm* 2014;11:791-798.
115. Didier R, Gaglia MA Jr, Koifman E, Kiramijyan S, Negi SI, Omar AF, et al. Cerebrovascular accidents after percutaneous coronary interventions from 2002 to 2014: incidence, outcomes, and associated variables. *Am Heart J* 2016;172:80-87.
116. Dinkel M, Schweiger H, Goerlitz P. Monitoring during carotid surgery: somatosensory evoked potentials vs. carotid stump pressure. *J Neurosurg Anesthesiol* 1992;4:167-175.
117. Donaldson MC, Ivarsson BL, Mannick JA, Whittemore AD. Impact of completion angiography on operative conduct and results of carotid endarterectomy. *Ann Surg* 1993;217:682-687.
118. Dong H, Jiang X, Peng M, Zou Y, Che W, Qian H, et al. The interval between carotid artery stenting and open heart surgery is related to perioperative complications. *Catheter Cardiovasc Interv* 2016;87 Suppl 1:564-569.
119. Dong S, Peng Z, Tao Y, Huo Y, Zhou H. Metabolic syndrome is

associated with increased risk of short-term post-procedural complications after carotid artery stenting. *Neurol Sci* 2017;38:1933-1939.
120. Dorigo W, Pulli R, Marek J, Troisi N, Pratesi G, Innocenti AA, et al. Carotid endarterectomy in female patients. *J Vasc Surg* 2009;50:1301-1307.
121. Lam RC, Lin SC, DeRubertis B, Hynecek R, Kent KC, Faries PL. The impact of increasing age on anatomic factors affecting carotid angioplasty and stenting. *J Vasc Surg* 2007;45:875-880.
122. Larsen SF, Zaric D, Boysen G. Postoperative cerebrovascular accidents in general surgery. *Acta Anaesthesiol Scand* 1988;32:698-701.
123. Lee JD, Bonaros N, Hong PT, Kofler M, Srivastava M, Herr DL, et al. Factors influencing hospital length of stay after robotic totally endoscopic coronary artery bypass grafting. *Ann Thorac Surg* 2013;95:813-818.
124. Lennard N, Smith JL, Gaunt ME, Abbott RJ, London NJ, Bell PR, et al. A policy of quality control assessment helps to reduce the risk of intraoperative stroke during carotid endarterectomy. *Eur J Vasc Endovasc Surg* 1999;17:234-240.
125. Liapis CD, Kakisis JD, Kostakis AG. Recurrent carotid artery stenosis: natural history and predisposing factors: a long-term follow-up study. *Int Angiol* 2001;20:330-336.
126. Likosky DS, Leavitt BJ, Marrin CA, Malenka DJ, Reeves AG, Weintraub RM, et al. Intra- and postoperative predictors of stroke after coronary artery bypass grafting. *Ann Thorac Surg* 2003;76:428-435.
127. Van der Linden J, Bergman P, Hadjinikolaou L. The topography of aortic atherosclerosis enhances its precision as a predictor of stroke. *Ann Thorac Surg* 2007;83:2087-2092.
128. Loponen P, Taskinen P, Laakkonen E, Nissinen J, Luther M, Wistbacka JO. Perioperative stroke in coronary artery bypass patients. *Scand J Surg* 2003;92:148-155.
129. Love A, Hollyoak MA. Carotid endarterectomy and local anaesthesia: reducing the disasters. *Cardiovasc Surg* 2000;8:429-435.
130. Lübke T, Ahmad W, Koushk Jalali B, Brunkwall J. Gender-based 30-day and long-term outcomes after carotid endarterectomy. *Vasa* 2015;44:289-295.
131. MacDonald P, Stadnyk K, Cossett J, Klassen G, Johnstone D, Rockwood K. Outcomes of coronary artery bypass surgery in elderly people. *Can J Cardiol* 1998;14:1215-1222.
132. Mandeville Y, Canovai E, Diebels I, Suy R, De Vleeschauwer P. Carotid bifurcation resection and interposition of a polytetrafluorethylene graft (BRIG) for carotid disease: a retrospective study of 153 consecutive procedures. *Ann Vasc Surg* 2015;29:1589-1597.
133. Mattos MA, Hodgson KJ, Londrey GL, Barkmeier LD, Ramsey DE, Garfield M, et al. Carotid endarterectomy: operative risks, recurrent stenosis, and long-term stroke rates in a modern series. *J Cardiovasc Surg (Torino)* 1992;33:387-400.
134. McCollum PT, da Silva A, Ridler BD, de Cossart L. Carotid endarterectomy in the U.K. and Ireland: audit of 30-day outcome. The Audit Committee for the Vascular Surgical Society. *Eur J Vasc Endovasc Surg* 1997;14:386-391.
135. McKhann GM, Grega MA, Borowicz LM Jr, Bechamps M, Selnes OA, Baumgartner WA, et al. Encephalopathy and stroke after coronary artery bypass grafting: incidence, consequences, and prediction. *Arch Neurol* 2002;59:1422-1428.
136. Mitchell RS, Miller DC, Dake MD, Semba CP, Moore KA, Sakai T. Thoracic aortic aneurysm repair with an endovascular stent graft: the "first generation". *Ann Thorac Surg* 1999;67:1971-1980.
137. Mukerji N, Manjunath Prasad KS, Vivar R, Mendelow AD. Carotid endarterectomy: safe and effective in a neurosurgeon's hands: a 25-year single-surgeon experience. *World Neurosurg* 2015;83:74-79.
138. Mullenix PS, Andersen CA, Olsen SB, Tollefson DF. Carotid endarterectomy remains the gold standard. *Am J Surg* 2002;183:580-583.
139. Naylor AR, Hayes PD, Allroggen H, Lennard N, Gaunt ME, Thompson MM, et al. Reducing the risk of carotid surgery: a 7-year audit of the role of monitoring and quality control assessment. *J Vasc Surg* 2000;32:750-759.
140. Newman MF, Wolman R, Kanchuger M, Marschall K, Mora-Mangano C, Roach G, et al. Multicenter preoperative stroke risk index for patients undergoing coronary artery bypass graft surgery. Multicenter Study of Perioperative Ischemia (McSPI) Research Group. *Circulation* 1996;94(9 Suppl):II74-II80.
141. Nicholls SC, Phillips DJ, Bergelin RO, Beach KW, Primozich JF, Strandness DE Jr. Carotid endarterectomy: relationship of outcome to early restenosis. *J Vasc Surg* 1985;2:375-381.
142. Nordanstig A, Rosengren L, Strömberg S, Österberg K, Karlsson L, Bergström G, et al. Editor's choice: very urgent carotid endarterectomy is associated with an increased procedural risk: the carotid alarm study. *Eur J Vasc Endovasc Surg* 2017;54:278-286.
143. Ott DA, Cooley DA, Chapa L, Coelho A. Carotid endarterectomy without temporary intraluminal shunt: study of 309 consecutive operations. *Ann Surg* 1980;191:708-714.
144. Pell JP, Slack R, Dennis M, Welch G. Improvements in carotid endarterectomy in Scotland: results of a national prospective survey. *Scott Med J* 2004;49:53-56.
145. Radu H, Bertog SC, Robertson G, Franke J, Rabe K, Hornung M, et al. Long-term results after carotid stent implantation. *J*

https://doi.org/10.5853/jos.2019.00304

Interv Cardiol 2013;26:613-622.
146. Rafiq S, Johansson PI, Ostrowski SR, Stissing T, Steinbrüchel DA. Hypercoagulability in patients undergoing coronary artery bypass grafting: prevalence, patient characteristics and postoperative outcome. *Eur J Cardiothorac Surg* 2012;41:550-555.
147. Roach GW, Kanchuger M, Mangano CM, Newman M, Nussmeier N, Wolman R, et al. Adverse cerebral outcomes after coronary bypass surgery: Multicenter Study of Perioperative Ischemia Research Group and the Ischemia Research and Education Foundation Investigators. *N Engl J Med* 1996;335:1857-1863.
148. Saini A, Hu YL, Kasirajan V, Han FT, Khan MZ, Wolfe L, et al. Long-term outcomes of minimally invasive surgical ablation for atrial fibrillation: a single-center experience. *Heart Rhythm* 2017;14:1281-1288.
149. Salazar JD, Wityk RJ, Grega MA, Borowicz LM, Doty JR, Petrofski JA, et al. Stroke after cardiac surgery: short- and long-term outcomes. *Ann Thorac Surg* 2001;72:1195-1202.
150. Salem MK, Sayers RD, Bown MJ, Eveson DJ, Robinson TG, Naylor AR. Rapid access carotid endarterectomy can be performed in the hyperacute period without a significant increase in procedural risks. *Eur J Vasc Endovasc Surg* 2011;41:222-228.
151. Samson RH, Showalter DP, Yunis JP. Routine carotid endarterectomy without a shunt, even in the presence of a contralateral occlusion. *Cardiovasc Surg* 1998;6:475-484.
152. Sandison AJ, Wood CH, Padayachee TS, Colchester AC, Taylor PR. Cost-effective carotid endarterectomy. *Br J Surg* 2000;87:323-327.
153. De Santo LS, Bancone C, Santarpino G, Romano G, De Feo M, Scardone M, et al. Microbiologically documented nosocomial infections after cardiac surgery: an 18-month prospective tertiary care centre report. *Eur J Cardiothorac Surg* 2008;33:666-672.
154. Schmitz C, Weinreich S, White J, Oengoeren I, Schneider R, Schneider D, et al. Can particulate extraction from the ascending aorta reduce neurologic injury in cardiac surgery? *J Thorac Cardiovasc Surg* 2003;126:1829-1838.
155. Schneider JR, Droste JS, Golan JF. Impact of carotid endarterectomy critical pathway on surgical outcome and hospital stay. *Vasc Endovascular Surg* 1997;31:685-692.
156. Schoenefeld E, Donas K, Radicke A, Osada N, Austermann M, Torsello G. Perioperative use of aspirin for patients undergoing carotid endarterectomy. *Vasa* 2012;41:282-287.
157. Schoof J, Lubahn W, Baeumer M, Kross R, Wallesch CW, Kozian A, et al. Impaired cerebral autoregulation distal to carotid stenosis/occlusion is associated with increased risk of stroke at cardiac surgery with cardiopulmonary bypass. *J Thorac Cardiovasc Surg* 2007;134:690-696.
158. Senay S, Toraman F, Akgün Y, Aydin E, Karabulut H, Alhan C, et al. Stroke after coronary bypass surgery is mainly related to diffuse atherosclerotic disease. *Heart Surg Forum* 2011;14:E366-E372.
159. Shapira OM, Hunter CT, Anter E, Bao Y, DeAndrade K, Lazar HL, et al. Coronary artery bypass grafting in patients with severe left ventricular dysfunction: early and mid-term outcomes. *J Card Surg* 2006;21:225-232.
160. Shaw PJ, Bates D, Cartlidge NE, Heaviside D, Julian DG, Shaw DA. Early neurological complications of coronary artery bypass surgery. *Br Med J (Clin Res Ed)* 1985;291:1384-1387.
161. Spes CH, Schwende A, Beier F, Hug M, Hein R, Strohm H, et al. Short- and long-term outcome after carotid artery stenting with neuroprotection: single-center experience within a prospective registry. *Clin Res Cardiol* 2007;96:812-821.
162. Stabile E, Salemme L, Sorropago G, Tesorio T, Nammas W, Miranda M, et al. Proximal endovascular occlusion for carotid artery stenting: results from a prospective registry of 1,300 patients. *J Am Coll Cardiol* 2010;55:1661-1667.
163. Subban V, Murdoch D, Savage ML, Crowhurst J, Saireddy R, Poon KK, et al. Outcomes of transcatheter aortic valve implantation in high surgical risk and inoperable patients with aortic stenosis: a single Australian Centre experience. *Intern Med J* 2016;46:42-51.
164. Suematsu Y, Nakano K, Sasako Y, Kobayashi J, Takamoto S. Strategies for CABG patients with carotid artery disease and perioperative neurological complications. *Heart Vessels* 2000;15:129-134.
165. Takach TJ, Ott DA, Reul GJ, Duncan JM, Livesay JJ, Cooley DA. Carotid endarterectomy: results in asymptomatic and symptomatic patients. *Tex Heart Inst J* 1996;23:42-44.
166. Tatoulis J, Buxton BF, Fuller JA, Royse AG. Total arterial coronary revascularization: techniques and results in 3,220 patients. *Ann Thorac Surg* 1999;68:2093-2099.
167. Trehan N, Mishra M, Dhole S, Mishra A, Karlekar A, Kohli VM. Significantly reduced incidence of stroke during coronary artery bypass grafting using transesophageal echocardiography. *Eur J Cardiothorac Surg* 1997;11:234-242.
168. Trehan N, Mishra M, Kasliwal RR, Mishra A. Reduced neurological injury during CABG in patients with mobile aortic atheromas: a five-year follow-up study. *Ann Thorac Surg* 2000;70:1558-1564.
169. Verhoeven BA, de Vries JP, Pasterkamp G, Ackerstaff RG, Schoneveld AH, Velema E, et al. Carotid atherosclerotic plaque characteristics are associated with microembolization during carotid endarterectomy and procedural outcome. *Stroke* 2005;36:1735-1740.

170. Veselka J, Cerná D, Zimolová P, Martinkovicová L, Fiedler J, Hájek P, et al. Feasibility, safety, and early outcomes of direct carotid artery stent implantation with use of the FilterWire EZ Embolic Protection System. *Catheter Cardiovasc Interv* 2009;73:733-738.
171. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. Endarterectomy for asymptomatic carotid artery stenosis. *JAMA* 1995;273:1421-1428.
172. Walkes JC, Earle N, Reardon MJ, Glaeser DH, Wall MJ Jr, Huh J, et al. Outcomes in single versus bilateral internal thoracic artery grafting in coronary artery bypass surgery. *Curr Opin Cardiol* 2002;17:598-601.
173. Weimar T, Schena S, Bailey MS, Maniar HS, Schuessler RB, Cox JL, et al. The cox-maze procedure for lone atrial fibrillation: a single-center experience over 2 decades. *Circ Arrhythm Electrophysiol* 2012;5:8-14.
174. Weinstein GS. Left hemispheric strokes in coronary surgery: implications for end-hole aortic cannulas. *Ann Thorac Surg* 2001;71:128-132.
175. Wenaweser P, Pilgrim T, Guerios E, Stortecky S, Huber C, Khattab AA, et al. Impact of coronary artery disease and percutaneous coronary intervention on outcomes in patients with severe aortic stenosis undergoing transcatheter aortic valve implantation. *EuroIntervention* 2011;7:541-548.
176. Burns RJ, Willoughby JO. South Australian carotid endarterectomy study. *Med J Aust* 1991;154:650-653.
177. Wöhrle J, Gonska B, Rodewald C, Seeger J, Scharnbeck D, Rottbauer W. Transfemoral aortic valve implantation with the New Edwards Sapien 3 valve for treatment of severe aortic stenosis: impact of valve size in a single center experience. *PLoS One* 2016;11:e0151247.
178. Woelfle KD, Bruijnen H, Neu J, Campbell P, Wack C, Loeprecht H. The role of intraoperative digital subtraction angiography for quality control of standard carotid endarterectomy using patch angioplasty. *Cardiovasc Surg* 2002;10:116-122.
179. Wolman RL, Nussmeier NA, Aggarwal A, Kanchuger MS, Roach GW, Newman MF, et al. Cerebral injury after cardiac surgery: identification of a group at extraordinary risk. Multicenter Study of Perioperative Ischemia Research Group (McSPI) and the Ischemia Research Education Foundation (IREF) Investigators. *Stroke* 1999;30:514-522.
180. Wong JH, Lubkey TB, Suarez-Almazor ME, Findlay JM. Improving the appropriateness of carotid endarterectomy: results of a prospective city-wide study. *Stroke* 1999;30:12-15.
181. Yadeau JT, Casciano M, Liu SS, Edmonds CR, Gordon M, Stanton J, et al. Stroke, regional anesthesia in the sitting position, and hypotension: a review of 4169 ambulatory surgery patients. *Reg Anesth Pain Med* 2011;36:430-435.
182. Young B, Moore WS, Robertson JT, Toole JF, Ernst CB, Cohen SN, et al. An analysis of perioperative surgical mortality and morbidity in the asymptomatic carotid atherosclerosis study. ACAS Investigators. Asymptomatic Carotid Atherosclerosis Study. *Stroke* 1996;27:2216-2224.
183. Zannetti S, Cao P, De Rango P, Giordano G, Parlani G, Lenti M, et al. Intraoperative assessment of technical perfection in carotid endarterectomy: a prospective analysis of 1305 completion procedures. Collaborators of the EVEREST study group. Eversion versus standard carotid endartectomy. *Eur J Vasc Endovasc Surg* 1999;18:52-58.
184. Zarins CK, White RA, Diethrich EB, Shackelton RJ, Siami FS; CaRESS Steering Committee and CaRESS Investigators. Carotid revascularization using endarterectomy or stenting systems (CaRESS): 4-year outcomes. *J Endovasc Ther* 2009;16: 397-409.
185. Zhang L, Bassin L, Cranney G, Lau A, Akhunji Z, Wolfenden H, et al. Aortic valve replacement after previous cardiac surgery. *Heart Lung Circ* 2015;24 Suppl 1:e21-e22.
186. Ziemann M, Heringlake M, Lenor P, Juhl D, Hanke T, Petersen M, et al. Cytomegalovirus serostatus as predictor for adverse events after cardiac surgery: a prospective observational study. *J Cardiothorac Vasc Anesth* 2017;31:2042-2048.
187. Zipfel B, Buz S, Hammerschmidt R, Krabatsch T, Duesterhoeft V, Hetzer R. Early clinical experience with the E-vita thoracic stent-graft system: a single center study. *J Cardiovasc Surg (Torino)* 2008;49:417-428.
188. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;6:e1000097.

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