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Differences in Postoperative Outcomes After Carotid Endarterectomies Performed by Female versus Male Surgeons

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Background: To evaluate whether the sex of the operating surgeon influences postoperative outcomes after carotid endarterectomy (CEA). We hypothesized that patients treated by female surgeons have lower complication rates or mortality.

Methods: A retrospective, single-center analysis was conducted of all CEA procedures performed between January 2012 and December 2023 by the Clinic of Vascular Surgery of the University Hospital Augsburg. Patient demographics, comorbidities, and operative details were collected from the German national quality assurance database. The primary outcomes included perioperative complications and 30-day mortality. Secondary outcomes included operative time and surgical technique preference. Outcomes were compared between cases performed by male and female surgeons using univariate analysis and multivariable logistic regression.

Results: A total of 1130 CEA operations met the inclusion criteria. Of these, 905 (80.1%) were performed by male surgeons and 225 (19.9%) by female surgeons. Patient characteristics were comparable between the two groups. Male surgeons more frequently used eversion endarterectomy (odds ratio for eversion by male vs. female surgeon 1.65; 95% confidence interval: 1.02−2.67; $P = 0.04$). The median incision-to-suture operative time was longer under female surgeons (101 min [interquartile range: 87−118] vs. 86 [70−106] min for male surgeons; $P < 0.001$). The rate of any perioperative complication was 4.4% for female surgeons versus 6.6% for male surgeons ($P = 0.32$). Thirty-day mortality was low in both groups (0.4% vs. 0.7%; $P = 0.67$).

Conclusion: Surgeon sex was not associated with significant differences in perioperative complications or mortality following CEA. Female surgeons had significantly longer operative times, without negatively impacting patient outcomes. These findings support sex equity in vascular surgery.

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INTRODUCTION

Carotid artery atherosclerosis is a major cause of ischemic stroke. Carotid endarterectomy (CEA) is an established surgical treatment for significant carotid stenosis and has been proven in landmark trials to prevent stroke in patients with high-grade carotid stenoses.[1−3] Guidelines recommend CEA and carotid stenting to reduce stroke risk in appropriate patients, with accepted perioperative stroke and death rates below 4% for symptomatic stenoses (and below 2% for asymptomatic stenoses).[4,5] Over the past decades, improvements in surgical technique and perioperative care have driven complication rates for CEA to low levels, making it a safe procedure with clear benefit in stroke risk reduction.

Surgical outcomes can be influenced by patient risk factors, disease severity, and technical aspects of the procedure. Surgeon-related factors, such as case volume and experience, are also known to affect outcomes in vascular surgery.[6] However, the potential impact of the surgeon's sex or gender on operative outcomes has recently become a topic of interest.[7] The representation of women in surgery and vascular surgery has historically been low, but it has been steadily rising in recent years.[8] This raises the question of whether there are any measurable differences in patient outcomes when operations are performed by female versus male surgeons. Prior studies in other fields have suggested that physician sex might play a role in patient outcomes. For example, an analysis of Medicare patients found that those treated by female physicians had lower mortality and readmission rates compared to those treated by male physicians.[9] In the surgical realm, a systematic review in cardiac surgery reported that female surgeons' patients had outcomes equal to or better than those of male surgeons.[10] Moreover, a recent large study of over 1 million surgical patients in the United States observed that patient−surgeon sex discordance was associated with a higher mortality risk, implying that female surgeons may achieve slightly better postoperative survival in certain scenarios.[7] These findings have sparked interest in examining surgeon sex as a potential contributor to surgical quality, although causation remains unclear and may involve complex factors such as communication, decision-making, or case selection biases.

In vascular surgery, and specifically in carotid artery surgery, data on the influence of surgeon sex are extremely limited. Most literature on sex differences in carotid outcomes has focused on patient sex rather than surgeon sex.[11] To our knowledge, no prior study has specifically examined whether the surgeon's sex affects the results of CEA.

In this context, we conducted a retrospective analysis of carotid endarterectomies performed at our institution to evaluate postoperative outcomes stratified by the operating surgeon's sex. We hypothesized that women have lower complication rates or mortality based on surgeon sex.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a single-center retrospective observational study, reported in adherence with The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[12] All data were obtained from the Department of Vascular and Endovascular Surgery at University Hospital Augsburg (Augsburg, Germany). The study protocol was reviewed and approved by the ethics committee of the Ludwig-Maximilians-University Munich (Project No. 24-0035). Patient consent was not required given the retrospective design and use of deidentified data from the German national quality assurance (QA) database. The study was registered at ClinicalTrials.gov (Identifier NCT06485102) prior to data analysis.

Patient Inclusion

We included all carotid artery revascularization surgeries performed for carotid stenosis at our institution between January 1, 2012, and December 31, 2023. We limited inclusion to open CEA procedures, as this was the standard surgical treatment for carotid stenosis in our department. Figure 1 illustrates the case inclusion process.

Surgeon Classification

Each CEA was categorized by the sex of the primary surgeon (referred to as the first operator, OP1). Surgeons were identified by name, and sex was determined from institutional records. Over the 12-year study period, a total of 33 different primary surgeons performed carotid surgeries, of whom 24 were male and 9 were female. We also recorded the sex of the assisting surgeon (second operator, OP2) for each case, as well as the seniority of OP1 and OP2 (Fig. 2). Surgeon seniority was classified as chief (department head), attending surgeon with >5 years of board certification, attending surgeon with <5 years of board certification, or resident

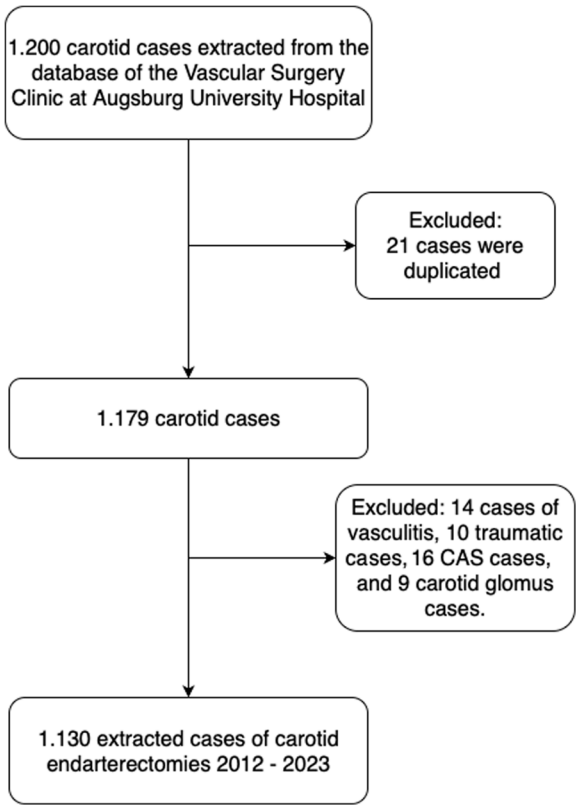

Fig. 1. Flow diagram of case selection for inclusion in the study. Out of 1200 recorded carotid interventions, cases were excluded for duplicate entries and non-CEA procedures (carotid stenting, tumor resection, etc.), yielding 1 130 carotid endarterectomy cases for analysis.

surgeon. This allowed analysis of whether surgeon experience level differed by sex group.

Data Collection

Clinical and operative data were extracted from a prospectively maintained external QA database, that is a functionally independent scientific body, established under § 137a SGB V.[13] It is mandated and financed by the Federal Joint Committee (Gemeinsamer Bundesausschuss), which commissions all national external QA activities. The Gemeinsamer Bundesausschuss, in turn, operates under the statutory supervision of the Federal Ministry of Health (Bundesministerium für Gesundheit); its directives—and therefore the outputs of the Institute for Quality Assurance and Transparency in Health—take effect only if the ministry raises no objections. Here, all data on carotid interventions must be reported by the hospitals or clinics. These data extracted by us locally were then supplemented by a review of electronic medical records when necessary to complete missing details. The QA database captures key variables for every carotid procedure as part of a national quality monitoring program.[14] Data fields utilized in this study included patient age, sex, and relevant comorbidities; symptom status of the carotid stenosis (symptomatic was defined as ipsilateral neurologic symptoms—stroke, transient ischemic attack [TIA], or amaurosis fugax—within the last 6 months, whereas asymptomatic indicated no recent symptoms); degree of carotid stenosis (typically measured by duplex ultrasound); American Society of Anesthesiologists (ASA) status[15]; use of antithrombotic medication at admission (antiplatelet or anticoagulant therapy); surgical technique of CEA (standard CEA with patch closure vs. eversion endarterectomy); type of anesthesia (general anesthesia, regional cervical block, or local anesthesia with sedation); the OP1 and OP2 surgeon sexes and their experience level as defined above; operative time (recorded as skin incision to skin closure time in minutes); intraoperative completion angiography (performed routinely in all cases to verify vessel patency and repair integrity before wound closure); postoperative length of hospital stay; and postoperative outcomes. The primary outcomes of interest were perioperative/postoperative complications and 30-day mortality. Perioperative/postoperative complications were defined as any of the following events occurring during the index hospitalization or within 30 days of surgery: stroke, TIA, cranial nerve injury, neck hematoma requiring reintervention, or any other major adverse event recorded in the database. For analysis, we considered the occurrence of *any complication* (yes/no for each case). Thirty-day mortality was defined as death from any cause within 30 days after the CEA, whether in-hospital or after discharge (determined via hospital records and follow-up reporting to the QA registry).

Statistical Analysis

All data were analyzed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation or median (interquartile range [IQR]) as appropriate based on distribution. Categorical variables were summarized as counts and percentages. We first compared baseline patient and operative characteristics between cases performed by male versus female surgeons. For univariate comparisons, we used the chi-square test (or Fisher's exact test) for categorical variables and the Student's *t*-test or Mann-Whitney *U* test for continuous variables, as

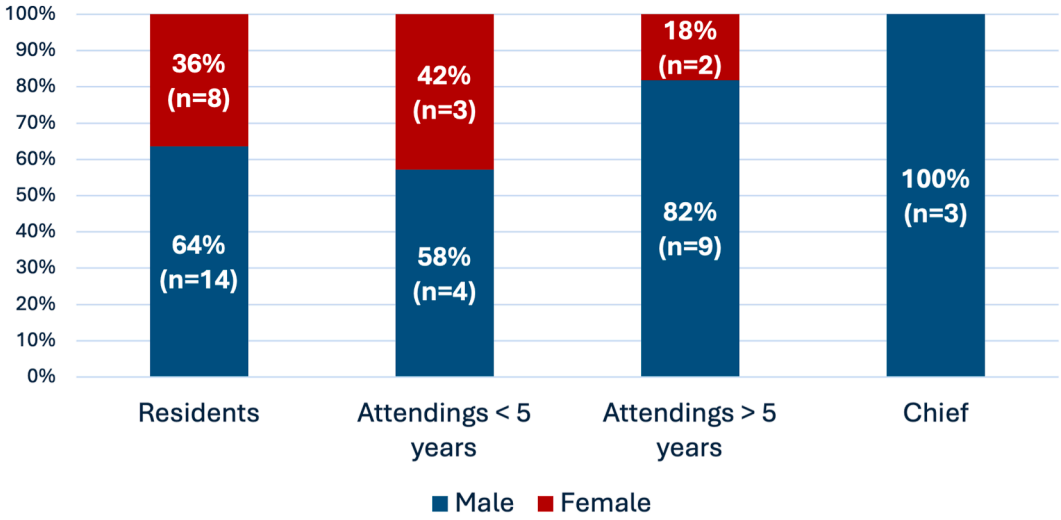

Fig. 2. Distribution of the 33 primary surgeons (OP1) by seniority. Attendings are grouped as under and over 5 years of experience.

appropriate. The threshold for statistical significance was set at $P < 0.05$ (two-tailed). In addition, a multivariate logistic regression analysis was performed to evaluate the independent effect of surgeon sex on the likelihood of perioperative complications, while adjusting for potential confounding factors. Variables entered into the logistic regression model included surgeon sex as the predictor of interest and the following covariates: patient age, sex, symptomatic versus asymptomatic stenosis, high-grade stenosis (≥70% vs. <70%), ASA class, use of patch versus eversion technique, and surgeon experience level. The results of the regression are presented as odds ratios (ORs) with 95% confidence intervals (CIs) for female versus male surgeon (reference). A similar analysis was performed for 30-day mortality. Finally, we examined any interaction between surgeon sex and patient sex on outcomes, as well as the influence of surgeon−assistant sex combinations on outcomes.

RESULTS

Surgeon Sex Case Distribution

Over the 12-year study period, 1130 CEA operations were analyzed. These procedures were performed by 33 primary surgeons (OP1: 9 female and 24 male surgeons). Male surgeons performed most cases (905 cases, 80.1%), whereas female surgeons performed 225 cases (19.9%, Fig. 3). The disparity in case numbers reflects the larger number of male surgeons and their longer tenure over the study period. The ratio of total cases by male versus female surgeons (4.0:1) is somewhat higher than the ratio of available surgeons (2.7:1).

Patient and Case Characteristics

Patient demographics and preoperative risk factors were well balanced between the two groups; see Table I. The median age of patients was 72 years in the female-surgeon group and 73 years in the male-surgeon group ($P = 0.18$). The proportion of male versus female patients was similar for female and male surgeons (approximately 70% male patients in both groups; $P = 0.96$). The symptom status of carotid stenoses did not differ by surgeon sex: more than half of cases in each group were symptomatic carotid stenoses (with recent neurologic events), and the rest were asymptomatic ($P = 0.55$). The severity of stenosis was also comparable; both groups had a similar mix of high-grade (≥70%) and moderate (50−69%) stenoses being operated, and there was no significant difference in laterality (left versus. right) of procedures between male and female surgeons. Patients operated by female versus male surgeons had nearly identical ASA class profiles, with the majority being ASA II or III ($P = 0.79$), indicating comparable preoperative health status. Additionally, rates of preoperative

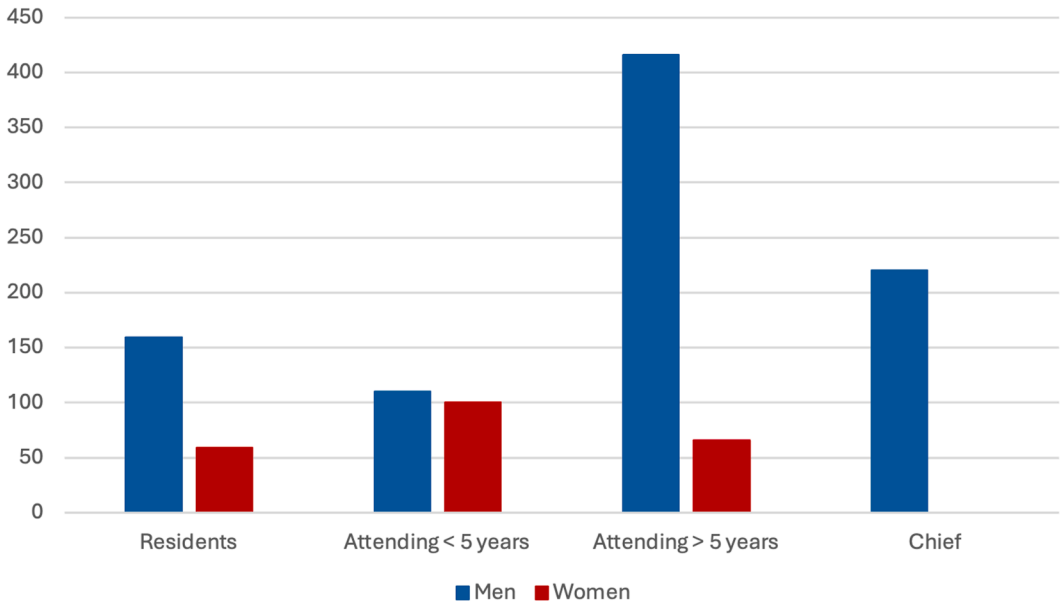

Fig. 3. The distribution of primary surgeons (OP1) by sex and seniority, highlighting that most procedures were performed by male surgeons. Attendings are grouped as under and over 5 years of experience.

Table I. Patient characteristics, operative variables, and outcomes for carotid endarterectomy cases stratified by primary surgeon sex

Variable	Male surgeon ($n = 905$)	Female surgeon ($n = 225$)	*P* value
Patient age (years, median)	73	72	0.18
Male patients (% of group)	71.8	72.0	0.96
Symptomatic stenosis (% of cases)	55.9	58.7	0.55
High-grade stenosis (≥70%) (% of cases)	78.0	80.4	0.48
ASA III–IV (% of patients)	54.1	52.9	0.79
Patch closure used (% of cases)	67.2	77.3	0.03[a]
Eversion technique (% of cases)	32.8	22.7	0.04[a]
Operative time (min, median)	86	101	<0.001[a]
Any complication (% of cases)	6.6 (60/905)	4.4 (10/225)	0.32
Stroke/TIA (% of cases)	1.43	0.88	0.78
Local complication[b] (% of cases)	4.4	2.7	0.29
30-day mortality (% of cases)	0.7 (6/905)	0.4 (1/225)	0.67
Hospital length of stay (days, median)	8	8	0.70

Values are number (percentage) for categorical variables and median (IQR) for continuous variables.
TIA, transient ischemic attack. ASA, American Society of Anesthesiologists.
[a]Statistically significant ($P < 0.05$).
[b]Local complication: cranial nerve injury, neck hematoma, or wound infection requiring intervention.

antiplatelet or anticoagulation therapy were similar. These findings suggest that there was no systematic bias in case selection: female and male surgeons operated on patients with equivalent baseline risk factors and disease characteristics.

Operative Technique and Process Measures

We observed some differences in how female and male surgeons approached the CEA procedure.

Notably, the choice of surgical technique (patch angioplasty vs eversion endarterectomy) varied by surgeon sex. Female surgeons were more likely to perform CEA with a patch closure, whereas male surgeons more frequently employed the eversion technique for CEA. In the female-surgeon cases, patch angioplasty was used in 72% of operations, compared to 67.2% in male-surgeon cases ($P = 0.03$). The adjusted operating room (OR) for using the eversion technique (male vs female surgeon) was 1.65 (95% CI: 1.02 − 2.67), indicating that male surgeons had 65% higher odds of choosing eversion over patch than female surgeons. Another notable difference was in operating time. The median skin-to-skin operative time for CEA performed by female surgeons was 101 min (IQR: 87−118), which was significantly longer than the median operative time of 86 min (IQR: 70−106) for male surgeons ($P < 0.001$). The multiple regression model confirmed that female surgeons operated on average 7.8 min slower than male surgeons ($P < 0.001$), adjusting for relevant confounders. When operating time was stratified by surgeon experience, differences emerged. Female resident surgeons operated on average 7 min faster than their male counterparts ($P < 0.2$). However, this trend reversed at the attending level: female attendings with less than 5 years of experience (after residency) took 3 min longer than their male peers ($P < 0.3$), and those with more than 5 years of experience had a significantly longer operative time by an average of 22 min ($P < 0.001$). The composition of the operative team differed in a predictable way: female surgeons more often had a male assisting surgeon (since most available assistants were male), whereas male surgeons sometimes had female assistants, but these team composition differences were inherent to the staff sex proportions and not an independent variable we analyzed for outcome effect.

Postoperative Outcomes

The primary outcome measures of perioperative complications and 30-day mortality did not differ significantly between female and male surgeon groups. Overall, 60 of the 905 cases performed by male surgeons had at least one postoperative complication (6.6%), compared to 10 of the 225 cases by female surgeons (4.4%). This reflects a lower complication rate in the female-surgeon group, but the difference was not statistically significant (absolute difference 1.43%; $P = 0.32$). The complications recorded included a combination of neurologic events and local complications. The incidence of stroke or TIA specifically was 1.43% in male-surgeon cases versus 0.88% in female-surgeon cases, while cranial nerve injuries (typically XII or VII nerve palsy) and neck hematomas requiring reoperation occurred in 3−4% of cases overall, with no significant sex-based disparity. Importantly, no difference in major stroke rates was detected between groups—the low rate of stroke after CEA was consistent with literature and did not appear related to surgeon sex. The 30-day mortality was very low in both cohorts. There were 6 deaths within 30 days among patients operated by male surgeons (0.7%) and 1 death among those operated by female surgeons (0.4%). This difference is not statistically meaningful given the rarity of events (Fisher's exact $P = 0.67$). Causes of death were stroke in three cases, myocardial infarction in two, and one unexplained sudden death at home; the single death in the female-surgeon group was due to a massive stroke. These outcomes indicate that both female and male surgeons achieved excellent and comparably low mortality after CEA. The combined end point of stroke or death within 30 days was approximately 2.5% in both groups, which meets recommended quality benchmarks.[5]

Secondary outcome analysis showed no significant difference in the length of postoperative hospital stay between the two groups. The median length of stay (LOS) was 8 days for both ($P = 0.70$). For symptomatic patients, median LOS was 11 days in the male group and 12 days in the female group, and for asymptomatic patients, the median was 5 days in both groups. Regardless of the surgeon's sex, symptomatic patients had a significantly longer LOS compared to asymptomatic patients ($P < 0.001$ for both groups). However, there were no significant differences in hospital stay duration between male and female primary surgeons, neither among symptomatic patients ($P = 0.82$) nor among asymptomatic patients ($P = 0.11$). The reported duration represents the total hospital stay as captured by the national QA dataset and therefore includes preoperative neurological admissions or referrals from other departments. This likely explains the comparatively long median stay observed. The dataset did not allow differentiation of the exact vascular-ward stay, which in routine practice is considerably shorter.

In multivariate logistic regression analysis adjusting for patient age, sex, symptom status, stenosis severity, ASA, surgical technique, and surgeon experience, the surgeon's sex was not significantly associated with the odds of a patient having a perioperative complication. The adjusted OR for a complication with a female surgeon (versus a male surgeon) was 0.72 (95% CI: ∼0.40−1.30;

$P = 0.28$), indicating a trend toward lower odds of complication with female surgeons, but this did not reach significance. None of the adjustment covariates substantially changed this finding, confirming that the absence of a sex effect was not due to imbalances in those factors. In the adjusted model for 30-day mortality, results were similar (female surgeon OR ~0.60; $P = 0.65$, wide CI reflecting few events).

DISCUSSION

In this study of CEA outcomes at a single high-volume vascular center, we found no significant differences in key patient outcomes based on the sex of the operating surgeon. Patients treated by female surgeons had equivalent rates of perioperative stroke, combined complications, and 30-day mortality compared to those treated by male surgeons. To our knowledge, this is the first study focusing on surgeon sex in the context of carotid artery surgery. The results provide evidence that female surgeons perform CEA with outcomes that are on par with their male colleagues, which is an important finding for workforce diversity and patient confidence in surgical care.

Our data showed a slight trend toward lower complication and mortality rates for female surgeons, but these differences were not statistically significant. The magnitude of the difference (2%) would have required a larger sample to detect with sufficient power, given the low overall event rates. Nonetheless, the direction of the trend aligns with reports from other fields suggesting potential outcome advantages with female physicians. For example, Tsugawa et al. observed lower mortality among hospitalized patients cared for by female doctors compared to male doctors in a large cohort.[9] Our findings are consistent with the studies discussed in the introduction, we found no evidence of worse outcomes with female surgeons; if anything, our results suggest female surgeons' patients may experience slightly fewer complications.[7,10] In our study, we took care to examine whether female and male surgeons were operating on different patient populations or complexity of cases. We found no significant differences in patient risk profiles or disease severity between the groups.

Female surgeons in our cohort had longer operative times for CEA compared with their male colleagues. In our department, however, surgical residents never operate independently; each procedure is performed under the direct supervision of an attending vascular surgeon who remains scrubbed for all critical steps. Therefore, the slightly shorter times observed among female residents likely reflect differences in case allocation and the extent of attending involvement rather than true differences in technical speed. Among attendings, this trend reversed—female attendings required more time on average than male attendings. Part of this difference relates to technique preference: male attendings, more frequently performed eversion endarterectomy, which is typically faster than patch closure.[16] Yet even after adjustment for technique, female attendings still had significantly longer operative times, suggesting that other factors such as greater teaching participation, more complex cases, or a more meticulous operative style may contribute. Similar findings have been reported in other surgical specialties, where longer procedure times among female surgeons were not associated with worse outcomes.[17]

Another interesting difference was the choice of surgical technique (patch vs eversion CEA). The preference for patch angioplasty among female surgeons and eversion among male surgeons could stem from training background or institutional role models. Prior studies have found no clear outcome difference between patch and eversion techniques in CEA, as both are effective.[18] The technique preference does highlight how surgical practice patterns might subtly differ by surgeon sex, possibly reflecting mentorship or personal choice, but without impacting patient safety.

Importantly, our analysis reinforces that patient sex does not influence CEA outcomes when treated by experienced surgeons, consistent with the findings of the large VASCUNET study.[11] We observed no difference in complication rates between male and female patients in our cohort, and both female and male surgeons operated on similar proportions of female patients.

Strengths and Limitations

The strengths of this study include a relatively large sample size for a single-center surgical series of CEA, spanning over a decade of practice. The data were derived from a mandatory QA registry, which enhances completeness and consistency of outcome reporting.[14] Additionally, we rigorously examined and adjusted for many potential confounders (patient factors, disease severity, surgeon experience), which increases confidence that the lack of outcome difference is a true finding rather than a result of case selection bias. The study specifically addresses a novel question in vascular surgery, contributing new knowledge to the literature on surgeon-related factors.

We acknowledge several limitations. First, as a retrospective observational study, there may be unmeasured variables and inherent biases that we cannot fully account for. Second, the number of female surgeons in the study was relatively small and did not include a chief surgeon. However, this reflects real-world conditions, as there are fewer women in vascular surgery roles; our findings are still valuable, though confirmatory studies from other centers would strengthen generalizability. Third, the low incidence of adverse outcomes like stroke and death means the study may be underpowered to detect very small differences. For example, while female surgeons had a lower observed mortality, the numbers are too low to draw any firm conclusions. A larger multicenter dataset would be needed to determine if any slight mortality difference exists.

We also considered teamwork factors: female surgeons in our study often worked with male assistants, simply due to the staff makeup (and vice versa). It has been hypothesized that sex dynamics within the OR team might influence performance or communication.[19] Our dataset did not reveal any clear effect of team sex composition on outcomes, but we did observe that female surgeons frequently led mixed-sex teams. This is an area that could be explored in future research—for instance, whether diverse teams have any advantages in surgical care delivery, as some organizational studies suggest diversity can enhance problem-solving.[20,21]

Implications

Our findings support the importance of women in vascular surgery, demonstrating that surgeon sex does not impact patient outcomes. This evidence helps reduce biases from patients, colleagues, or institutions regarding sex-related concerns in surgical quality. Female vascular surgeons, despite being fewer, achieve the same high standards as their male counterparts. Promoting women's participation in surgery can only bring benefits to the field. The comparable outcomes observed also affirm the effectiveness of current training programs in producing skilled surgeons regardless of sex, highlighting merit and expertise as the key determinants of surgical success. These results should encourage continued efforts to actively support and foster women in the traditionally male-dominated surgical specialty, recognizing their valuable contributions to improving patient care and enriching the surgical profession overall.

CONCLUSION

In conclusion, this study found no significant differences in postoperative outcomes of CEA based on the operating surgeon's sex. Female surgeons did tend to have lower perioperative stroke and complication rates, but they were statistically indistinguishable from those of male surgeons. Both had equally low 30-day mortality. Female surgeons had longer operative times, but this did not adversely affect patient outcomes. The quality of carotid surgery in our experience is high and consistent, independent of surgeon sex. These findings contribute to the evidence that men and women surgeons perform at an equivalent level in vascular surgery, which is reassuring for both patients and surgical teams. As more women enter the field of vascular surgery, maintaining objective assessments of outcomes will be important to continue ensuring excellence in care. Our results support that surgical talent and outcomes know no sex—what matters most is training, experience, and adherence to good surgical practice. Future research should build on these findings by examining larger data sets and other surgical specialties to further our understanding of how surgeon-related factors influence outcomes, ultimately guiding improvements in surgical training and patient care.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Stefan Ionac: Writing — review & editing, Writing — original draft, Software, Methodology, Data curation, Conceptualization. **Hagen Kerndl:** Writing — review & editing, Software, Data curation. **Tobias Dominik Warm:** Visualization, Software, Investigation. **Alexander Hyhlik-Dürr:** Supervision. **Yvonne Gosslau:** Writing — review & editing, Visualization, Formal analysis, Conceptualization.

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