Value in Health Sciences
Sağlık Bilimlerinde Değer

2026;16(3):593-601
https://doi.org/10.33631/sabd.1970963

e-ISSN: 2792-0542
https://dergipark.org.tr/en/pub/sabd

Research Article / Araştırma Makalesi

The Role and Importance of Regional Anaesthesia Versus General Anaesthesia in Carotid Endarterectomy

Karotis Endarterektomisinde Bölgesel Anestezi ve Genel Anestezinin Rolü ve Önemi

Kemal Eşref Erdoğan[1*], Muhammet Fethi Sağlam[1], Emrah Uğuz[1], Murat Yücel[2], Hüseyin Bayram[3], Nur Gizem Elipek[2], Garip Altıntaş[2], Mete Hıdıroğlu[1]

[1] Department of Cardiovascular Surgery, Ankara Yildirim Beyazit University, Faculty of Medicine, Ankara Bilkent City Hospital, Ankara, Türkiye.
ror.org/05ryemn72

[2] Department of Cardiovascular Surgery, Ankara Bilkent City Hospital, Ankara, Türkiye.
ror.org/033fqnp11

[3] Department of Cardiovascular Surgery, University of Health Sciences, Faculty of Medicine, Ankara Bilkent City Hospital, Ankara, Türkiye.
ror.org/03k7bde87

*Corresponding author / Sorumlu yazar:
kemal_esref@hotmail.com.tr

ABSTRACT

Aim: To compare clinical outcomes, complication rates, and hospital resource use among patients undergoing carotid endarterectomy (CEA) under general anaesthesia (GA) or regional/local anaesthesia (RA) at a single tertiary vascular surgery centre.

Material and Methods: We conducted a retrospective analysis of 102 consecutive CEA patients, with 60 receiving GA and 42 receiving RA. The primary endpoint was the occurrence of stroke, TIA, myocardial infarction (MI), or death within 30 days. Secondary endpoints included individual event rates, ICU and hospital stay duration, operative metrics, and complication rates. Multivariable logistic regression was used to identify predictors of prolonged ICU stay (>12 hours).

Results: The groups had similar baseline clinical and demographic characteristics. The composite 30-day endpoint showed no significant difference between GA and RA patients (5.0% vs. 4.8%; p=1.000), with no significant differences in stroke (5.0% vs. 2.4%; p=0.641), 30-day mortality (3.3% vs. 0%; p=0.511), or any surgical complication. The notable difference was in ICU length of stay, which was significantly longer for GA patients (median 17 h [IQR 16–19] vs. 3 h [IQR 3–16]; p<0.001). In the multivariable regression, GA was the only independent predictor of prolonged ICU stay (OR=30.81, 95% CI 8.26–114.92; p<0.001).

Conclusion: Regional anaesthesia offers a safety profile comparable to GA in CEA, with similar rates of neurological and cardiac complications. GA independently predicts longer ICU stays, suggesting that RA can provide significant benefits in hospital resource use without compromising clinical outcomes.

Keywords: Carotid endarterectomy; Anaesthesia, conduction; Anaesthesia, general; Intensive care units; Postoperative complications; Health resources

ÖZ

Amaç: Tek bir üçüncü basamak vasküler cerrahi merkezinde genel anestezi (GA) ve rejyonel/lokal anestezi (RA) altında karotis endarterektomi (KEA) uygulanan hastalar arasında klinik sonuçlar, komplikasyon oranları ve hastane kaynak kullanımı açısından karşılaştırma yapmak.

Gereç ve Yöntemler: GA alan 60 ve RA alan 42 olmak üzere toplam 102 ardışık KEA hastası retrospektif olarak incelendi. Birincil sonlanım noktası, 30 gün içinde inme, geçici iskemik atak (GİA), miyokard enfarktüsü (Mİ) veya ölüm gelişmesi olarak belirlendi. İkincil sonlanım noktaları; bireysel olay oranları, yoğun bakım ünitesi (YBÜ) ve hastane yatış süreleri, operatif metrikler ve komplikasyon oranlarını kapsadı. Uzamış YBÜ yatışının (>12 saat) bağımsız prediktörlerini belirlemek amacıyla çok değişkenli lojistik regresyon analizi uygulandı.

Bulgular: Gruplar başlangıç özellikleri açısından benzerdi. Bileşik 30 günlük sonlanım noktasında GA ve RA hastaları arasında istatistiksel olarak anlamlı bir fark saptanmadı (%5,0'a karşı %4,8; p=1,000). İnme (%5,0'a karşı %2,4; p=0,641), 30 günlük mortalite (%3,3'e karşı %0; p=0,511) ve cerrahi komplikasyonlar açısından da gruplar arasında anlamlı fark görülmedi. Belirgin fark YBÜ yatış süresinde gözlemlendi; GA hastalarında yatış süresi anlamlı biçimde daha uzundu (ortanca 17 s [IQR 16–19]'a karşı 3 s [IQR 3–16]; p<0,001). Çok değişkenli regresyon analizinde GA, uzamış YBÜ yatışının tek bağımsız prediktörü olarak belirlendi (OR=30,81; %95 GA 8,26–114,92; p<0,001).

Sonuç: Rejyonel anestezi, KEA'da nörolojik ve kardiyak komplikasyon oranları bakımından GA ile karşılaştırılabilir bir güvenlik profili sunmaktadır. GA'nın uzamış YBÜ yatışını bağımsız olarak öngörmesi, RA'nın klinik sonuçlardan ödün vermeksizin hastane kaynak kullanımı açısından önemli avantajlar sağlayabileceğine işaret etmektedir.

Anahtar kelimeler: Karotis endarterektomisi, rejyonel anestezi, genel anestezi, yoğun bakım üniteleri, postoperatif komplikasyonlar, sağlık kaynakları.

Received / Geliş: 15.06.2026
Revision / Revizyon: 01.09.2026
Accepted / Kabul: 02.09.2026
Online / Çevrimiçi: 22.09.2026

Cite as/Atıf için: Erdoğan KE, Sağlam MF, Uğuz E, Yüzcel M, Bayram H, Elipek NG, et al. The role and importance of regional anaesthesia versus general anaesthesia in carotid endarterectomy. Value Health Sci. 2026;16(3):593–601. doi:10.33631/sabd.1970963.

This is an open access paper distributed under the terms and conditions of the Creative Commons Attribution-NonCommercial 4.0 International License.
Bu makale, Creative Commons Atıf-GayriTicari 4.0 Uluslararası Lisansı (CC BY-NC 4.0) hükümleri ve koşulları kapsamında açık erişim olarak yayımlanmıştır.

INTRODUCTION

For patients with significant internal carotid artery stenosis, surgery has been the best defence against ischemic stroke for many years. The NASCET, ECST, and ACAS trials established this foundation and carotid endarterectomy (CEA) remains the standard revascularization strategy for symptomatic stenosis ≥50% and selected cases of asymptomatic stenosis ≥60–70% (1–3). This position is supported by the latest ESVS 2023 guidelines, despite the increasing use of stenting and improvements in medical treatment (4).

The choice of anaesthesia for CEA, whether GA or RA, has been debated for a long time. Supporters of GA highlight its controlled airway, stable operating conditions, and predictable hemodynamic, while advocates for RA argue that continuous monitoring of an awake patient gives the best real-time indication of cerebral perfusion, allowing for more selective shunting and quicker detection of ischemia (5,6).

The GALA Trial, the largest RCT on this subject with 3,526 patients, found no significant difference in the rates of stroke, MI, or death between GA and RA (7). Cochrane reviews have supported this finding and both ESVS and AHA/ASA guidelines leave the anaesthetic choice to institutions based on individual patient factors (4,8,9,10).

Aside from clinical outcomes, the impact of anaesthetic choice on ICU use and hospital logistics remains incompletely characterized, particularly in single-centre series with granular patient-level data from contemporary practice — a gap that large administrative databases, despite their scale, cannot fully address. Registry analyses suggest that RA may lead to shorter ICU stays but these findings carry the limitations inherent to administrative datasets (11,12).

Shunt use adds another dimension to this debate. Under RA, the neurological status of the awake patient during test clamping is the most reliable indicator of reduced cerebral perfusion (5,13). Under GA, clinicians rely on surrogates such as TCD, near-infrared spectroscopy, and stump pressure — none of which are universally accepted or as sensitive as monitoring an awake patient (14).

Given this context, we aimed to compare perioperative outcomes, complication rates, and ICU use between GA and RA in a consecutive CEA cohort from our centre. We hypothesized that RA would be equally safe while offering a meaningful advantage in critical care resource use — an increasingly important consideration in today's healthcare environment.

MATERIAL AND METHODS

Study Design and Ethical Approval

From January 2019 to December 2022, all patients who underwent CEA at our centre were entered into a prospectively maintained database. We performed a retrospective analysis of this cohort. The study protocol was approved by the institutional review board (Approval No: E2-23-4281; Approval Date: June 7, 2023) and was conducted in accordance with the Declaration of Helsinki. Since this study was non-interventional, individual consent was not required.

Patient Selection

We screened all consecutive patients who had elective or urgent CEA during the study period. We included adults (≥18 years) with duplex- or CTA-confirmed internal carotid stenosis who received either GA or RA and had complete perioperative records. We excluded patients who underwent other procedures at the same session, had CEA for stroke in progress, or had incomplete data. Of 220 patients who underwent CEA during the study period, 118 were excluded: 102 for concomitant procedures (CEA combined with coronary artery bypass grafting), 5 for CEA performed for stroke in progress, and 11 for incomplete perioperative records. The remaining 102 patients met all eligibility criteria and formed the study cohort (Figure 1).

No a priori power calculation was performed, as this was a retrospective observational study analysing a consecutive cohort. Post hoc power calculations indicate that the sample size is adequate for the primary multivariable outcome (prolonged ICU stay; n=72 events, EPV=10.3), but underpowered to detect clinically meaningful differences in low-frequency neurological and cardiac events. (Figure 2).

Anaesthetic Technique

The choice of anaesthesia was made jointly by the attending anaesthesiologist and vascular surgeon based on patient comorbidities, cervical anatomy, and patient preference. No institutional protocol favoured one technique over the other. GA was given through standard intravenous induction and maintained with inhaled volatile agents or total intravenous anaesthesia (TIVA), with endotracheal intubation. RA involved a cervical plexus block — deep, superficial, or combined — guided by ultrasound and supplemented with local infiltration as needed. All RA procedures were done with the patient awake, allowing for continuous neurological monitoring.

Surgical Technique

Intraluminal shunting was performed selectively. In GA patients, shunting was indicated when intraoperative TCD monitoring demonstrated a reduction in mean flow velocity exceeding 50% from baseline, or when stump (back-bleeding) pressure was <50 mmHg. In RA patients, shunting was performed upon detection of any new neurological deficit (motor weakness, dysphasia, or deteriorating consciousness) during the test clamping period.

Outcome Measures

Our primary outcome was a composite of ischemic stroke, TIA, myocardial infarction, or all-cause mortality within 30 days. Secondary outcomes included each individual event, wound complications (bleeding, nerve injury, hematoma, infection, restenosis, revision surgery), and lengths of ICU and hospital stay. We defined prolonged ICU stay as any admission exceeding 12 hours — the point at which our unit typically reassesses patients forward transfer after confirming hemodynamic stability and early neurological recovery, a threshold consistent with comparable published studies. Critically, the same ward transfer criteria — hemodynamic stability, absence of new neurological deficit, and adequate pain control — were applied to both GA and RA patients, minimizing the likelihood that observed differences in ICU stay were attributable to differential institutional care pathways rather than anaesthetic technique; however, as this was a retrospective study, the possibility of residual confounding cannot be excluded. Stroke was defined as a new focal

neurological deficit lasting more than 24 hours with imaging confirmation; TIA as a deficit resolving within 24 hours without imaging-confirmed infarction; and MI per the Fourth Universal Definition (15).

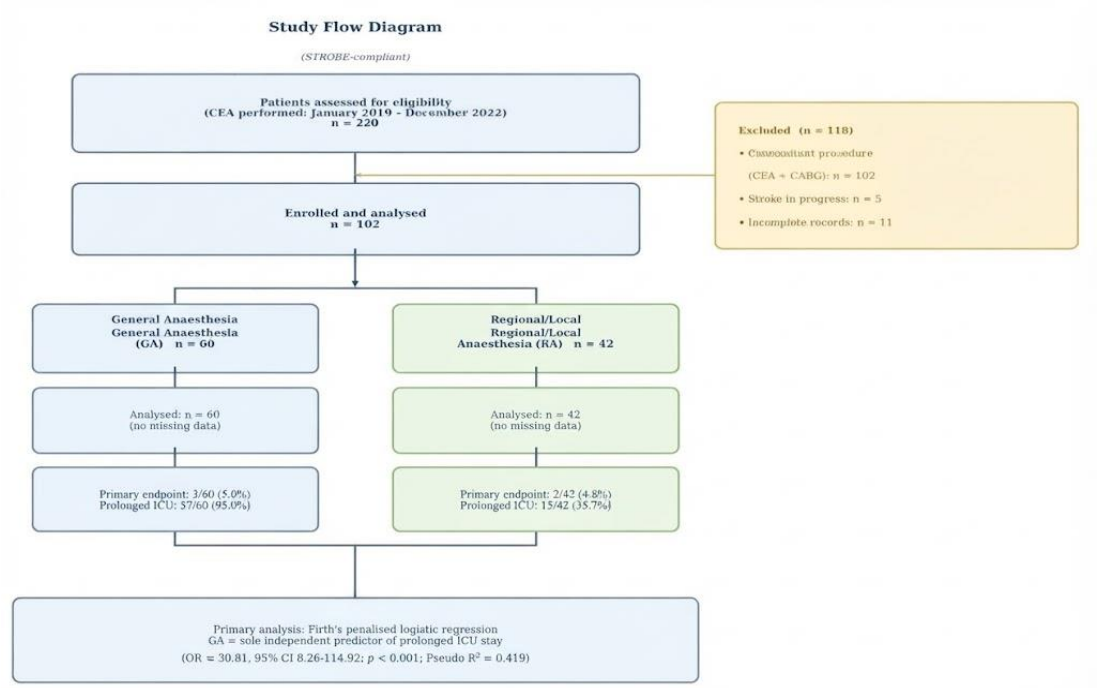


Figure 1. Study flow diagram (STROBE-compliant). Of 220 patients assessed for eligibility, 118 were excluded: 102 for concomitant procedures (CEA combined with coronary artery bypass grafting), 5 for CEA performed for stroke in progress, and 11 for incomplete perioperative records. The remaining 102 patients were included in the final analysis. CEA = Carotid Endarterectomy; CABG = Coronary Artery Bypass Grafting; GA = General Anaesthesia; RA = Regional/Local Anaesthesia; ICU = Intensive Care Unit; OR = Odds Ratio; CI = Confidence Interval.

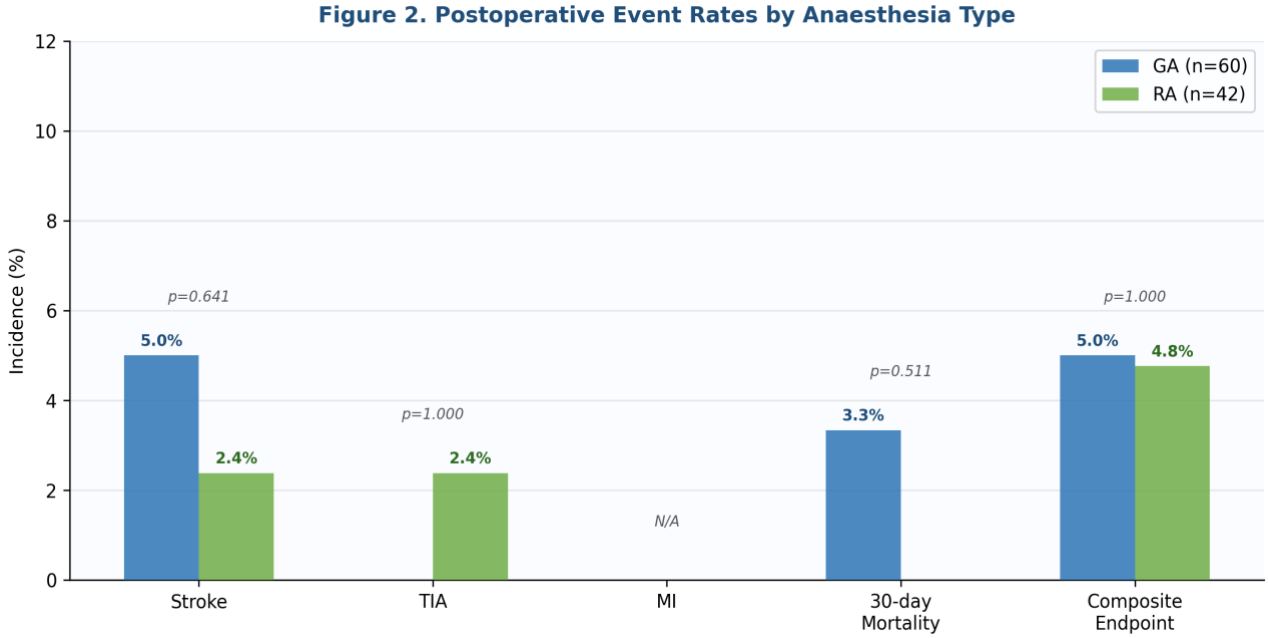


Figure 2. Postoperative event rates (%) by anaesthesia type. Grouped bar chart depicting the incidence of postoperative stroke, TIA, myocardial infarction, 30-day in-hospital mortality, and the composite endpoint in patients undergoing CEA under general anaesthesia (GA) versus regional/local anaesthesia (RA). p-values by Fisher's exact test. No statistically significant differences were observed for any individual outcome or the composite endpoint. GA = General Anaesthesia; RA = Regional/Local Anaesthesia; TIA = Transient Ischemic Attack; MI = Myocardial Infarction.

Statistical Analysis

All analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) and Python 3.11 (SciPy and Stats models libraries).

Continuous variables were first tested for normality using the Shapiro–Wilk test. Haemoglobin and LDL cholesterol

met normality criteria and are presented as mean ± SD, with group comparisons by independent t-test. Other continuous variables — age, ejection fraction, operative and cross-clamp times, ICU and hospital stay, and standard laboratory results — were non-normally distributed and are described as median (IQR) and were compared using the Mann-Whitney U test. Categorical data are reported as n (%). Chi-square tests were used for group comparisons, with Fisher's exact test applied when any expected count was below five. This included COPD, chronic kidney disease, atrial fibrillation, pulmonary hypertension, bilateral stenosis, unstable plaque, prior TIA, and all rare postoperative events including stroke, bleeding, nerve injury, hematoma, revision surgery, and 30-day mortality. With only five events in the composite endpoint, the minimum required events per variable (EPV) criterion ruled out multivariable modelling for the primary outcome; univariate logistic regression was used instead; it is acknowledged that with only five events, this analysis also has severely limited statistical power and the results should be interpreted with considerable caution, as the absence of a significant predictor does not exclude the possibility of clinically meaningful associations. For prolonged ICU stay (72 events; EPV=10.3), given the near-complete separation in the data (57 of 60 GA patients had prolonged ICU stay), Firth's penalized likelihood logistic regression was applied in place of standard maximum likelihood estimation to obtain stable, unbiased coefficient estimates. Pre-defined covariates were anaesthesia type (GA vs. RA as reference), age, symptomatic status, ejection fraction, coronary artery disease, diabetes, and hypertension. Results are presented as OR with 95% CI; model fit was assessed by McFadden's Pseudo R^2. A $p<0.05$ (two-tailed) threshold was used throughout. The dataset was complete for all variables, so no imputation was necessary.

RESULTS

One hundred and two patients were included: 60 in the GA group and 42 in the RA group. The two groups were well-matched at baseline (Table 1). Mean age was 72.1 ± 8.2 years in the GA group and 71.0 ± 9.5 years in the RA group (p=0.434), with a similar proportion of men in each group (approximately three-quarters). Cardiovascular risk factors — hypertension, diabetes, coronary artery disease, and hyperlipidaemia — were evenly distributed (all p>0.05), as was the proportion with symptomatic stenosis (51.7% vs. 52.4%; p=0.942). Cardiac function, laboratory values, and carotid imaging findings were also comparable (Table 1).

Table 1. Baseline demographic and clinical characteristics stratified by anaesthesia type.

Variable	GA (n=60)	RA (n=42)	p-value
Demographic Characteristics			
Age (years)	72.0 (66.0–77.3)	71.5 (65.3–76.0)	0.434
Male sex, n (%)	45 (75.0)	32 (76.2)	0.885
Comorbidities			
Hypertension, n (%)	42 (70.0)	30 (71.4)	0.877
Diabetes mellitus, n (%)	33 (55.0)	22 (52.4)	0.789
Coronary artery disease, n (%)	36 (60.0)	27 (64.3)	0.662
Hyperlipidaemia, n (%)	29 (48.3)	21 (50.0)	0.869
Smoking, n (%)	13 (21.7)	10 (23.8)	0.794
COPD, n (%)	7 (11.7)	5 (11.9)	0.969
Chronic kidney disease, n (%)	6 (10.0)	4 (9.5)	0.934
Atrial fibrillation, n (%)	5 (8.3)	3 (7.1)	0.829
Anaemia, n (%)	16 (26.7)	13 (31.0)	0.628
Neurological Status			
Symptomatic stenosis, n (%)	31 (51.7)	22 (52.4)	0.942
Prior TIA, n (%)	12 (20.0)	5 (11.9)	0.272
Prior stroke (CVA), n (%)	20 (33.3)	18 (42.9)	0.325
Preoperative Medications			
Preoperative statin use, n (%)	51 (85.0)	37 (88.1)	0.645
Laboratory & Cardiac Values			
Haemoglobin (g/dL), mean ± SD	13.7 ± 1.6	13.3 ± 1.5	0.193
Ejection fraction (%), median (IQR)	55.0 (52.0–60.0)	55.0 (50.0–63.0)	0.915
LDL cholesterol (mg/dL), mean ± SD	95.1 ± 38.3	96.1 ± 32.0	0.894
CRP (mg/L), median (IQR)	1.1 (0.6–2.4)	1.4 (0.6–3.4)	0.428
Carotid Imaging			
Left carotid stenosis (%), median (IQR)	70.0 (30.0–90.0)	80.0 (50.0–95.0)	0.241
Right carotid stenosis (%), median (IQR)	15.0 (0.0–90.0)	30.0 (0.0–80.0)	0.725
Bilateral significant stenosis, n (%)	4 (6.7)	1 (2.4)	0.397
Unstable plaque morphology, n (%)	21 (35.0)	16 (38.1)	0.743

Continuous normally distributed data: mean ± SD (t-test); non-normal data: median (IQR) (Mann-Whitney U). Categorical data: n (%). GA = General Anaesthesia; RA = Regional/Local Anaesthesia; TIA = Transient Ischemic Attack; CVA = Cerebrovascular Accident; COPD = Chronic Obstructive Pulmonary Disease; LDL = Low-Density Lipoprotein; CRP = C-Reactive Protein; IQR = Interquartile Range.

The operative profiles were nearly identical between groups (Table 2). Patch angioplasty rates were 93.3% and 92.9%, respectively (p=0.933), and total operative time was similar (p=0.293). Median cross-clamp time was slightly shorter in the GA group (18.5 min vs. 19.5 min; p=0.046), but this one-minute difference has no clinical significance. Four patients required shunting in each group (p=0.712). The key difference appeared postoperatively: GA patients spent a median of 17.0 hours in the ICU (IQR 16.0–19.0) compared to 3.0 hours (IQR 3.0–16.0) in the RA group — a difference that was statistically significant (p<0.001; Figure 3). Hospital length of stay did not differ statistically between groups (p=0.658; Figure 4).

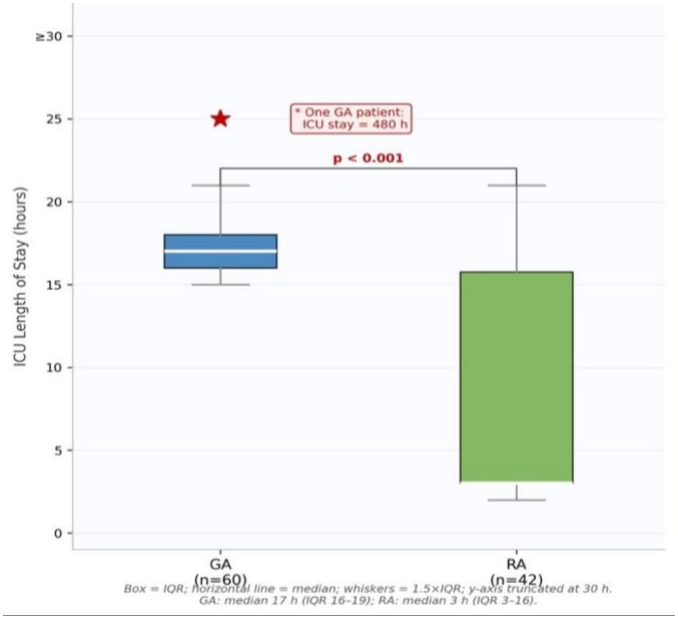


Figure 3. ICU length of stay (hours) by anaesthesia type. Box-and-whisker plot; horizontal line = median; box = IQR; whiskers = 1.5×IQR. Y-axis truncated at 30 hours for visual clarity; one GA patient had an outlier ICU stay of 480 hours (shown as *). GA patients had significantly longer ICU stays (median 17 h [IQR 16–19] vs. 3 h [IQR 3–16]; p<0.001). GA = General Anaesthesia; RA = Regional/Local Anaesthesia; ICU = Intensive Care Unit; IQR = Interquartile Range.

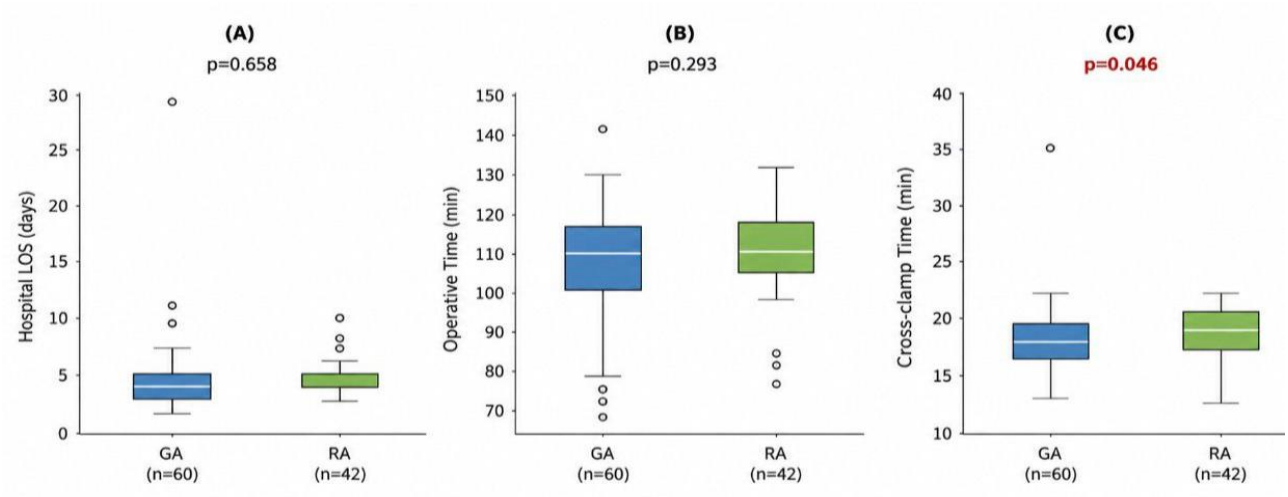


Figure 4. Operative metrics by anaesthesia type. Box plots comparing (A) hospital length of stay (days), (B) total operative time (minutes), and (C) cross-clamp time (minutes) between GA and RA groups. Hospital LOS: p=0.658; operative time: p=0.293; cross-clamp time: p=0.046. All comparisons by Mann–Whitney U test. GA = General Anaesthesia; RA = Regional/Local Anaesthesia.

Postoperative outcomes are detailed in Table 3. The composite 30-day endpoint was reached in 3 GA patients (5.0%) and 2 RA patients (4.8%; p=1.000). Individual outcome rates were also comparable: postoperative stroke occurred in 3 vs. 1 patient (5.0% vs. 2.4%; p=0.641), one RA patient experienced a TIA (vs. none in GA; p=1.000), and 30-day mortality was 3.3% in the GA group versus 0% in the RA group (p=0.511). Both deaths occurred in patients with significant coronary artery disease who developed postoperative stroke; a cardiac aetiology was considered contributory in both cases. No myocardial infarction was recorded in either group, and no statistically significant difference was observed in surgical complications — including bleeding, cranial nerve injury, hematoma, and restenosis — between the two groups.

Table 2. Operative details and perioperative management.

Variable	GA (n=60)	RA (n=42)	p-value
Operative Details			
Operative side — Right, n (%)	28 (46.7)	19 (45.2)	
Operative side — Left, n (%)	30 (50.0)	23 (54.8)	
Operative side — Bilateral, n (%)	2 (3.3)	0 (0.0)	
Patch angioplasty, n (%)	56 (93.3)	39 (92.9)	0.933
Cross-clamp time (min), median (IQR)	18.5 (17.0–20.0)	19.5 (18.0–21.0)	**0.046**
Total operative time (min), median (IQR)	111.0 (103.0–119.5)	112.5 (106.5–118.3)	0.293
Intraoperative shunt use, n (%)	4 (6.7)	4 (9.5)	0.712
Postoperative Management			
Dual antiplatelet therapy, n (%)	60 (100.0)	41 (97.6)	0.412
Postoperative statin, n (%)	60 (100.0)	42 (100.0)	
Postoperative i.v. nitroglycerin (Perlinganit®), n (%)	7 (11.7)	1 (2.4)	0.083
ICU length of stay (hours), median (IQR)	17.0 (16.0–19.0)	3.0 (3.0–16.0)	**<0.001**
Hospital length of stay (days), median (IQR)	4.0 (3.0–5.0)	4.0 (4.0–5.0)	0.658

ICU = Intensive Care Unit; IQR = Interquartile Range; GA = General Anaesthesia; RA = Regional/Local Anaesthesia. Bold p-values indicate statistical significance (p<0.05).

Table 3. Postoperative outcomes and complications.

Outcome	GA (n=60)	RA (n=42)	p-value
Primary Composite Endpoint			
Stroke + TIA + MI + Death, n (%)	3 (5.0)	2 (4.8)	1.000
Neurological Outcomes			
Postoperative stroke (CVA), n (%)	3 (5.0)	1 (2.4)	0.641
Postoperative TIA, n (%)	0 (0.0)	1 (2.4)	1.000
Cardiac Outcomes & Mortality			
Postoperative myocardial infarction, n (%)	0 (0.0)	0 (0.0)	
30-day in-hospital mortality†, n (%)	2 (3.3)	0 (0.0)	0.511
Surgical Complications			
Postoperative bleeding, n (%)	2 (3.3)	2 (4.8)	1.000
Cranial nerve injury, n (%)	2 (3.3)	2 (4.8)	1.000
Wound hematoma, n (%)	0 (0.0)	2 (4.8)	0.168
Restenosis, n (%)	1 (1.7)	0 (0.0)	1.000
Revision surgery, n (%)	3 (5.0)	2 (4.8)	1.000
Hospital Resource Utilization			
ICU length of stay (hours), median (IQR)	17.0 (16.0–19.0)	3.0 (3.0–16.0)	**<0.001**
Hospital length of stay (days), median (IQR)	4.0 (3.0–5.0)	4.0 (4.0–5.0)	0.658

All categorical comparisons by Fisher's exact test. Continuous data by Mann-Whitney U. GA = General Anaesthesia; RA = Regional/Local Anaesthesia; TIA = Transient Ischemic Attack; CVA = Cerebrovascular Accident; MI = Myocardial Infarction; ICU = Intensive Care Unit; IQR = Interquartile Range. Bold p-values indicate p<0.05. †Both 30-day deaths occurred in patients who also experienced postoperative stroke; counted once in the composite endpoint.

On regression analysis, given only five composite endpoint events, multivariable modelling was not feasible; univariate regression identified no statistically significant predictor, including anaesthesia type (OR=1.05, 95% CI 0.17–6.59; p=0.956); given the very small number of events (n=5), however, this analysis had negligible statistical power and the absence of a significant predictor should not be interpreted as evidence that no clinically meaningful relationship exists. For prolonged ICU stay (>12 hours), multivariable logistic regression identified GA as the sole independent predictor (OR=30.81, 95% CI 8.26–114.92; p<0.001; Pseudo R^2=0.419), with no other covariate reaching significance (Table 4; Figure 5).

Table 4. Multivariable logistic regression — independent predictors of prolonged ICU stay (>12 hours).

Variable	OR (95% CI)	p-value
General anaesthesia (vs. RA)	**30.81 (8.26–114.92)**	**<0.001**
Hypertension	3.93 (0.93–16.63)	0.063
Diabetes mellitus	2.47 (0.71–8.65)	0.156
Coronary artery disease	1.44 (0.40–5.16)	0.577
Ejection fraction (per %)	1.02 (0.95–1.10)	0.557
Symptomatic stenosis	0.80 (0.25–2.58)	0.705
Age (per year)	1.00 (0.94–1.07)	0.899

Pseudo R^2 = 0.419 (McFadden). Events-per-variable ratio = 10.3. OR = Odds Ratio; CI = Confidence Interval; RA = Regional/Local Anaesthesia (reference category). Bold values indicate p<0.05.

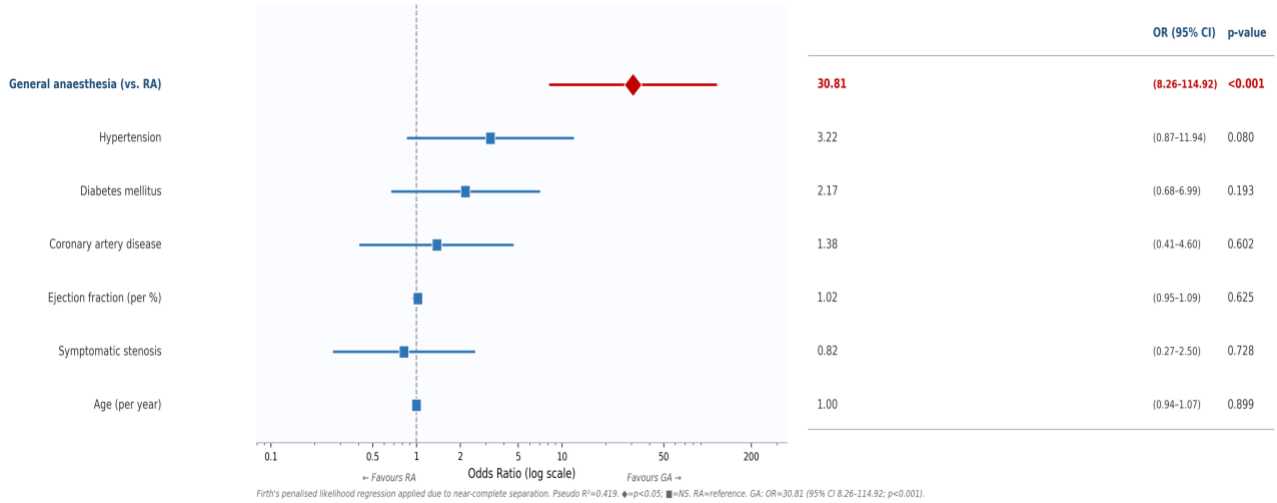


Figure 5. Firth's penalized logistic regression — predictors of prolonged ICU stay (>12 hours). Each point represents the odds ratio (OR) with 95% confidence intervals on a log scale. Red diamond = statistically significant predictor ($p<0.05$); blue squares = non-significant covariates. Firth's penalized likelihood method was applied due to near-complete separation in the data. GA was the sole independent predictor (OR=30.81, 95% CI 8.26–114.92; $p<0.001$; Pseudo $R^2=0.419$). RA = reference category; OR = Odds Ratio; CI = Confidence Interval.

DISCUSSION

The central message of this study is straightforward: in our hands, GA and RA produced equivalent clinical outcomes after CEA, yet RA was associated with a markedly shorter ICU stay. This pattern aligns with the broader literature and adds a contemporary single-centre perspective to the existing evidence from randomized trials and registry analyses.

Regarding clinical outcomes, the 30-day composite of stroke, TIA, MI, and death occurred in 5.0% of GA patients and 4.8% of RA patients ($p=1.000$) — a finding of reassuring equivalence across all individual outcome components (Table 3; Figure 3). The GALA Trial, the largest RCT addressing this question (n=3,526), reported composite event rates of 4.8% in the GA arm versus 4.5% in the LA arm (OR 1.07; 95% CI 0.80–1.43), and our results replicate this finding, reinforcing the conclusion that neither anaesthetic approach confers a safety advantage with respect to neurological or cardiac morbidity (7).

Postoperative stroke rates were 5.0% in the GA group and 2.4% in the RA group ($p=0.641$). The numerical difference is in a direction consistent with larger registry data, but our study was not powered to detect significance for events this rare — a recognized limitation of single-centre series. A propensity score-matched analysis of the ACS-NSQIP database (n=37,204) by Kline et al. (11). reported significantly lower stroke and TIA rates in the RA group for elective CEA. Similarly, a hospital policy-based analysis reported a lower risk of in-hospital stroke or death with LA compared to GA (OR 0.47; 95% CI 0.33–0.67) (16). The direction of effect in our dataset aligns with these registry-based findings, though the present study was underpowered to detect a significant difference in such low-frequency events. Thirty-day mortality was 3.3% in the GA group and 0% in the RA group ($p=0.511$); both deaths occurred in patients with significant cardiac comorbidities, and causality with anaesthetic technique cannot be established in a retrospective design.

Where the two groups diverged meaningfully was in ICU utilization (Figure 3). GA patients spent a median of 17 hours in critical care (IQR 16–19) compared with just 3 hours (IQR 3–16) in the RA group ($p<0.001$). On multivariable regression, GA emerged as the only independent predictor of prolonged ICU stay after adjustment for age, cardiac function, symptomatic status, and comorbidities (OR=30.81, 95% CI 8.26–114.92; $p<0.001$; Pseudo $R^2=0.419$; Table 4; Figure 5). The wide confidence interval is acknowledged — near-complete separation in the model, with only 3 of 60 GA patients having a short ICU stay, inflates the point estimate — but does not diminish the clinical or statistical significance of the finding.

A word on selection bias before drawing conclusions from these differences: the potential inherent to the retrospective non-randomized design warrants explicit consideration. The allocation of anaesthetic technique was based on clinician and patient preference without a formal protocol. As demonstrated in Table 1, all baseline demographic and clinical characteristics — including ejection fraction, coronary artery disease, hypertension, diabetes mellitus, symptomatic status, and prior cerebrovascular events — were statistically equivalent between groups (all $p>0.05$), providing reassurance against systematic allocation of higher-risk patients to GA. Furthermore, the institutional practice favoured RA as the default approach in anatomically straightforward cases without significant patient anxiety or contraindications to awake surgery; GA was reserved for cases with anticipated difficult cervical anatomy, patient refusal of awake surgery, or specific anaesthesiologic indications. This practice pattern supports the overall comparability of the two groups.

The practical implications are hard to overlook. ICU beds are among the most resource-intensive assets in any hospital, Dakour-Aridi et al. similarly reported lower total hospital costs and shorter length of stay with RA in a large national inpatient database (12). The mechanistic basis is multifactorial: GA requires a post-anaesthetic recovery period with airway monitoring, hemodynamic

surveillance, and management of emergence phenomena (hypertension, agitation, nausea) necessitating critical care-level nursing. In contrast, hemodynamically stable RA patients who remain neurologically intact throughout an awake procedure can frequently transfer to a standard ward following cervical block resolution, bypassing a prolonged ICU admission. The institutional care pathway at our centre reflects this distinction.

Total hospital stay was similar in both groups (median 4.0 days; p=0.658), suggesting that while RA shortens the critical care phase, ward-level recovery — wound healing, mobilization, discharge fitness — proceeds at the same pace regardless of anaesthetic technique (17).

Beyond ICU stay, operative metrics were comparable between groups, as shown in Table 2 and Figure 4. Figure 4A confirms similar hospital length of stay (p=0.658); Figure 4B shows equivalent total operative time (p=0.293); and Figure 4C depicts the marginally shorter cross-clamp time in the GA group (18.5 vs. 19.5 min; p=0.046) — a one-minute difference of no clinical consequence. Shunt use was also similar across groups (6.7% vs. 9.5%; p=0.712). In GA patients, the shunt decision rested on TCD and back-pressure criteria; in awake RA patients, it was driven by neurological change during test clamping — clinically the most direct and reliable sign of inadequate cerebral perfusion (13). The comparability of shunt rates reflects a selective, protocol-driven shunting policy in both arms, consistent with current ESVS 2023 guideline recommendations (4). This marginal difference plausibly reflects the absolute stillness of the anaesthetized patient during local dissection but produced no divergence in neurological outcomes (5).

From a technical standpoint, patch angioplasty was used in over 92% of patients in both groups (p=0.933), consistent with our centre's preference for closure technique supported by Cochrane evidence showing lower rates of perioperative stroke, occlusion, and restenosis compared to primary closure (18). The near-identical operative profiles across groups — patch use, operative time, cross-clamp duration — provide reassurance that differences in outcome reflect the anaesthetic choice, not the surgery itself.

The complication profile was reassuringly similar between the two groups. Cranial nerve injuries occurred in two patients per group (3.3% vs. 4.8%; p=1.000) — in keeping with published CEA rates of 3–8%. Postoperative bleeding was also rare in both groups (3.3% vs. 4.8%; p=1.000). Wound hematoma was seen only in RA patients (4.8% vs. 0%; p=0.168), though without statistical significance. The low overall complication rate across both groups reflects the standardized, high-volume surgical environment in which this cohort was treated.

Beyond the primary findings, several methodological features of this study deserve mention. The dataset is complete — no missing values across 102 patients — removing any need for imputation. Groups were well-balanced at baseline without requiring formal matching, supporting a fair comparison. The regression model for ICU outcome was appropriately powered (EPV=10.3), and covariate selection was pre-specified to limit overfitting. Practically speaking, an OR of 30.81 (95% CI 8.26–114.92) for GA as a predictor of prolonged ICU stay is a striking finding with direct implications for pathway planning in centres where critical care capacity is constrained.

This study has several limitations that should be kept in mind. First, the retrospective non-randomized design introduces potential selection bias in anaesthetic allocation, and unmeasured confounders cannot be excluded despite well-balanced baseline characteristics. Second, the sample size (n=102) limits statistical power for low-frequency events; the composite endpoint (n=5) precluded multivariable analysis. The initial standard logistic regression yielded a very wide confidence interval for the ICU OR, reflecting near-complete separation (only 3 of 60 GA patients had a short ICU stay). Firth's penalized logistic regression was therefore applied as the primary multivariable analysis, yielding a more conservative estimate (OR=30.81, 95% CI 8.26–114.92; p<0.001) with a 53% narrower confidence interval; this result should nonetheless still be interpreted with appropriate caution given the sample size. Third, single-centre origin limits generalizability to institutions with different surgical volumes, anaesthetic protocols, or postoperative care pathways. Fourth, long-term neurological follow-up was unavailable for all patients. Fifth, formal cost analysis was not performed, and the economic implications of the ICU stay difference could not be quantified. Finally, the study spans four years (2019–2022), during which anaesthetic preferences and team experience may have evolved; a potential temporal shift toward RA and its influence on observed outcomes was not formally assessed and represents a further limitation.

CONCLUSION

In this cohort, no statistically significant differences were observed in clinical outcomes between regional and general anaesthesia for CEA. Where they differ is in critical care: GA is independently associated with substantially longer ICU utilization (OR=30.81, 95% CI 8.26–114.92; p<0.001), a finding with tangible implications for perioperative pathway planning and healthcare resource allocation. These results support an individualized approach to anaesthetic selection consistent with current guidelines and argue for prospective studies with embedded health-economic analysis to quantify the full value of RA in this surgical population.

DECLARATIONS

Acknowledgements: The authors have no specific acknowledgements to declare.

Author Contributions: Conceptualization, K.E.E., M.F.S. and E.U.; Methodology, K.E.E. and M.F.S.; Validation, M.H.; Formal Analysis, M.F.S. and N.G.E.; Investigation, M.Y., H.B. and G.A.; Resources, E.U.; Data Curation, K.E.E., M.Y., H.B., N.G.E. and G.A.; Writing–Original Draft, K.E.E. and N.G.E.; Writing–Review & Editing, M.F.S., E.U. M.Y., H.B., G.A. and M.H.; Supervision, M.F.S., E.U. and M.H.; Project administration, K.E.E.. All authors have read and approved the final version of the manuscript.

Conflict of Interest: The authors declare no conflict of interest.

Supporting Institutions: This research received no external funding.

Ethical Approval: We performed a retrospective analysis of this cohort. The study protocol was approved by the institutional review board (Approval No: E2-23-4281; Approval Date: June 7, 2023), and it was conducted according to the Declaration of Helsinki.
Plagiarism Statement: Not published previously; not under consideration elsewhere. Similarity report provided.
Use of AI Tools: AI tools used solely for language editing and grammar checking. All scientific content and conclusions are the sole responsibility of the authors.
Data Availability: Available from the corresponding author upon reasonable request.

REFERENCES

1. North American Symptomatic Carotid Endarterectomy Trial Collaborators; Barnett HJM, Taylor DW, Haynes RB, Sackett DL, Peerless SJ, et al. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med. 1991;325(7):445-53. doi:10.1056/NEJM199108153250701.
2. European Carotid Surgery Trialists' Collaborative Group. MRC European Carotid Surgery Trial: interim results for symptomatic patients with severe (70–99%) or with mild (0–29%) carotid stenosis. Lancet. 1991;337(8752):1235-43. doi:10.1016/0140-6736(91)92916-P.
3. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. Endarterectomy for asymptomatic carotid artery stenosis. JAMA. 1995;273(18):1421-8. doi:10.1001/jama.1995.03520420037035.
4. Naylor R, Rantner B, Ancetti S, de Borst GJ, De Carlo M, Halliday A, et al. Editor's Choice — European Society for Vascular Surgery (ESVS) 2023 clinical practice guidelines on the management of atherosclerotic carotid and vertebral artery disease. Eur J Vasc Endovasc Surg. 2023;65(1):7–111. doi:10.1016/j.ejvs.2022.04.011.
5. Stoneham MD, Knighton JD. Regional anaesthesia for carotid endarterectomy. Br J Anaesth. 1999;82(6):910-9. doi:10.1093/bja/82.6.910.
6. Tangkanakul C, Counsell CE, Warlow CP. Local versus general anaesthesia in carotid endarterectomy: a systematic review of the evidence. Eur J Vasc Endovasc Surg. 1997;13(5):491-9. doi:10.1016/s1078-5884(97)80178-5.
7. GALA Trial Collaborative Group; Lewis SC, Warlow CP, Bodenham AR, Colam B, Rothwell PM, et al. General anaesthesia versus local anaesthesia for carotid surgery (GALA): a multicentre, randomised controlled trial. Lancet. 2008;372(9656):2132-42. doi:10.1016/S0140-6736(08)61699-2.
8. Vaniyapong T, Chongruksut W, Rerkasem K. Local versus general anaesthesia for carotid endarterectomy. Cochrane Database Syst Rev. 2013;(12):CD000126. doi:10.1002/14651858.CD000126.pub4.
9. Hajibandeh S, Hajibandeh S, Antoniou SA, Torella F, Antoniou GA. Meta-analysis and trial sequential analysis of local vs. general anaesthesia for carotid endarterectomy. Anaesthesia. 2018;73(11):1280-9. doi:10.1111/anae.14320.
10. Brott TG, Halperin JL, Abbara S, Bacharach JM, Barr JD, Bush RL, et al. 2011 ASA / ACCF / AHA / AANN / AANS / ACR / ASNR / CNS / SAIP / SCAI / SIR / SNIS / SVM / SVS guideline on the management of patients with extracranial carotid and vertebral artery disease. Stroke. 2011;42(8):e464-540. doi:10.1161/STR.0b013e3182112cc2.
11. Kline LA, Kothandaraman V, Knio ZO, Zuo Z. Effect of regional versus general anesthesia on thirty-day outcomes following carotid endarterectomy: a cohort study. Int J Surg. 2023;109(5):1291-8. doi:10.1097/JS9.0000000000000356.
12. Dakour Aridi H, Paracha N, Nejim B, Locham S, Malas MB. Anesthetic type and hospital outcomes after carotid endarterectomy from the Vascular Quality Initiative database. J Vasc Surg. 2018;67(5):1419-28. doi:10.1016/j.jvs.2017.09.028.
13. Rerkasem K, Rothwell PM. Routine or selective carotid artery shunting for carotid endarterectomy (and different methods of monitoring in selective shunting). Cochrane Database Syst Rev. 2009;(4):CD000190. doi:10.1002/14651858.CD000190.pub2.
14. Guay J. Regional or general anaesthesia for carotid endarterectomy? Evidence from published prospective and retrospective studies. J Cardiothorac Vasc Anesth. 2007;21(1):127-32. doi:10.1053/j.jvca.2006.07.022.
15. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth universal definition of myocardial infarction (2018). J Am Coll Cardiol. 2018;72(18):2231-64. doi:10.1016/j.jacc.2018.08.1038.
16. Kirchhoff F, Knappich C, Kallmayer M, Bohmann B, Lohe V, Tsantilas P, Naher S, Eckstein HH, Kuehnl A. Association between hospital policy on local versus general anesthesia, and outcomes of carotid endarterectomy: secondary data analysis of the German Statutory Carotid Quality Assurance Database. Stroke Vasc Interv Neurol. 2024;4(6):e001420. doi:10.1161/SVIN.123.001420.
17. Siu A, Patel J, Prentice HA, Cappuzzo JM, Hashemi H, Mukherjee D. A cost analysis of regional versus general anesthesia for carotid endarterectomy. Ann Vasc Surg. 2017;39:189-94. doi:10.1016/j.avsg.2016.05.124.
18. Rerkasem A, Orrapin S, Howard G, Rerkasem K. Carotid endarterectomy for symptomatic carotid stenosis. Cochrane Database Syst Rev. 2020;9(9):CD001081. doi:10.1002/14651858.CD001081.pub4.