

Postoperative Stroke and Delirium After Cardiac Surgery in a Young Middle Eastern Cohort: Procedure-Specific Incidence, Relationship to Bypass Duration, and One-Year Mortality: a retrospective cohort study

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Abstract

Background

Postoperative neurological complications are well characterized in older North American and European cardiac surgical cohorts. We describe the incidence of postoperative stroke and delirium, their distribution across procedure types, their relationship to cardiopulmonary bypass duration, and their association with one-year mortality in a young Middle Eastern cardiac surgical population.

Methods

This retrospective cohort study included 256 adults who underwent cardiac surgery with cardiopulmonary bypass at a tertiary referral center in Riyadh, Saudi Arabia, between 2020 and 2025. Outcomes were imaging-confirmed stroke and delirium within 30 days of surgery and all-cause mortality at one year. Associations were estimated with penalized logistic regression adjusted for age, sex, bypass duration, and procedure group.

Results

The median age was 52 years, 46% of patients were younger than 50 years, and isolated valve surgery accounted for 52% of operations. Stroke occurred in 19 patients (7.4%), delirium in 28 (10.9%), and either in 35 (13.7%). Among 73 patients undergoing isolated coronary artery bypass grafting there were no strokes and one case of delirium, compared with 10.6% and 12.9% after isolated valve surgery and 9.8% and 19.6% after combined or other complex procedures ($P = 0.005$ and $P = 0.001$). Each additional hour of bypass was associated with delirium after adjustment for age, sex, and procedure group (odds ratio 1.39, 95% confidence interval 1.03 to 1.86) but not with stroke (odds ratio 1.17, 95% confidence interval 0.80 to 1.63), and within isolated valve surgery bypass duration was associated with neither outcome. One-year mortality was 52.6% after stroke, 25.0% after delirium without stroke, and 2.3% in patients with neither complication; adjusted odds ratios were 30.1 (95% confidence interval 8.8 to 118) and 6.5 (95% confidence interval 1.4 to 28.1), respectively.

Conclusions

In this young, valve-dominated Middle Eastern cohort, postoperative stroke and delirium were concentrated in valve and complex procedures and were rare after isolated coronary surgery. Bypass duration behaved as a marker of procedure type rather than an independent predictor of stroke. Both complications carried a large excess in one-year mortality and justify structured postoperative neurological surveillance.

Background

Stroke and delirium are the two most consequential neurological complications of cardiac surgery. In the Multicenter Study of Perioperative Ischemia, adverse cerebral outcomes followed 6.1% of coronary operations and were associated with a five- to tenfold increase in in-hospital death [1]. Delirium is more frequent and is linked to late mortality and prolonged cognitive impairment [2–5]. Perioperative stroke in contemporary North American series occurs in 1% to 2% of patients with operative mortality of 15% to 20% [6, 7].

Most of this evidence comes from patients in their late sixties and seventies with coronary or degenerative valve disease [1, 6–9]. Cardiopulmonary bypass (CPB) duration is a recurring correlate of neurological injury in these cohorts [9–12], but longer bypass runs accompany more complex operations with more aortic manipulation and embolic exposure, so bypass time may be a marker of complexity rather than a cause of injury. Pooled analyses have not consistently found bypass time to be an independent predictor once procedure type and patient factors are accounted for [13, 14], although some single-center cohorts have [15].

Cardiac surgical populations in the Middle East differ from those in the published literature. Rheumatic heart disease remains prevalent [16], valve surgery is performed in patients decades younger than in Western series [17], and atrial fibrillation is common in these patients even at young ages. Regional data on postoperative neurological complications are limited, and most have addressed delirium alone [18].

We therefore describe, in a young Middle Eastern cardiac surgical cohort, the incidence and overlap of postoperative stroke and delirium, their distribution across procedure types, whether CPB duration was associated with either complication after accounting for the operation performed, and the association of each complication with one-year mortality.

Methods

Study design and setting

We conducted a retrospective cohort study at King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia, a tertiary referral center with adult cardiac surgical, structural heart, and heart transplant programs and a dedicated cardiac surgical intensive care unit (CSICU). The study was approved by the institutional Research Ethics Committee (approval number 2251569, dated 4 September 2025), which waived individual informed consent because the study used existing de-identified records. The study conformed to the Declaration of Helsinki and is reported according to the STROBE recommendations [19].

Participants

Adult cardiac surgical admissions to the CSICU between January 2020 and December 2025 were identified from unit records. To avoid over-representation of any single period or team, a random sample of eligible admissions distributed across the study years was drawn for chart abstraction, and 350 records were reviewed. Patients were eligible if they were 18 years or older and underwent cardiac surgery with CPB. Patients were excluded if surgery was performed without CPB (off-pump coronary surgery or isolated mechanical circulatory support cannulation), if CPB details were not documented, or if they had a documented history of stroke or dementia. Each patient was counted once. The analytic cohort comprised 256 patients (Fig. 1) and represents a sample of institutional cardiac surgical activity, not the complete surgical volume.

Data sources and variables

Data were abstracted from the electronic health record, operative and perfusion notes, and CSICU documentation: age, sex, diabetes mellitus, hypertension, atrial fibrillation, preoperative left ventricular assist device support, the procedure, total CPB duration, aortic cross-clamp time, lowest mean arterial pressure (MAP) during bypass, and nadir core temperature. Procedures were grouped a priori into isolated coronary artery bypass grafting (CABG), isolated valve surgery, and a combined or other category comprising combined CABG and valve operations, other complex cardiac and great vessel procedures, and heart transplantation. Vital status at one year was obtained for all patients.

Outcome definitions

The two primary outcomes, analyzed separately, were stroke and delirium within 30 days of surgery. Stroke was a new ischemic infarct or intracranial hemorrhage confirmed on computed tomography or magnetic resonance imaging. Delirium was a positive Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) result [20] or, in its absence, contemporaneous documentation of confusion, agitation, encephalopathy, or fluctuating consciousness identified on structured chart review using the approach of Inouye and colleagues [21]. CAM-ICU screening was in routine use throughout the study period but not under a research protocol, and its frequency was not verified as uniform.

Stroke-code activation was recorded as a process-of-care measure, not an outcome, and its overlap with confirmed stroke is reported. Documented cognitive decline (new chart-documented impairment or neurology consultation for a deficit) was recorded descriptively because no preoperative cognitive baseline was available. For the mortality analysis, patients were classified into three mutually exclusive phenotypes: stroke (with or without delirium), delirium without stroke, and neither. The secondary outcome was all-cause mortality at one year. CSICU length of stay was documented for only 77 patients and was not analyzed.

Statistical analysis

Continuous variables are summarized as median (interquartile range, IQR) and categorical variables as counts and percentages, with Wilson 95% confidence intervals (CIs) where stated. Groups were compared with the Kruskal-Wallis test and with exact tests; for tables with more than two rows, an exact P value was obtained by Monte Carlo sampling of tables with fixed margins (200,000 samples). Because the isolated CABG group had zero strokes, standard maximum-likelihood logistic regression yields unstable estimates, so all logistic models used the Firth penalized likelihood, reporting odds ratios (ORs) with profile-likelihood CIs and likelihood-ratio P values [22].

CPB duration was analyzed per 60-minute increase. For each of stroke and delirium we fitted three models: unadjusted; adjusted for age and sex; and adjusted for age, sex, and procedure group. Procedure group was included deliberately, because the operation determines both bypass duration and neurological risk through mechanisms independent of bypass time, and omitting it would attribute the effect of operative complexity to CPB. We also examined the CPB association within isolated valve surgery alone, the largest homogeneous group. For one-year mortality we fitted models with the composite of stroke or delirium, and with the three-level phenotype, adjusted for age, CPB duration, and procedure group. Pre-specified sensitivity analyses excluded heart transplant recipients and patients cooled below 28 degrees Celsius. Event numbers (19 strokes, 28 delirium events, 19 deaths) limited each model to a few covariates. Missing covariate values were few (cross-clamp time 30, MAP 1, diabetes 1, atrial fibrillation 1) and were handled by complete-case analysis. Two-sided $P < 0.05$ was considered significant. Analyses used Python 3.12 (statsmodels 0.14, SciPy 1.17).

Results

Cohort characteristics

The 256 patients had a median age of 52 years (IQR 39 to 61); 118 (46.1%) were younger than 50 and 37 (14.5%) were 65 or older. Isolated valve surgery accounted for 132 operations (51.6%), isolated CABG for 73 (28.5%), and combined or other procedures for 51 (19.9%; 6 combined CABG and valve, 39 other complex cardiac or great vessel, 6 heart transplants). Baseline and intraoperative characteristics by procedure group are shown in Table 1. Isolated CABG patients were older with more diabetes and hypertension, whereas atrial fibrillation was almost confined to valve and complex surgery (34.8% and 30.0% versus 1.4%). Median CPB duration was 102, 154, and 146 minutes in the three groups, and bypass exceeded 180 minutes in 4.1%, 30.3%, and 27.5%. Eighteen patients (7.0%) were cooled below 28 degrees Celsius, all in the valve and complex groups.

Table 1
Baseline and intraoperative characteristics by procedure group.

Characteristic	All patients (N = 256)	Isolated CABG (n = 73)	Isolated valve (n = 132)	Combined or other (n = 51)
Age, years	52 (39–61)	58 (53–65)	48 (35–59)	41 (30–51)
Cardiopulmonary bypass, min	132 (96–177)	102 (86–120)	154 (118– 191)	146 (105–207)
Aortic cross-clamp, min a	92 (68–121)	70 (60–90)	97 (77–128)	118 (86–141)
Lowest MAP on bypass, mmHg	56 (52–62)	58 (51–63)	58 (54–62)	55 (50–60)
Nadir temperature, degrees C	34 (32–35)	35 (34–35)	33 (32–34)	34 (32–35)
Male sex	155 (60.5)	61 (83.6)	57 (43.2)	37 (72.5)
Age 65 years or older	37 (14.5)	20 (27.4)	15 (11.4)	2 (3.9)
Diabetes mellitus	87 (34.1)	50 (68.5)	30 (22.9)	7 (13.7)
Hypertension	94 (36.7)	46 (63.0)	38 (28.8)	10 (19.6)
Atrial fibrillation	62 (24.3)	1 (1.4)	46 (34.8)	15 (30.0)
Preoperative LVAD	2 (0.8)	0 (0.0)	0 (0.0)	2 (3.9)
Nadir temperature below 28 degrees C	18 (7.0)	0 (0.0)	9 (6.8)	9 (17.6)
Bypass longer than 180 min	57 (22.3)	3 (4.1)	40 (30.3)	14 (27.5)
Values are median (interquartile range) or n (%). a Missing for 30 patients (1 CABG, 16 valve, 13 combined or other). CABG, coronary artery bypass grafting; LVAD, left ventricular assist device; MAP, mean arterial pressure.				

Incidence and overlap of stroke and delirium

Imaging-confirmed stroke occurred in 19 patients (7.4%; 95% CI 4.8 to 11.3) and delirium in 28 (10.9%; 95% CI 7.7 to 15.4). Thirty-five patients (13.7%; 95% CI 10.0 to 18.4) had at least one: 7 stroke alone, 12 both, and 16 delirium alone (Fig. 2). A stroke code was activated in 19 patients, 17 of whom had imaging-confirmed stroke, so the process measure and the outcome were nearly interchangeable. Cognitive decline was documented in 16 patients, all but one of whom had stroke or delirium, adding a single patient to the 36 with any documented neurological event.

Distribution across procedure groups

Both complications were concentrated in valve and complex surgery (Table 2, Fig. 3). Among 73 isolated CABG patients there were no strokes and one case of delirium (1.4%). Stroke occurred in 14 of 132 patients after isolated valve surgery (10.6%) and 5 of 51 after combined or other procedures (9.8%; exact $P = 0.005$). Delirium occurred in 17 (12.9%) and 10 (19.6%) respectively (exact $P = 0.001$). Two of six heart transplant recipients and two of six combined CABG and valve patients had a neurological complication. No stroke occurred among the 37 patients aged 65 or older, just over half of whom were CABG patients, against 19 among the 219 younger patients (8.7%; Fisher $P = 0.085$). Delirium did not differ by age group (10.8% versus 11.0%).

Table 2

Neurological outcomes within 30 days and one-year mortality, overall and by procedure group.

Outcome	All, n (%; 95% CI) (N = 256)	Isolated CABG (n = 73)	Isolated valve (n = 132)	Combined or other (n = 51)	Exact P ^a
Imaging-confirmed stroke	19 (7.4; 4.8 to 11.3)	0 (0.0)	14 (10.6)	5 (9.8)	0.005
Delirium	28 (10.9; 7.7 to 15.4)	1 (1.4)	17 (12.9)	10 (19.6)	0.001
Stroke or delirium	35 (13.7; 10.0 to 18.4)	1 (1.4)	23 (17.4)	11 (21.6)	< 0.001
Stroke and delirium (both)	12 (4.7; 2.7 to 8.0)	0 (0.0)	8 (6.1)	4 (7.8)	0.039
Documented cognitive decline ^b	16 (6.2; 3.9 to 9.9)	0 (0.0)	8 (6.1)	8 (15.7)	0.001
Stroke-code activation ^c	19 (7.5; 4.8 to 11.3)	0 (0.0)	13 (9.8)	6 (11.8)	0.004
One-year all-cause mortality	19 (7.4; 4.8 to 11.3)	0 (0.0)	12 (9.1)	7 (13.7)	0.002
Group columns are n (%). ^a Monte Carlo exact test across groups. ^b Descriptive; all but one also had stroke or delirium. ^c Process measure; 17 of 19 occurred with imaging-confirmed stroke (one value missing). CABG, coronary artery bypass grafting; CI, Wilson 95% confidence interval.					

Cardiopulmonary bypass duration

Median CPB duration was 126 minutes (IQR 95 to 170) with neither complication, 159 minutes (IQR 137 to 200) with stroke, and 169 minutes (IQR 148 to 235) with delirium alone (Fig. 4). Stroke occurred in 3.9%, 9.3%, and 10.5% of patients with bypass below 120, 120 to 180, and above 180 minutes; delirium in 3.9%, 14.4%, and 17.5%.

Table 3 shows the CPB models. For stroke, the unadjusted OR per additional hour was 1.35 (95% CI 0.97 to 1.83), unchanged by adjustment for age and sex, and 1.17 (95% CI 0.80 to 1.63; $P = 0.39$) once

procedure group was added; in that model only valve surgery (OR 18.4) and combined or other surgery (OR 14.7) relative to CABG were associated with stroke. For delirium, the unadjusted OR was 1.58 (95% CI 1.20 to 2.09) and 1.39 (95% CI 1.03 to 1.86; $P = 0.031$) after full adjustment, with age also associated (OR 1.03 per year, 95% CI 1.00 to 1.06). Within isolated valve surgery (131 patients with complete data, 14 strokes, 17 delirium events), CPB duration was associated with neither stroke (OR 1.16, 95% CI 0.79 to 1.72) nor delirium (OR 1.23, 95% CI 0.86 to 1.75). On unadjusted analysis, cross-clamp time behaved like CPB (delirium OR 1.36 per 30 minutes, 95% CI 1.11 to 1.66; stroke OR 1.15, 95% CI 0.89 to 1.48); higher nadir MAP was associated with lower odds of stroke (OR 0.71 per 5 mmHg, 95% CI 0.52 to 0.98) and delirium (OR 0.75, 95% CI 0.58 to 0.98), and atrial fibrillation with delirium (OR 2.66, 95% CI 1.18 to 5.98). Event numbers precluded adding these to the adjusted models.

Table 3

Penalized logistic regression: cardiopulmonary bypass duration in relation to stroke and delirium, and neurological complications in relation to one-year mortality.

Model	OR (95% CI) a	P
Stroke (19 events)		
Unadjusted	1.35 (0.97 to 1.83)	0.074
Adjusted for age and sex	1.34 (0.96 to 1.88)	0.086
Adjusted for age, sex, procedure group	1.17 (0.80 to 1.63)	0.39
Isolated valve surgery only (14 events)	1.16 (0.79 to 1.72)	0.45
Delirium (28 events)		
Unadjusted	1.58 (1.20 to 2.09)	0.001
Adjusted for age and sex	1.61 (1.21 to 2.15)	0.001
Adjusted for age, sex, procedure group	1.39 (1.03 to 1.86)	0.031
Isolated valve surgery only (17 events)	1.23 (0.86 to 1.75)	0.26
One-year mortality (19 deaths) b		
Stroke or delirium, unadjusted	26.5 (9.5 to 84.7)	< 0.001
Stroke or delirium, adjusted	15.9 (5.6 to 51.3)	< 0.001
Stroke (with or without delirium), adjusted	30.1 (8.8 to 118)	< 0.001
Delirium without stroke, adjusted	6.5 (1.4 to 28.1)	0.018
a Firth penalized likelihood, profile-likelihood confidence intervals; bypass odds ratios per 60-minute increase. Procedure group was the dominant term in the fully adjusted stroke model (valve OR 18.4; combined or other OR 14.7, versus CABG). b Adjusted for age, bypass duration, and procedure group; phenotype rows are from one model with "neither" as reference. CABG, coronary artery bypass grafting; CI, confidence interval; OR, odds ratio.		

One-year mortality

Nineteen patients (7.4%; 95% CI 4.8 to 11.3) died within one year: 52.6% (10 of 19) after stroke, 25.0% (4 of 16) after delirium without stroke, and 2.3% (5 of 221) with neither (Fig. 5; exact $P < 0.001$ for stroke and $P = 0.001$ for delirium alone versus neither). No isolated CABG patient died. Fourteen of the 19 deaths (74%) occurred in patients with a neurological complication.

In the penalized model adjusted for age, CPB duration, and procedure group (Table 3), the composite of stroke or delirium had an OR for one-year death of 15.9 (95% CI 5.6 to 51.3); by phenotype, 30.1 (95% CI 8.8 to 118) for stroke and 6.5 (95% CI 1.4 to 28.1) for delirium without stroke. CPB duration retained an association with mortality (OR 1.57 per hour, 95% CI 1.08 to 2.29); age did not. The estimate for neurological complication was unchanged after excluding heart transplant recipients (OR 22.7, 95% CI 7.1 to 72.5) or patients cooled below 28 degrees Celsius (OR 26.1, 95% CI 7.4 to 91.7).

Discussion

In this cohort of 256 adults undergoing cardiac surgery with CPB at a Middle Eastern tertiary center, one patient in fourteen had an imaging-confirmed stroke and one in nine developed delirium within 30 days, with substantial overlap. Both complications were concentrated in valve and complex operations and almost absent after isolated CABG. CPB duration, strongly associated with both outcomes on crude analysis, was no longer associated with stroke once the operation was taken into account and was associated with neither outcome within isolated valve surgery. Both complications were followed by a large excess in one-year mortality that persisted after adjustment.

A young, valve-dominated population

The median age of 52 years, with nearly half the cohort younger than 50, is well over a decade below that of the cohorts that define current understanding of neurological risk after cardiac surgery [1, 6–9]. This reflects the persistence of rheumatic valve disease in the region [16] and matches other reports from our institution [17]. Valve surgery is the majority procedure and CABG the minority, the reverse of Western registries, so risk models derived in older coronary patients [7–9] cannot be applied directly.

The stroke rate of 7.4% is higher than the 1% to 2% of contemporary registries [6–8]. Three features of the cohort account for much of the difference: half of the operations were valve procedures, after which clinical stroke has been detected in as many as 17% of patients when they are examined systematically [23]; atrial fibrillation was present in a third of valve and complex patients, providing a cardioembolic substrate independent of the operation; and stroke was defined by imaging rather than by clinical deficit alone. The absence of stroke among patients aged 65 or older, half of whom underwent CABG, inverts the age gradient of Western cohorts and reflects the fact that in this population age tracks with coronary rather than valve disease.

Bypass duration as marker rather than cause

The central methodological question for any study of CPB duration is whether the operation that makes a long bypass run necessary is a confounder or a mediator. We treated it as a confounder, because aortic manipulation and embolic exposure are properties of the procedure that influence neurological risk regardless of pump time. Under that assumption the crude association between CPB duration and stroke disappeared, the association with delirium was attenuated, and within isolated valve surgery neither outcome was associated with bypass duration. These findings agree with the meta-analysis by Gaudino and colleagues, in which bypass and cross-clamp times were not associated with early or delayed stroke [13], and with the review by Gosselt and colleagues, which judged the evidence for CPB duration as an independent delirium risk factor to be weak [14]. They also fit the observation that avoiding bypass altogether does not reduce stroke: in the CORONARY trial, off-pump CABG produced no reduction in stroke at five years [24]. Single-center cohorts that identified bypass time as an independent predictor [10, 11, 15] adjusted for fewer procedural variables.

The residual association between CPB duration and delirium after adjustment may reflect the systemic inflammatory response, sedative exposure, and prolonged ventilation that accompany longer operations [2, 14], or unmeasured differences in complexity within our broad procedure groups. Our data support the view that a long bypass run identifies a patient at increased risk and justifies closer surveillance; they do not support the claim that shortening bypass would itself prevent neurological injury. The unadjusted association between lower nadir MAP on bypass and both outcomes is in keeping with the hypotension threshold for stroke described by Sun and colleagues [25], but event numbers did not allow it to be tested with adjustment.

Prognostic weight of stroke and delirium

More than half of the patients who had a stroke and a quarter of those with delirium alone were dead within a year, compared with one in forty of those with neither. Mortality after stroke is in keeping with large series [1, 6, 7], and the excess after delirium with the two- to threefold increase in late mortality reported in older Western patients [3, 5] and in a recent Egyptian cohort [26]. Our adjusted estimates are large and imprecise, and delirium in particular is likely to be partly a marker of postoperative illness severity rather than a cause of death. What the data do show is that in a young population in which death after cardiac surgery is uncommon, three quarters of first-year deaths occurred in patients with a documented neurological complication.

Clinical implications

Neurological risk in this population is determined mainly by the operation and the patient rather than by bypass time, so surveillance should target patients undergoing valve and complex surgery and those with atrial fibrillation, irrespective of pump duration. Because delirium was identified partly through unstructured documentation and was probably under-ascertained, protocolized twice-daily CAM-ICU screening with a low threshold for neuroimaging would improve both detection and the quality of future regional data.

Strengths and limitations

Strengths include complete one-year vital status, an imaging-based stroke definition, separation of stroke from delirium with explicit reporting of overlap, and penalized regression for stable estimates with zero-event cells.

Several limitations apply. The design is retrospective and single-center, and the cohort is a random sample of institutional activity rather than the complete surgical volume; case volume was not analyzed and may influence practice and outcome detection. Event numbers were small, which restricted adjustment to a few covariates and produced wide confidence intervals; operative urgency, reoperation, transfusion, ventricular and renal function, carotid disease, and perfusion parameters other than nadir MAP and temperature were not available, and residual confounding is likely. The procedure groups are broad and the combined or other category is heterogeneous. Delirium ascertainment relied partly on chart documentation and may have differed between patients with longer and shorter intensive care stays. Cognitive decline could not be analyzed without a preoperative baseline. Mortality was analyzed as a binary one-year outcome because date and cause of death were unavailable. Finally, the residual association between bypass duration and delirium may reflect unmeasured operative complexity and is hypothesis-generating.

Conclusions

In a young Middle Eastern cohort in which valve surgery predominated, postoperative stroke and delirium were common after valve and complex operations and rare after isolated coronary surgery. Cardiopulmonary bypass duration was a marker of the operation performed rather than an independent predictor of stroke, and both complications were followed by a large excess in one-year mortality. Prospective regional studies with protocolized delirium screening and fuller characterization of operative complexity are needed to identify which of these risks can be modified.

Abbreviations

CABG
coronary artery bypass grafting
CAM-ICU
Confusion Assessment Method for the Intensive Care Unit
CI
confidence interval
CPB
cardiopulmonary bypass
CSICU
cardiac surgical intensive care unit
IQR
interquartile range
MAP

mean arterial pressure

OR

odds ratio

STROBE

Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

The study was approved by the Research Ethics Committee (Institutional Review Board) of King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia (approval number 2251569, dated 4 September 2025), which waived the requirement for individual informed consent because the study used existing de-identified clinical records. The study was conducted in accordance with the Declaration of Helsinki.

Clinical trial number:

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The de-identified analytic dataset and the analysis code that generated all results, tables, and figures are available from the corresponding author on reasonable request, subject to institutional data governance approval.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AB conceived and designed the study, obtained ethics approval, supervised data abstraction, performed the statistical analysis, and drafted the manuscript. AZ, TS, AH, MA, JD, and KA contributed to data acquisition and to the definition and adjudication of neurological outcomes. AZ, AE, RN, and RQ contributed to study design, interpretation of the data, and critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figures

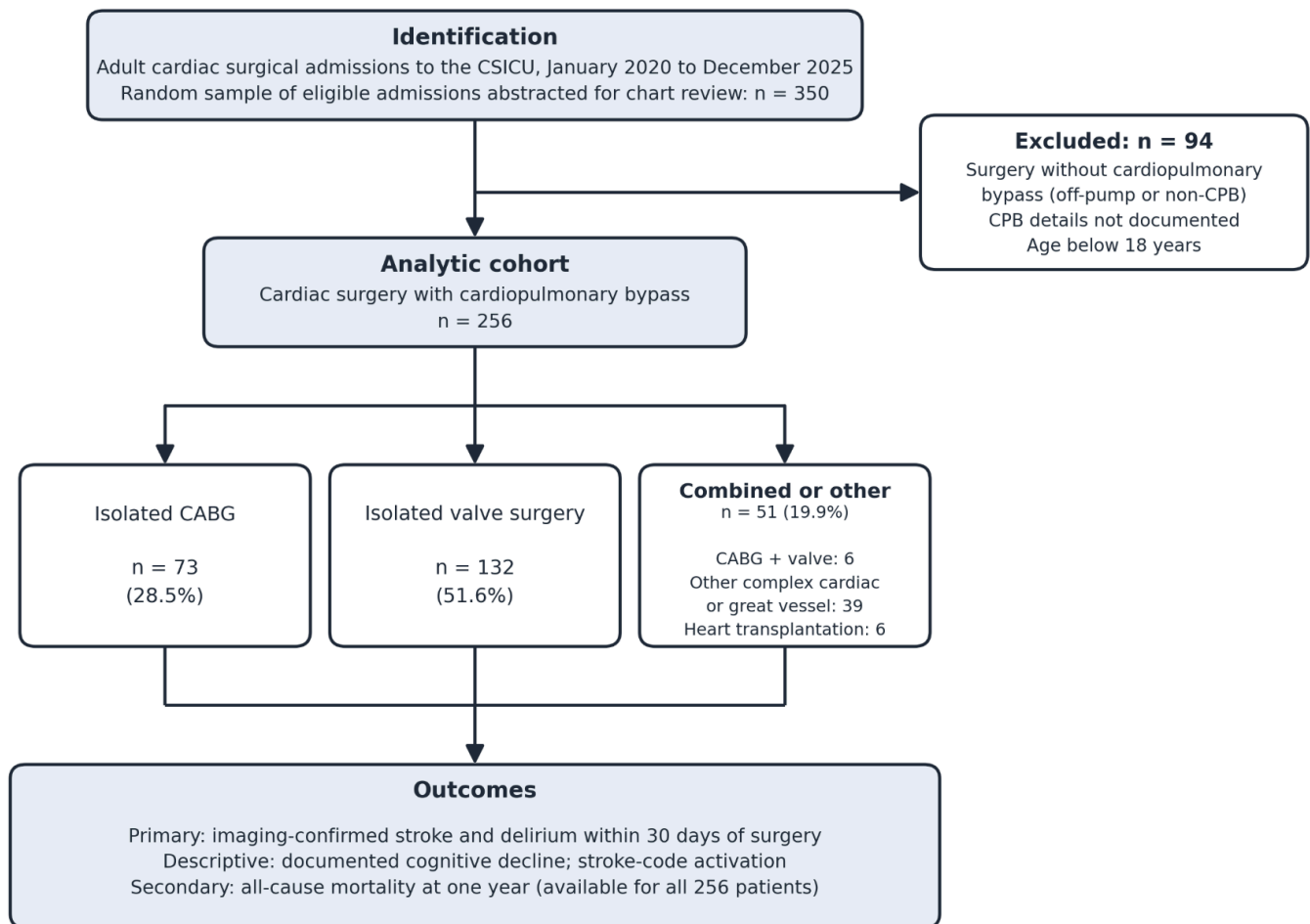


Figure 1

Derivation of the analytic cohort. CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; CSICU, cardiac surgical intensive care unit.

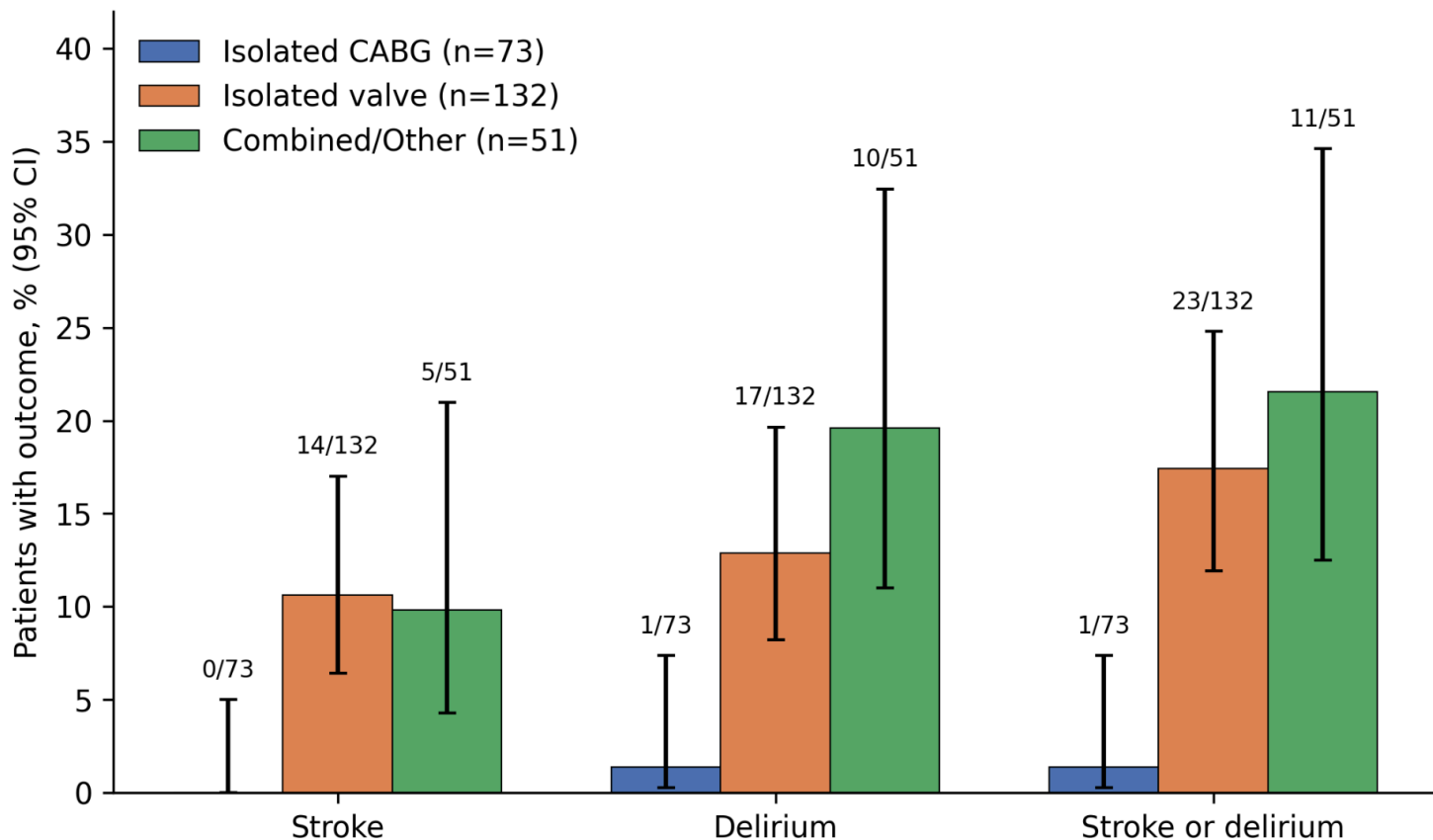


Figure 2

Overlap of neurological events within 30 days of surgery. Of 36 patients with any documented neurological event, 7 had stroke alone, 12 had stroke and delirium, 16 had delirium alone, and 1 had documented cognitive decline without stroke or delirium. Stroke-code activation occurred in 19 patients, 17 of whom had imaging-confirmed stroke.

Stroke-code activation: 19 patients, 17 of whom had imaging-confirmed stroke

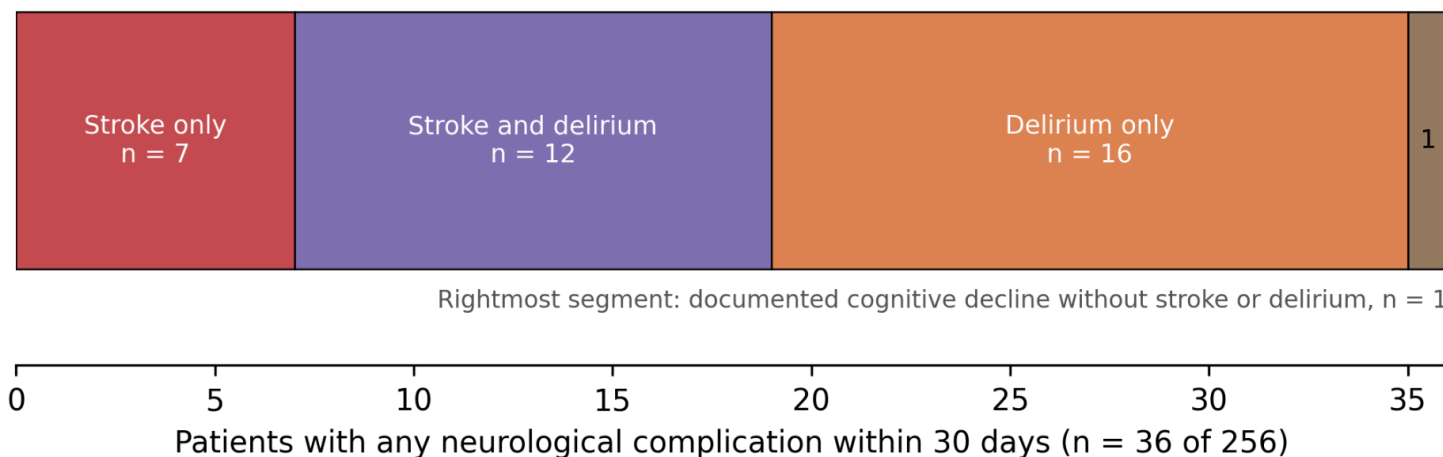


Figure 3

Incidence of stroke, delirium, and either complication by procedure group. Bars show the percentage of patients with 95% Wilson confidence intervals; the number of events over the group size is shown above each bar. CABG, coronary artery bypass grafting.

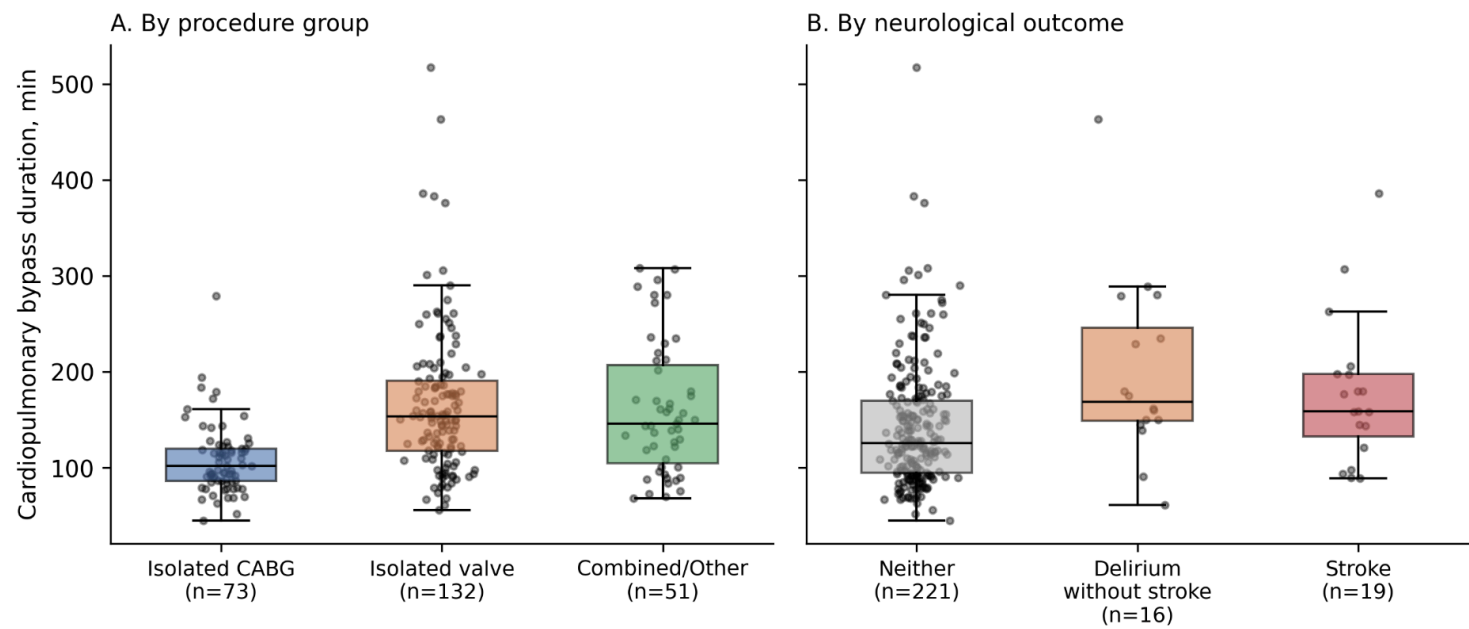


Figure 4

Cardiopulmonary bypass duration by procedure group (A) and by neurological outcome (B). Boxes show median and interquartile range; points are individual patients. CABG, coronary artery bypass grafting.

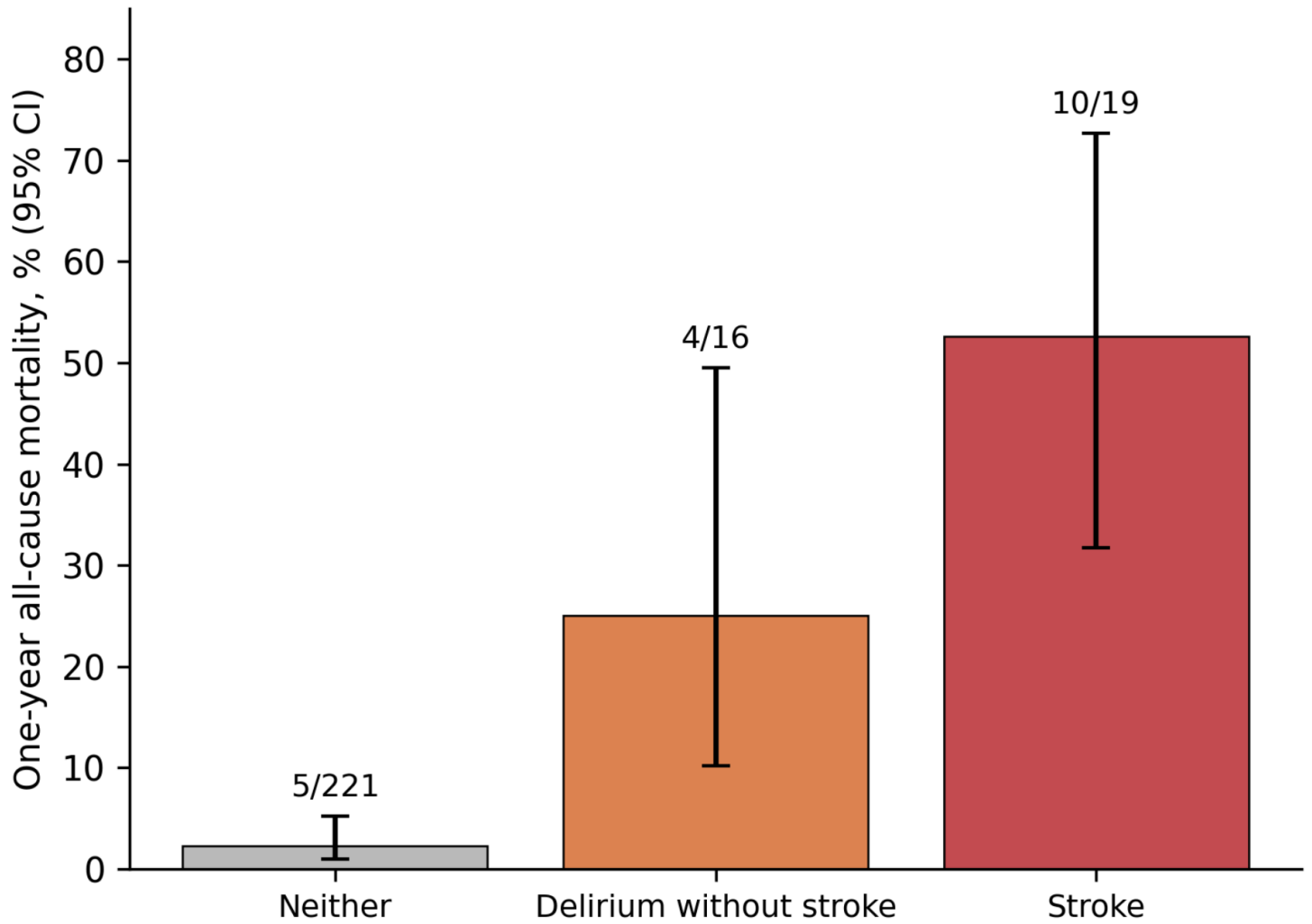


Figure 5

One-year all-cause mortality by neurological phenotype. Bars show the percentage of patients who died with 95% Wilson confidence intervals; deaths over group size are shown above each bar.