REVIEW ARTICLE

Electroencephalography for Detecting and Predicting Postoperative Delirium: A Systematic Review of Clinical Utility

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Postoperative delirium (POD) is a major, preventable, neurocognitive complication in geriatric surgical patients, associated with higher complications and prolonged hospitalization. Electroencephalography (EEG) abnormalities, particularly generalized slowing, reduced alpha power, and burst suppression, have long been linked to delirium and may identify brains that are particularly susceptible to POD, or "vulnerable brains". Recent evidence suggests that intraoperative EEG patterns predict POD risk, while portable and automated EEG systems offer emerging tools for detection and monitoring. This systematic review synthesized findings across the perioperative phases to evaluate the EEG's role in predicting, diagnosing, and managing POD. Thirty-one studies were analyzed, spanning pre-, intra-, and postoperative EEG applications. Most cohorts included adults aged 60 or older undergoing cardiac, general, orthopedic, or neurovascular procedures. Consistent EEG markers of delirium vulnerability included reduced alpha power and peak frequency, increased delta/theta activity and burst suppression, and decreased spectral edge frequency and entropy. Predictive accuracy ranged from AUC 0.70 to 0.90, with most PODs occurring within 0–48 hours postoperatively. Across studies, EEG signatures: low alpha activity and prolonged burst suppression, preceded clinical symptoms. This supports EEG as an early, objective biomarker of cortical fragility. While single-channel systems improved feasibility, raw and quantitative EEG offered superior sensitivity. Standardized protocols, multicenter validation, and integration with perioperative care systems are needed to translate the EEG-guided monitoring into delirium prevention strategies.

INTRODUCTION

Postoperative delirium (POD) is a common, morbid neurocognitive complication among older surgical patients, associated with higher in-hospital mortality, major complications, prolonged length of stay, and non-home discharge. It usually occurs in 20% of patients after surgery [17]. In a recent national cohort of

over 5.5 million U.S. surgical hospitalizations, POD was linked to approximately 3.5-fold higher odds of death or major complications and approximately 4-fold higher odds of non-home discharge, underscoring its clinical and health-system burden [21]. Incidence varies widely by procedure type and urgency. Systematic reviews report an incidence of about 19% after elective surgery and about 32% after emergency procedures, with a higher risk after complex cardiac and abdominal operations [35].

Clinically, delirium is an acute, fluctuating disturbance in attention and awareness that develops over hours to days; dementia is a chronic, progressive decline across cognitive domains evolving from months to years. Importantly, delirium is often preventable and reversible if precipitants are addressed, whereas most dementias are not [18]. Electroencephalography (EEG) provides a direct window into cortical network dynamics and has long been recognized to exhibit characteristic changes during delirium. Qualitative and quantitative studies consistently show generalized slowing, with increased delta/theta power, reduced alpha power, and diminished functional connectivity (Table 1). Additionally, the degree of slowing correlates with delirium severity [34]. Beyond diagnosis, EEG may stratify risk. Intraoperative burst-suppression, which is an ultra-slow, high-amplitude pattern signifying cortical inactivation, has been associated with higher POD risk in meta-analyses, highlighting anesthetic depth as a modifiable factor [23]. Parallel advances in point-of-care and reduced-lead EEG suggest pragmatic screening pathways on wards and in ICUs, with portable systems and automated qEEG features showing promise for differentiating delirium, including delirium superimposed on dementia, and forecasting adverse outcomes [31].

Alpha Power	The strength of brainwave activity in the alpha frequency band (8-12 Hz)
Peak Frequency	The frequency with the highest power within a certain band
Burst Suppression	A pattern of severe brain inactivity, showing sudden, high-voltage bursts of brain waves followed by long periods of flat, suppressed (low-voltage) electrical activity
Spectral Edge Frequency (SEF)	The frequency at which 95% of the power is located
(Spectral) Entropy	Quantifies the complexity, disorder, or unpredictability in EEG waves. Higher values typically indicate wakefulness and higher complexity. Lower values suggest deep sleep or anesthesia.

Table 1. Definitions.

This review synthesizes clinical evidence on EEG use in the context of postoperative delirium across three phases: 1) pre-/intraoperative EEG as a risk marker and target for anesthetic titration (e.g., burst-suppression minimization); 2) postoperative diagnostic and severity monitoring using conventional and quantitative EEG; and 3) implementation considerations for portable EEG screening in surgical and

critical-care settings, including differentiation from dementia. We conclude by outlining the key knowledge gaps and the priorities for future trials that aim to integrate EEG into perioperative delirium prevention and postoperative care.

METHODOLOGY

Our systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Google Scholar, PubMed, and the University of Texas at Dallas Eugene McDermott Library were used to retrieve studies examining the association between EEG and postoperative delirium. Studies published in the last 10 years (2015-2025) were included in the search. All searches were made, and articles were accumulated on September 15, 2025. The same search string was used with each database: "EEG neuromonitoring and postoperative delirium patients".

Once studies from databases were imported into Zotero, duplicates were removed, and the remaining studies were divided evenly among authors for initial screening. Included studies had to be in English, include multiple human participants, include all details of an original study, and be relevant to both EEG and postoperative delirium. As a result, excluded studies were either 1) not in English, 2) case studies, 3) animal studies, 4) review papers, or 5) were deemed irrelevant by the authors. Studies deemed irrelevant may have discussed POD but not EEG or discussed EEG but lacked a notable focus on postoperative delirium outcomes. The remaining studies were divided again for eligibility assessment, in which each author individually searched for PDFs, attached them to Zotero, and screened the full studies to ensure they met all criteria. Any articles that were not available online were retrieved through UTD's interlibrary loan. Details of the screening process, including inclusion and exclusion criteria, are presented in the PRISMA diagram (Figure 1).

RESULTS

Management of Study Heterogeneity

Considerable heterogeneity existed across the included studies regarding the surgical population, the timing of EEG acquisition during perioperative care, and anesthetic protocols. To address this, findings were synthesized using a structured narrative approach rather than a meta-analysis. Results were intentionally stratified by each category of variability: perioperative phase (pre-, intra-, and postoperative), delirium assessment window (PACU, early POD 0-48 hours, POD days 1-5), and surgical category (Table 2). Summary tables were used to organize evidence by surgery type (Table 3), by timing of delirium onset

(Table 4), and by the best-supported EEG markers by perioperative phase (Table 6). By organizing results across perioperative phase, surgical context, and outcome timing, this approach highlights clinically actionable EEG markers while remaining transparent about inter-study heterogeneity.

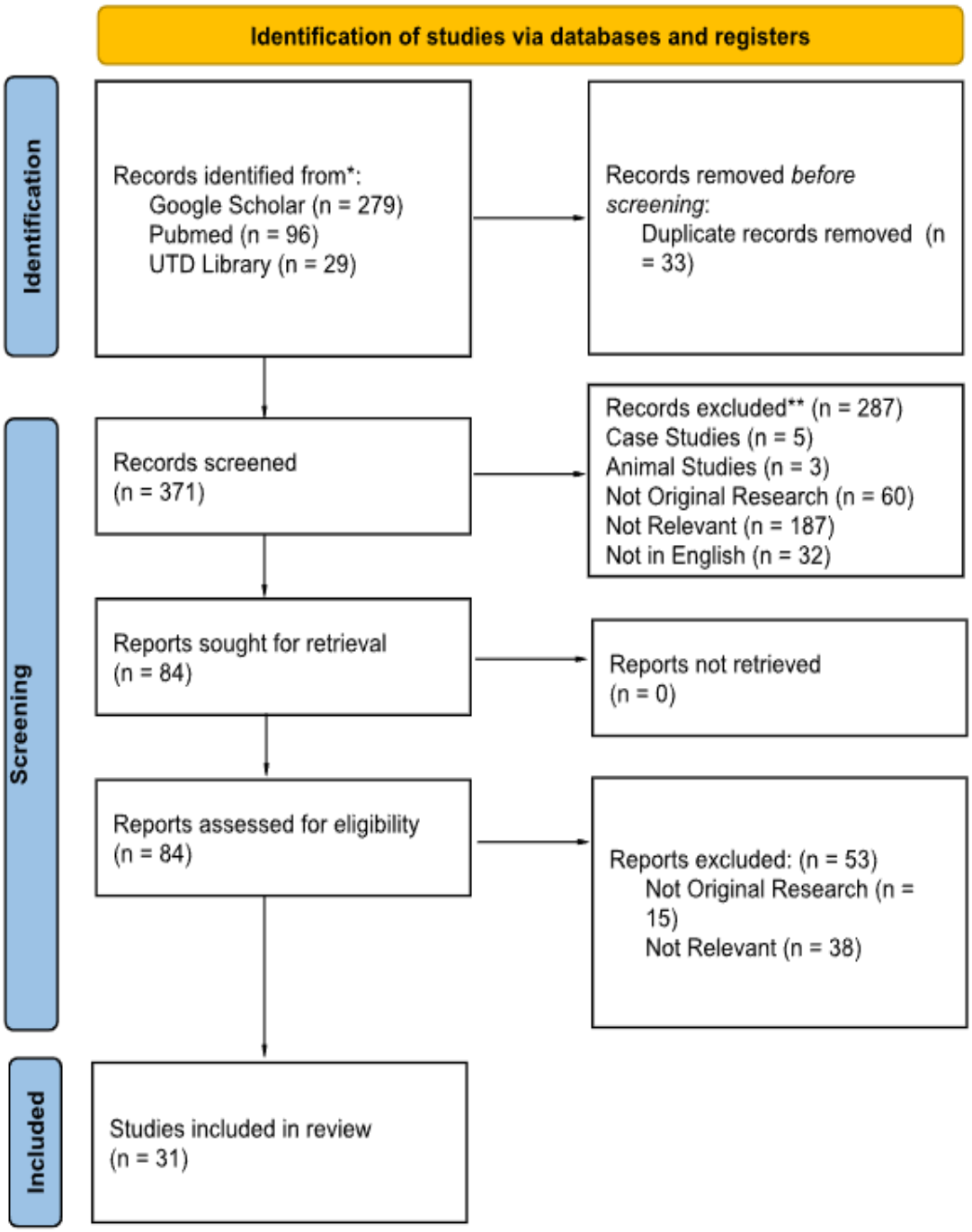

Figure 1. PRISMA Chart.

	Total patients	Sample	Basic Methodology	Key Results	Main Discussion Points
1	n=71	≥60 y, older adults	32-channel awake EEG pre-op (eyes closed vs eyes open); inattention and delirium features assessed pre-op and 2×/day post-op until discharge; multivariable regression adjusted for age & MMSE.	Lower alpha attenuation pre-op was associated with higher odds of postoperative inattention (OR 0.73) and higher delirium severity (OR 0.79).	Blunted pre-op alpha suppression with eye opening may be a neural biomarker of vulnerability to postoperative attentional deficits/delirium.
2	n= 1,161	Median age 64 (no POD) vs 67 (POD); ~30–38% female, higher in POD group	Retrospective cohort; continuous intraoperative EEG during cardiovascular surgery; ICU delirium scored repeatedly with ICDSC (≥4 = POD); EEG changes labeled transient vs persistent.	POD incidence 23.7%; significant EEG change in 11.3% overall; EEG change doubled POD risk (adj OR 1.97); persistent EEG change had even higher risk (adj OR 2.65); specificity 91.5%, NPV 78.7%.	Intraop EEG changes, especially persistent slowing, serve as an early signal of brain ischemia and strongly identify high-risk patients; this may enable intraoperative intervention (raising MAP, reperfusion) to prevent POD.
3	n=578	Mean age 64.8 yr; 20.2% female	Retrospective cohort; adults undergoing cardiovascular surgery with continuous intraoperative neuromonitoring (EEG + SSEP); POD screened repeatedly in ICU using ICDSC ≥4; logistic regression for predictors.	POD incidence 21.8% (126/578). A significant IONM change doubled the odds of POD (OR 2.02). Baseline EEG abnormality also doubled the odds of POD (OR 2.34). Combining EEG and SSEP had high specificity (~94%) for POD.	Real-time EEG/SSEP changes likely reflect intraoperative cerebral hypoperfusion; these alerts can identify high-risk brains and allow immediate hemodynamic intervention to potentially prevent delirium.
4	n=425	Median age 71 (no POD) vs 75 (POD); ~32–39% female	Retrospective cohort of carotid endarterectomy cases; continuous intraoperative EEG + SSEP; POD in ICU scored by ICDSC ≥4; logistic regression adjusted for age and ASA.	POD incidence 11.1% (47/425); significant IONM change in 15.3% of patients; IONM change tripled POD risk (aOR 3.94, 95% CI 1.91 -- 7.98); SSEP change alone had aOR 5.15.	Real-time IONM changes (especially SSEP drops suggesting cerebral hypoperfusion) are a strong early warning sign of delirium and may enable intraoperative rescue (raising BP, shunting, restoring flow).
5	n=273	Mean age 54–58 yr (POD vs no POD); ~75% male overall (76.3% vs 73.5%)	Retrospective cohort; adults undergoing craniotomy for aneurysm clipping with intraoperative EEG + SSEP monitoring; "significant" IONM change defined per ACNS criteria; delirium screened twice daily in ICU using ICDSC ≥4.	POD incidence 30.4% (83/273); significant IONM change in 15.4% of cases; IONM change ↑ POD risk (45.2% vs 27.7%); adjusted OR 2.09 (95% CI 1.01–4.32); SSEP changes alone also predicted POD (aOR 2.17).	Real-time intraoperative neurophysiologic changes (especially SSEP drops suggesting focal hypoperfusion) identify brains at risk for postoperative delirium and may represent a modifiable intraoperative warning signal.
6	n=470	Median age 56–57 yr; ~75% female	Retrospective cohort; adults undergoing craniotomy for aneurysm clipping with continuous intraoperative neuromonitoring (IONM: SSEP + EEG); POD identified in ICU by ICDSC ≥4 and on wards by ICD codes; multivariable logistic regression adjusted for clinical and intraoperative factors.	POD incidence 24.5% (115/470); significant IONM change occurred in 30.4% of POD vs 12.7% of non-POD; IONM change doubled POD risk (aOR 2.41, 95% CI 1.40–4.17); SSEP change alone similar (aOR 2.49); ruptured aneurysm (aOR 2.76) and new postoperative focal neurologic deficit (aOR 2.11) also independently increased POD risk.	Real-time intraoperative neurophysiologic changes, especially SSEP drops suggesting cerebral hypoperfusion, are strong early warning signals for postoperative delirium; EEG alone was less predictive. These markers could enable intraoperative intervention to reduce the risk of POD.
7	n=200	≥60 yr; median age ~73 yr; ~75% male overall (more males in propofol group)	Randomized factorial trial; at surgical closure, patients got either a short propofol infusion or routine desflurane wean; intraop EEG (frontal) analyzed; PACU delirium assessed ~30 min after extubating with 3D-CAM, CAM-ICU, NuDESC.	Propofol reduced alpha power and increased burst suppression (66% vs 34%) during emergence, but PACU delirium was similar (36.7% vs 33.3%); patients with "disorganized thinking" had lower MoCA, lower intraoperative alpha power, greater burst suppression, and longer stay.	In older adults, giving propofol at emergence did not reduce immediate delirium; low alpha / high burst suppression marks a "vulnerable brain" with delayed cognitive recovery and longer hospitalization.
8	n=7,318	Mean age 57 yrs overall: POD cases older (74 yrs). ~45% male overall.	Retrospective before/after evaluation; hospital-wide adoption of intraoperative processed EEG (pEEG) in July 2015 to titrate anesthetic and avoid burst suppression; POD screened twice daily for 72h postop (Nursing Delirium Screening Scale + CAM).	POD fell from 1.18% to 0.41% overall, and from 5.1% to 1.56% in ≥75 yr; pEEG use lowered POD odds (aOR 0.33) independently.	Routine depth monitoring to limit anesthetic overdose/burst suppression may prevent early POD, especially in the oldest patients.
9	n=125	Median age 71 vs 80 yr (no-POD vs POD); ~63% female overall; POD pts was older and more often ASA III	Single-center prospective cohort; continuous 4-channel frontal EEG under general anesthesia; extracted band power (delta/theta/alpha/beta) ~1 hr into surgery; POD assessed twice daily with 3D-CAM/CAM-ICU for 72 hrs postop.	POD incidence 8.8% (11/125); lower intraoperative alpha power independently predicted POD (OR 10.21); other independent risk factors: age ≥75, preop anemia, preop depression, low MMSE; MMSE ≥25 was protective. AUC for alpha ~0.74	Low frontal alpha during stable anesthesia reflects a "fragile brain"; combining EEG with simple preop screens (cognition, anemia, mood) can flag high-risk patients early.
10	n=388	Median age 81 yrs; 61% female	Multicenter RCT in ≥70y hip fracture surgery patients; randomized to twice-daily postoperative delirium screening with automated EEG (DeltaScan) vs standard nurse-rated DOS for 3 days; primary outcome = hospital length of stay; delirium diagnosed by geriatrician.	No difference in length of stay (median 7 vs 7 days); POD incidence similar (17% DOS vs 19% EEG); DOS had better delirium discrimination (AUC 0.84) than EEG (AUC 0.66).	Automated single-channel EEG screening was feasible but did not shorten stay, did not outperform standard bedside screening, and is less practical/cost-effective for routine geriatric hip fracture care.

	Total patients	Sample	Basic Methodology	Key Results	Main Discussion Points
11	n=1140	≥60 yr; median age 70–71 yr; ~75% male overall	Multicenter RCT; cardiac surgery with CPB; EEG-guided group had anesthetic titrated to reduce burst suppression; control = usual care; blinded delirium assessment POD1–5 with CAM / CAM-ICU plus chart review.	POD incidence similar: 18.15% (EEG-guided) vs 18.10% (usual care); no difference in ICU or hospital LOS; EEG guidance lowered anesthetic dose and cut suppression time by ~7.7 min but did not change outcomes.	Minimizing EEG suppression during cardiac surgery did not prevent delirium or shorten stay; delirium risk was instead associated with age, EuroSCORE II, prior delirium, depression, longer anesthesia, and longer EEG suppression.
12	n=515	≥60 yr, mixed sex (approx. balanced across groups)	Multicenter RCT; BIS 50 ("lighter") vs BIS 35 ("deeper"); delirium assessed postop days 1–5 with 3D-CAM / CAM-ICU.	POD 19% (BIS 50) vs 28% (BIS 35); OR 0.58; absolute ↓ ~10%.	Lighter EEG-guided anesthesia (with less burst suppression) reduces delirium and improves cognitive outcomes.
13	n=200	Age 73 ± 7 yr; ~72% male in both groups	Randomized trial ≥60 yr; EEG-guided fentanyl↑ / desflurane↓ to maximize frontal alpha vs routine care; PACU delirium scored with 3D-CAM ~30 min after extubating.	The titration group had slightly higher early alpha (+0.8 dB at +20 min), more fentanyl, less desflurane, but PACU delirium was similar (37% vs 33%, P=0.553).	Frontal alpha in older adults is only weakly modifiable; boosting alpha did not lower immediate delirium or improve recovery.
14	n=26	Older adults (≥60 years); mixed sex (not limited to one sex)	Prospective observational; daily CAM/CAM-ICU delirium assessments + serial frontal/occipital EEG (eyes open / eyes closed); mixed-effects modeling of EEG band power (delta/theta/alpha) vs delirium presence, severity, and recovery over time.	Lower occipital alpha power and higher theta/delta power were associated with delirium and greater delirium severity; frontal theta power changed systematically as delirium resolved over days.	A small bedside EEG montage can objectively track the presence, severity, and recovery trajectory of postoperative delirium, suggesting EEG spectral power as a practical delirium biomarker.
15	n=60	63.3 ± 10.5 yr vs 54 ± 13.1 yr); ~65% male in both groups	qEEG in the first hour after ICU arrival post–cardiac surgery; delirium (CAM/CAM-ICU) followed up to 7 days; EEG band power and complexity features tested for POD prediction.	Abnormal aEEG amplitude (very low or very high in quartiles Q1/Q4) strongly predicted POD (adj OR ~12.4); qEEG peak F3–P3 had AUC 0.81 (90% sens / 72% spec); delirium pts had lower alpha, higher delta, higher delta/alpha ratio, and altered complexity patterns.	A brief, limited-montage bedside qEEG in the immediate ICU period can identify high-risk brains after cardiac surgery and may enable earlier intervention than clinical screening alone.
16	n=626 enrolled (125 with PACU delirium = 20%)	Median age 56 vs 63 yrs (no-delirium vs delirium); 39% female overall (61% male)	Prospective observational study across 4 hospitals; continuous intraoperative frontal EEG + emergence EEG; CAM-ICU screening ~15 and ~60 min after PACU arrival to diagnose PACU delirium; perioperative and 30-day outcomes collected.	PACU delirium in 20%; intraoperative burst suppression during maintenance ↑ odds (adjusted OR 1.66); "unfavorable" emergence trajectories lacking spindle-dominant alpha activity ↑ odds up to ~6.5×, especially with ketamine or N_2O; PACU delirium doubled 30-day readmission and prolonged LOS.	Specific EEG signatures (burst suppression and no-spindle emergence) mark brains that wake "cognitively fragile," and PACU delirium is an early warning linked to worse recovery and longer hospitalization
17	828 included (73 POD / 755 no POD); 328 after matching (67 POD / 261 no POD)	Mean age ~70 yr in POD vs ~64 yr no POD (pre-match); mostly male cardiac population	Secondary analysis of prospective cardiac surgery cohort; intraoperative frontal EEG under isoflurane (CeMAC 0.7–0.8) before bypass; extracted peak alpha frequency (6–17 Hz); POD identified by validated chart review; propensity score matching on 18 clinical variables.	POD pts had slower frontal alpha (7.9 Hz) than non-POD pts (8.8–8.9 Hz), $p < 0.001$, and this difference persisted after matching; slower alpha remained independently associated with POD.	Slower intraoperative alpha frequency is a marker of a "vulnerable brain" in cardiac surgery and may be an early biomarker of delirium risk.
18	n=815	Mean age 43 ± 12.6 yr; 61% female; all POD cases were >60 yr	Prospective observational study; adults ≥21 yr with normal cognition (MMSE >25) undergoing elective noncardiac surgery under GA; CAM used daily for 7 postop days; perioperative factors (ASA class, fluids, blood loss, duration, agent, hypotension, drains, etc.) analyzed.	POD incidence 0.73% (6/815); all cases age >60; POD associated with ASA II, longer surgery (>180 min), longer anesthesia (>120 min), sevoflurane (vs desflurane), >2 L fluids, >1 L blood loss, transfusion, hypotension, and indwelling catheters/drains.	Even in a relatively young rural surgical population, delirium clustered in older, higher-acuity patients and was linked to modifiable intraoperative factors (depth/agent choice, hemodynamics, fluid/blood management). Screening for cognitive impairment pre-op (MMSE) may help prevent complications.
19	n= 220	Median age 71 yr (delirium pts older: 74 vs 67); ~81% male overall	Single-center prospective cohort; elective cardiac surgery with bypass; 5-min frontal EEG ~30 min after induction; extracted alpha (8–12 Hz) power; delirium screened 3×/day in ICU and 2×/day on ward using CAM-ICU/CAM + chart review until discharge.	POD incidence 29.5% (65/220); delirium patients had lower intraoperative frontal alpha power (–14.0 dB vs –11.6 dB, P<0.001); lower alpha power predicted POD (adj OR 0.88 per dB, 95% CI 0.81–0.96) when cognition was not included.	Low intraoperative alpha power reflects a "vulnerable brain," correlates with worse preop cognition, and can flag high-risk patients early—potentially replacing full neurocognitive testing when that's not practical.
20	n=62	Median age 59 yrs; 65% male	Prospective observational cardiac surgery cohort with continuous intraoperative frontal EEG; epileptiform discharges identified; delirium screened twice daily POD1–POD3 using CAM / CAM-ICU.	POD in 31%; epileptiform discharges in 26%; discharges were more common in delirium pts (52.6% vs 14%); epileptiform discharges independently predicted POD (OR 5.00).	Intraoperative epileptiform discharges signal acute cortical instability during bypass and are a strong independent predictor of early postoperative delirium.

	Total patients	Sample	Basic Methodology	Key Results	Main Discussion Points
21	n=456	Mean age ~71 63% male	Multicenter cross-sectional study in ICU and wards; single-channel (Fp2–Pz) 4-min resting EEG + 98 qEEG features; random forest classification to separate (1) delirium vs no delirium and (2) postop vs non-postop delirium; delirium diagnosed by expert panel using DSM-5–based structured interview.	EEG model classified delirium vs no delirium with AUC 0.76 (sens 0.77, spec 0.63); main features were ↓theta peak freq, ↓relative alpha, ↑delta/theta slowing, and altered autocorrelation. The model could NOT distinguish postop from non-postop delirium (AUC 0.50).	A single forehead–parietal lead can objectively detect delirium, but postoperative delirium lacks a unique EEG signature; physiologically, delirium appears the same whether surgical or medical.
22	n=144	median 78 years /55 male (38.2%), 89 female (61.8%)	Pre-op EEG + MoCA + FRAIL → logistic model	AUC 0.92 for POD ≤48h (49.3% incidence)	Brain vulnerability is detectable pre-op
23	n=239	Mean age ~72 yr; ~47% female; all ≥65 yr	Retrospective cohort (secondary analysis of PANDA-G); continuous frontal raw EEG during spine surgery; visual identification of burst suppression vs device burst suppression ratio; delirium assessed q12h (CAM-ICU, NuDESC, chart) through postop stay.	POD in 27% (64/239); burst suppression seen in 73.4% of delirium pts vs 50.9% no-delirium (P=0.001); maintenance-phase burst suppression (after 60 min) strongly associated with POD (67.2% vs 46.3%, P=0.004); effect of burst suppression > age.	Visually confirmed intraoperative burst suppression—especially during maintenance, not just induction—is a modifiable EEG marker of delirium risk and is more informative than age or the monitor's processed burst suppression ratio.
24	n=151	Median age 77 yr; higher POD rate in males (58% male in POD vs 38% male in no-POD)	Prospective single-center cohort; frontal EEG at baseline and 1, 2, 15 min after loss of consciousness; spectral decomposition (periodic + aperiodic); delirium screened twice daily x5 days with multiple tools (CAM-ICU, DSM-based assessments).	POD patients showed lower alpha/beta power, lower spectral edge frequency at 1 min, and lower aperiodic offset at 15 min; the EEG-only logistic model had an AUC of 0.73 for POD prediction.	Early EEG changes within the first 15 min of induction reveal a "vulnerable brain" phenotype; these signatures may allow anesthesiologists to identify high-risk patients and tailor management immediately.
25	n=82	≥60 yr; 54% male	Pooled analysis of 3 prospective studies; 32-channel intraoperative EEG; calculated dose-adjusted frontoparietal alpha power; delirium assessed postop with CAM / 3D-CAM.	Lower dose-adjusted alpha power → higher POD odds (OR 1.44); AUC 0.71; also linked to worse preop processing speed/executive function, but not CSF Alzheimer's biomarkers.	Low alpha under anesthesia reflects a "vulnerable brain" with slowed cognition and higher delirium risk, independent of Alzheimer 's-type CSF pathology.
26	n=89	Median age 71 yr in both groups; ~60% male / 40% female	Pre-op awake EEG (eyes open/closed); spectral features compared between patients with vs without PACU delirium; delirium screened with bCAM in PACU and postop days 1–3.	31.5% developed PACU delirium; those patients already had lower beta/gamma power and lower SEF / PeEn / spectral entropy pre-op; these EEG features predicted PACU delirium with AUC ~0.70–0.73.	Pre-op frontal EEG can flag cognitively vulnerable patients before surgery, potentially allowing targeted prevention without full neurocognitive testing.
27	n=266	Median age 68 yrs; 72.6% female overall	Prospective matched cohort ≥60 yrs; elective major orthopedic surgery; daily delirium screening POD1–7 with 3D-CAM; continuous frontal EEG to measure intraoperative alpha power; mediation analysis.	POD: 16.7% in diabetics vs 6.0% in non-diabetics; diabetes ↑ POD odds (adj OR 3.2); lower intraoperative alpha power explained ~20% of this association.	Diabetes is an independent delirium risk factor in older ortho patients, and low intraoperative alpha power reflects a "vulnerable brain" linking diabetes to POD.
28	n=81	Mean age 72.9 ± 6.2 yr; 57 male / 24 female	Prospective observational cardiac surgery cohort ≥60 yr; bilateral BIS (including burst suppression ratio, BSR) recorded pre-, intra-, and post-op; POD assessed daily in ICU with CAM-ICU; patients followed for ICU stay, LOS, and 6-month survival.	POD incidence 32% (26/81); delirium patients spent longer in intraoperative burst suppression (median 107 vs 44 min) and had higher intraoperative BSR; burst suppression duration predicted POD (AUC 0.73); delirium was linked to longer ICU stay and higher 6-month mortality (11.5% vs 0%).	Longer intraoperative burst suppression reflects a brain that is highly sensitive to anesthesia and predicts delirium and worse outcomes; effect is not explained by "too-deep" anesthesia on BIS alone.
29	905 total; DOSS cohort 443, SC-EEG cohort 462	Median age 75 yrs; 72% male overall	Prospective quasi-experimental, consecutive cohorts after cardiac surgery; routine nurse DOSS screening vs twice-daily single-channel EEG (DeltaScan); delirium confirmed by DSM-5; compared delirium incidence and hospital length of stay.	Delirium detection was higher with SC-EEG (20%) than DOSS (14%) (P=0.016); overall length of stay was 0.11 nights shorter with SC-EEG (P=0.002); no significant LOS reduction in delirious patients alone.	Adding bedside single-channel EEG improves detection (likely catches hypoactive delirium) and slightly shortens stay at the population level but does not clearly shorten stay for patients who become delirious.
30	116 analyzed (ages 3–6)	48 months median age; 64 male / 52 female	Prospective observational; EEG-derived "brain status" indices (wavelet index, pain threshold index, anxiety index, comfort index) recorded at four emergence timepoints; delirium scored with PAED scale.	Delirium incidence 31.9%; anxiety index AUC 0.84 and comfort index AUC 0.89 for predicting delirium; comfort index sensitivity 91.9%, specificity 83.5.	EEG-derived anxiety/comfort indices can identify kids at high risk for delirium, whereas standard depth (wavelet index) and nociception (pain threshold index) did not predict it.
31	n=80	≥60 yrs; elderly breast cancer surgery patients; sex not the focus	Retrospective case-control; continuous SedLine EEG during breast cancer surgery; extracted PSI, SEF (L/R), burst suppression %, α/β power; POD defined by Nu-DESC; compared POD vs no-POD and ran multivariable logistic regression.	POD 22.5% (18/80); POD patients had lower SEF-L / SEF-R, more burst suppression, lower α- and β-band power; independent predictors of POD were ↓MMSE, ↓SEF-L/R, and absence of hypertension.	Reduced intraoperative SEF and frontal α/β power reflect cortical vulnerability and can act as early EEG warning markers for delirium risk in older surgical patients.

Table 2. Results analysis across 31 studies.

Surgical Category	Number of Studies
Cardiac / Cardiovascular	9
General noncardiac (mixed specialties)	13
Orthopedic (non-spine)	4
Spine (dedicated spine cohort)	1
Neurosurgical: aneurysm clipping	2
Neurovascular: carotid endarterectomy	1
Pediatric	1
Breast cancer surgery (included in general noncardiac)	1

Table 3. Types of surgery across studies.

Postoperative Time Window	Number of Studies Reporting Risk in This Window	General POD Risk Trend	Representative Notes from Studies
Immediate emergence / PACU (0–1 hour)	5 studies	Moderate–High risk, often brief but clinically meaningful	Delirium while in PACU occurred in 20–37% of older adults in some trials; pediatric delirium occurred in ~32%. EEG markers (spindle absence, low alpha) predicted immediate disorientation.
Early postoperative period (0–48 hours)	Majority (approx. 20 studies)	Highest overall risk window for POD onset	Most studies reported that POD peaked within 24–48 hours. Hip fracture and major surgery cohorts showed nearly all delirium beginning in this window.
Early ICU period (POD 1–3)	9 studies (mostly cardiac/vascular/neuro)	Sustained high risk, especially after complex surgeries	Cardiac and neurovascular studies consistently found delirium most common on POD 1–3, with rates 20–33%, especially with burst suppression or IONM changes.
Postoperative Days 3–5	6 studies	Risk is declining, but still present in vulnerable patients	Delirium frequency generally decreased after day 2; however, some studies (e.g., cardiac, orthopedic) still identified new or persistent delirium through day 5.
Postoperative Days 5–7	3–4 studies	Low but non-zero risk; often persistent rather than new onset	Studies tracking delirium through day 7 (general surgery, orthopedic) showed rare new-onset delirium after day 4; most cases after day 5 represented prolonged delirium, not new cases.

Table 4. Postoperative delirium (POD) risk over time across studies.

Across the 31 studies, sample sizes ranged widely, with most falling into the small-study category (<150 participants) and only a few large datasets exceeding 500–1,000 patients, including one study with 7,318 patients. Most cohorts consisted of older adults, typically aged 60 or older, with one pediatric cohort and a small number of mixed-age adult samples. Sex distribution across the full dataset was more male than female, largely due to multiple cardiac and vascular surgical cohorts, whereas several orthopedic and breast cancer cohorts were female-majority. The studies spanned a broad range of surgical populations, with the most common being general noncardiac surgery (n=13), followed by cardiac surgery (n=9), orthopedic procedures (n=4), aneurysm clipping (n=2), spinal surgery (n=1), and carotid endarterectomy (n=1), with one pediatric cohort included (n=1).

Among the studies using intraoperative, ICU, PACU, or preoperative EEG monitoring, several consistent EEG patterns differentiated patients who developed postoperative delirium from those who did not (Table 5). The most frequent findings included reduced intraoperative alpha power, slower peak alpha frequency, increased delta and theta power, reduced spectral edge frequency, lower EEG entropy, and higher rates or longer durations of burst suppression. Quantitative EEG studies in the ICU and postoperative period also commonly identified lower alpha/beta activity, increased slowing, and altered complexity measures, with many predictive models achieving AUC values of 0.70-0.90. Across all surgical categories, the highest incidence of POD occurred during the first 24–48 hours, with many ICU-based cardiac and neurovascular cohorts showing rates between 20–33%, PACU-based studies reporting 20–37%, and general surgical cohorts ranging from 8–30%. Studies extending assessments through postoperative days 3–5 showed fewer new cases, and those extending assessments through day 7 reported that nearly all delirium cases began earlier in the hospitalization.

Phase	Markers	Implication
Preoperative	Low alpha attenuation, lower beta/gamma, lower entropy	Increased vulnerability to future POD
Induction	Early drop in SEF; EEG lacking spindle/alpha organization	Early delirium risk
Intraoperative/Maintenance	Low frontal alpha power/slow peak alpha frequency; burst suppression duration	Strongest recurring risk marker
Postoperative (PACU/ICU)	Increased delta/theta + reduced alpha/complexity	Detection/severity tracking

Table 5. Summary of Best-Evidence EEG markers by perioperative phase.

DISCUSSION

Throughout the studies included in this systematic review, postoperative delirium (POD) consistently emerged as a common and clinically significant complication associated with worse patient outcomes during both the short and long term. Many studies reported higher rates of ICU admission, prolonged hospital length of stay, increased readmission rates, and elevated mortality among patients who developed delirium [32, 11, 15]. A recurrent trend was the temporal pattern of POD onset, with delirium most often appearing immediately after surgery or within the first 24-48 hours postoperatively, highlighting a period of heightened postoperative neurophysiologic vulnerability [16, 13, 7, 25, 12]. Patient risk factors were consistent across studies as well, and frequently included older age, preexisting cognitive impairment, diabetes, anemia, and mood disorders, all of which seem to contribute to increased POD susceptibility [30, 9, 19, 27].

Identifying a POD "Vulnerable Brain"

The focus of this review was to examine the use of EEG in predicting and, if possible, preventing POD. A central finding across studies was the presence of a distinct EEG signature that seems to signify a "vulnerable brain" or "vulnerable brain phenotype", which strongly correlates with later POD development. The studies identified consistent abnormalities that seemed to signify this "vulnerable brain", including reduced alpha power, slower peak alpha frequency, increased delta and theta activity, lower spectral edge frequency, and reduced entropy, which were more prominent in patients who developed POD [17, 20, 27, 28, 37]. These EEG features were frequently detectable before the onset of clinical symptoms, underscoring their potential to signal early physiological risk. Additionally, burst suppression emerged as one of the most consistent predictors of POD across a range of surgical populations. Several large cohorts and randomized trials demonstrated that prolonged or easily provoked burst suppression strongly correlated with subsequent delirium, even when anesthetic concentrations fell within typical clinical targets. These findings suggest that burst suppression reflects an underlying cortical fragility rather than simply deep anesthesia [7, 12, 13, 26, 32].

Intraoperative alpha power was another frequently observed predictor, with lower alpha activity associated with baseline cognitive slowing, poorer executive function, and advanced age. Across studies, diminished alpha rhythms were interpreted as a marker of reduced synaptic integrity or impaired thalamocortical connectivity, providing further support for alpha power as an additional potential indicator of brain vulnerability [9, 17, 20, 28]. Additionally, in neurosurgical and vascular populations, studies using intraoperative neuromonitoring found that patients who developed POD exhibited greater IONM changes, such as somatosensory evoked potential (SSEP) decrements, as indicators of intraoperative cerebral

hypoperfusion. These findings point to IONM as a potential intervention point, where hemodynamic correction or surgical adjustment might mitigate delirium risk [2, 4, 15].

Preoperative EEG

Several studies also evaluated the role of preoperative EEG in risk stratification. Resting-state abnormalities, such as reduced beta and gamma activity, lower entropy, and diminished alpha attenuation with eye opening, were more common among patients who later developed delirium. These findings suggest that incorporating brief perioperative screening, especially in older or frail individuals, into perioperative risk assessment may be valuable [29, 1]. However, studies evaluating processed EEG indices, such as BIS, SedLine, or DeltaScan, found that although these devices are feasible and easy to implement, they are generally less accurate than raw or multichannel quantitative EEG. Even in trials where processed-EEG guidance reduced anesthetic dosing or minimized burst suppression, delirium incidence did not consistently decrease, which emphasizes the limitations of relying solely on processed indices [11, 10, 13].

Machine Learning

Several investigations explored the use of machine learning applied to EEG features, with many models achieving moderate to high discriminative performance. These studies highlight the promise of automated, data-driven EEG analysis for real-time risk prediction in the operating room or ICU, but generalizability across patient populations and recording modalities remains limited [15, 24, 27].

Limitations and Future Research

Common limitations across the literature included heterogeneity in EEG acquisition methods, variability in delirium assessment tools, confounding effects of anesthetics and comorbidities, and limited long-term follow-up. Many authors emphasized the need for standardization of assessment protocols, larger multicenter trials, and long-term follow-up in future research. Implementing these in future studies will be critical to advancing the integration of EEG-based monitoring into POD risk management.

Detection and Prevention

This review also highlights an important distinction between improving delirium detection and delirium prevention. While several studies demonstrated better identification of delirium, these improvements did not reliably translate into lower delirium incidence or shorter hospital stays [33, 10]. While determining whether EEG can be used to prevent POD remains to be studied, its use in accurately predicting POD

remains useful for helping doctors, patients, and families understand the risk of certain surgeries and for preparing individuals involved in postoperative recovery to best care for the patient.

CONCLUSION

EEG consistently reveals early warning signs of postoperative delirium, such as reduced alpha activity, increased slow-wave power, and episodes of burst suppression, which often emerge during surgery or even beforehand, frequently preceding clinical symptom onset. Because delirium most often develops in the first 24–48 hours after surgery, early identification of at-risk patients is especially important. Although processed EEG makes monitoring easier, raw and quantitative EEG measures continue to show the strongest and most reliable associations with delirium risk. Based on these findings, we recommend a practical "EEG bundle" that includes brief preoperative EEG screening and targeted intraoperative raw EEG review with clear thresholds that prompt standardized preventive steps. Future multicenter studies should validate this approach in real-world settings, include longer-term outcomes, and evaluate workflow and cost considerations. Standardizing EEG reporting, like montage, timing, metrics, and clinical endpoints, will also be essential for integrating these tools into routine perioperative care.

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REFERENCES

1. Acker, L., Wong, M. K., Wright, M. C., Reese, M., Giattino, C. M., Roberts, K. C., Au, S., Colon-Emeric, C., Lipsitz, L. A., Devinney, M. J., Browndyke, J., Eleswarpu, S., Moretti, E., Whitson, H. E., Berger, M., & Woldorff, M. G. (2024). Preoperative electroencephalographic alpha-power changes with eyes opening are associated with postoperative attention impairment and inattention-related delirium severity. *British Journal of Anaesthesia*, *132*(1), 154–163. https://doi.org/10.1016/j.bja.2023.10.037
2. Al-Qudah, A. M., Alkalbani, L., Tallapaneni, P. S., Vinuthna, D. V., Suresh, V., Anetakis, K. M., Crammond, D., Balzer, J., Shandal, V., Visweswaran, S., Subramaniam, K., Sadhasivam, S., & Thirumala, P. (2025). Predicting Postoperative Delirium Using Intraoperative Neuromonitoring in Patients Undergoing Craniotomy for Aneurysm Clipping Surgery. *European Neurology*, *88*(1), 1–10. https://doi.org/10.1159/000541593
3. Al-Qudah, A. M., Sivaguru, S., Anetakis, K., Crammond, D. J., Balzer, J. R., Thirumala, P. D., Subramaniam, K., Sadhasivam, S., & Shandal, V. (2024). Role of Intraoperative Electroencephalography in Predicting Postoperative Delirium in Patients Undergoing Cardiovascular Surgeries. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, *164*, 40–46. https://doi.org/10.1016/j.clinph.2024.05.012
4. Al-Qudah, A. M., Sivaguru, S., Anetakis, K. M., Crammond, D., Balzer, J. R., Subramaniam, K., Sadhasivam, S., Shandal, V., & Thirumala, P. D. (2024). Role of Intraoperative Neurophysiological Monitoring in Predicting Postoperative Delirium in Patients Undergoing Carotid Endarterectomy Surgeries. *European Neurology*, *87*(5–6), 242–249. https://doi.org/10.1159/000540311
5. Al-Qudah, A. M., Ta'ani, O. A., Thirumala, P. D., Sultan, I., Visweswaran, S., Nadkarni, N., Kiselevskaya, V., Crammond, D. J., Balzer, J., Anetakis, K. M., Shandal, V., Subramaniam, K., Subramanium, B., & Sadhasivam, S. (2024). Role of Intraoperative Neuromonitoring to Predict Postoperative Delirium in Cardiovascular Surgery. *Journal of Cardiothoracic and Vascular Anesthesia*, *38*(2), 526–533. https://doi.org/10.1053/j.jvca.2023.09.010
6. Al-Qudah, A. M., Tallapaneni, P. S., Crammond, D. J., Balzer, J., Anetakis, K. M., Shandal, V., Biaesch, J., Ghannam, M., Nadkarni, N., Gross, B. A., Lang, M., Subramanium, K., Sadhasivam, S., & Thirumala, P. D. (2025). Intraoperative neuromonitoring as an independent predictor for postoperative delirium in ICU following aneurysm clipping. *eNeurologicalSci*, *38*, 100549. https://doi.org/10.1016/j.ensci.2025.100549
7. Banerji, A., Gaskell, A. L., Voss, L. J., Pullon, R. M., Termaat, J., García, P. S., & Sleigh, J. W. (2025). EEG alpha power and delirium in the postanaesthesia care unit in older adults: The AlphaMax trial part 2 - effect of propofol infusion during emergence from desflurane anaesthesia☆. *British Journal of Anaesthesia*, S0007-0912(25)00502-1. https://doi.org/10.1016/j.bja.2025.07.051
8. Chen, Y.-C., Hung, I.-Y., Hung, K.-C., Chang, Y.-J., Chu, C.-C., Chen, J.-Y., Ho, C.-H., & Yu, C.-H. (2023). Incidence change of postoperative delirium after implementation of processed electroencephalography monitoring during surgery: A retrospective evaluation study. *BMC Anesthesiology*, *23*, 330. https://doi.org/10.1186/s12871-023-02293-9
9. Dai, Y., Shen, C., Shi, K., Liu, Q., Qiu, X., & Sun, J. (2024). Intraoperative Electroencephalogram Frontal Low Alpha Power for Predicting Postoperative Delirium in Elderly Patients after Orthopedic Surgery: A Prospective Cohort Study. *Annali Italiani Di Chirurgia*, *95*(6), 1134–1146. https://doi.org/10.62713/aic.3641
10. de Fraiture, E. J., Schuijt, H. J., Menninga, M., Koevoets, I. A. I., Verheul, T. F. M., van Goor, C. W., Nijdam, T. M. P., van Dartel, D., Hegeman, J. H., & van der Velde, D. (2024). Automated EEG-Based Brainwave Analysis for the Detection of Postoperative Delirium Does Not Result in a Shorter Length of Stay in Geriatric Hip Fracture Patients: A Multicentre Randomized Controlled Trial. *Journal of Clinical Medicine*, *13*(22). https://doi.org/10.3390/jcm13226987
11. Deschamps, A., Ben Abdallah, A., Jacobsohn, E., Saha, T., Djaiani, G., El-Gabalawy, R., Overbeek, C., Palermo, J., Courbe, A., Cloutier, I., Tanzola, R., Kronzer, A., Fritz, B. A., Schmitt, E. M., Inouye, S. K., Avidan, M. S., & Canadian Perioperative Anesthesia Clinical Trials Group. (2024). Electroencephalography-Guided Anesthesia and Delirium in Older Adults After Cardiac Surgery: The ENGAGES-Canada Randomized Clinical Trial. *JAMA*, *332*(2), 112–123. https://doi.org/10.1001/jama.2024.8144
12. Evered, L. A., Chan, M. T. V., Han, R., Chu, M. H. M., Cheng, B. P., Scott, D. A., Pryor, K. O., Sessler, D. I., Veselis, R., Frampton, C., Sumner, M., Ayeni, A., Myles, P. S., Campbell, D., Leslie, K., & Short, T. G. (2021). Anaesthetic depth and delirium after major surgery: A randomised clinical trial. *BJA: British Journal of Anaesthesia*, *127*(5), 704–712. https://doi.org/10.1016/j.bja.2021.07.021
13. Gaskell, A. L., Banerji, A., Pullon, R. M., Termaat, J., García, P. S., & Sleigh, J. W. (2025). EEG alpha power and delirium in the postanaesthesia care unit in older adults: The AlphaMax trial part 1—Effect of desflurane and fentanyl titration during maintenance. *British Journal of Anaesthesia*, S0007-0912(25)00491-X. https://doi.org/10.1016/j.bja.2025.07.045
14. Guay, C. S., Kafashan, M., Huels, E. R., Jiang, Y., Beyoglu, B., Spencer, J. W., Geczi, K., Apakama, G., Ju, Y.-E. S., Wildes, T. S., Avidan, M. S., & Palanca, B. J. A. (2023). Postoperative Delirium Severity and Recovery Correlate With Electroencephalogram Spectral Features. *Anesthesia and Analgesia*, *136*(1), 140–151. https://doi.org/10.1213/ANE.0000000000006075
15. Guo, Z., Wan, W., Liu, W., Liu, L., Yang, Y., Yang, C., & Cui, X. (2024). Quantitative electroencephalography predicts postoperative delirium in adult cardiac surgical patients from a prospective observational study. *Scientific Reports*, *14*(1), 31101. https://doi.org/10.1038/s41598-024-82422-7
16. Hesse, S., Kreuzer, M., Hight, D., Gaskell, A., Devari, P., Singh, D., Taylor, N. B., Whalin, M. K., Lee, S., Sleigh, J. W., & García, P. S. (2019). Association of electroencephalogram trajectories during emergence from anaesthesia with delirium in the postanaesthesia care unit: An early sign of postoperative complications. *BJA: British Journal of Anaesthesia*, *122*(5), 622–634. https://doi.org/10.1016/j.bja.2018.09.016
17. Hight, D., Ehrhardt, A., Lersch, F., Luedi, M. M., Stüber, F., & Kaiser, H. A. (2024). Lower alpha frequency of intraoperative frontal EEG is associated with postoperative delirium: A secondary propensity-matched analysis. *Journal of Clinical Anesthesia*, *93*, 111343. https://doi.org/10.1016/j.jclinane.2023.111343
18. Jandu, J. S., Mohanaselvan, A., & Fang, X. (2025, February 17). Differentiating delirium versus dementia in older adults. In StatPearls. Treasure Island (FL): StatPearls Publishing. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK570594/
19. Karan, B., & Ravi, P. R. (2025). Postoperative Delirium in Adult Patients Undergoing Surgery: A Prospective Observational Study in a Peripheral Hospital in the Southern Region of India. *Journal of Marine Medical Society*, *27*(2), 200–206.
20. Khalifa, C., Lenoir, C., Robert, A., Watremez, C., Kahn, D., Mastrobuoni, S., Aphram, G., Ivanoiu, A., Bonhomme, V., Mouraux,

A., & Momeni, M. (2023). Intra-operative electroencesystematic reviewphalogram frontal alpha-band spectral analysis and postoperative delirium in cardiac surgery: A prospective cohort study. *European Journal of Anaesthesiology*, *40*(10), 777–787. https://doi.org/10.1097/EJA.0000000000001895

21. Lander, H. L., Dick, A. W., Joynt Maddox, K. E., Oldham, M. A., Fleisher, L. A., Mazzeffi, M., Lustik, S. J., … Glance, L. G. (2025). Postoperative delirium in older adults undergoing noncardiac surgery. JAMA Network Open, 8(7), e2519467. https://doi.org/10.1001/jamanetworkopen.2025.19467
22. Li, N., Liu, X., Gao, Y., Yin, L., Zhao, W., Ma, R., & Ni, X. (2022). Association of electroencephalogram epileptiform discharges during cardiac surgery with postoperative delirium: An observational study. *Frontiers in Surgery*, *9*, 900122. https://doi.org/10.3389/fsurg.2022.900122
23. Likhvantsev, V. V., Berikashvili, L. B., Smirnova, A. V., Polyakov, P. A., Yadgarov, M. Y., Gracheva, N. D., Romanova, O. E., Abramova, I. S., Shemetova, M. M., & Kuzovlev, A. N. (2024). Intraoperative electroencephalogram patterns as predictors of postoperative delirium in older patients: A systematic review and meta-analysis. *Frontiers in Aging Neuroscience*, *16*, 1386669. https://doi.org/10.3389/fnagi.2024.1386669
24. Lodema, D. Y., Ditzel, F. L., Hut, S. C. A., van Dellen, E., Otte, W. M., & Slooter, A. J. C. (2024). Single-channel qEEG characteristics distinguish delirium from no delirium, but not postoperative from non-postoperative delirium. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, *161*, 93–100. https://doi.org/10.1016/j.clinph.2024.01.009
25. Nawan, A., Wang, G., Zhao, C., Zhang, W., Jiang, B., & Feng, Y. (2024). A Novel Preoperative Electroencephalogram-Derived Index to Predict Early Postoperative Delirium in Elderly Patients After Hip Fracture Surgeries: Development of a Prediction Model. *Geriatric Orthopaedic Surgery & Rehabilitation*, *15*, 21514593241258654. https://doi.org/10.1177/21514593241258654
26. Pawar, N., Zhou, S., Duarte, K., Wise, A., García, P. S., Kreuzer, M., & Barreto Chang, O. L. (2024). Intraoperative Burst Suppression by Analysis of Raw Electroencephalogram Postoperative Delirium in Older Adults Undergoing Spine Surgery: A Retrospective Cohort Study. *Journal of Neurosurgical Anesthesiology*. https://doi.org/10.1097/ANA.0000000000001015
27. Pollak, M., Leroy, S., Röhr, V., Brown, E. N., Spies, C., & Koch, S. (2024). Electroencephalogram Biomarkers from Anesthesia Induction to Identify Vulnerable Patients at Risk for Postoperative Delirium. *Anesthesiology*, *140*(5), 979–989. https://doi.org/10.1097/ALN.0000000000004929
28. Reese, M., Wright, M. C., Roberts, K. C., Browndyke, J. N., Bennett, M., Acker, L., Devinney, M. J., Reekes, T. H., Waligorska, T., Shaw, L. M., Blennow, K., Zetterberg, H., Cohen, H. J., Mathew, J. P., Whitson, H. E., Westover, M. B., Woldorff, M. G., & Berger, M. (2025). Associations between anaesthetic dose-adjusted intraoperative EEG alpha power, processing speed, and postoperative delirium: Analysis of data from three prospective studies. *British Journal of Anaesthesia*, *135*(1), 109–120. https://doi.org/10.1016/j.bja.2024.12.041
29. Schüßler, J., Ostertag, J., Georgii, M.-T., Fleischmann, A., Schneider, G., Pilge, S., & Kreuzer, M. (2023). Preoperative characterization of baseline EEG recordings for risk stratification of post-anesthesia care unit delirium. *Journal of Clinical Anesthesia*, *86*, 111058. https://doi.org/10.1016/j.jclinane.2023.111058
30. Shang, Z., Jiang, Y., Fang, P., Zhu, W., Guo, J., Li, L., Liang, Y., Zhang, S., Ma, S., Mei, B., Fan, Y., Xie, Z., Shen, Q., & Liu, X. (2024). The Association of Preoperative Diabetes With Postoperative Delirium in Older Patients Undergoing Major Orthopedic Surgery: A Prospective Matched Cohort Study. *Anesthesia and Analgesia*, *138*(5), 1031–1042. https://doi.org/10.1213/ANE.0000000000006893
31. Shinozaki, G., Chan, A. C., Sparr, N. A., Zarei, K., Gaul, L. N., Heinzman, J. T., Robles, J., Yuki, K., Chronis, T. J., Ando, T., Wong, T., Sabbagh, S., Weckmann, M. T., Lee, S., Yamada, T., Karam, M. D., Noiseux, N. O., Shinozaki, E., & Cromwell, J. W. (2018). Delirium detection by a novel bispectral electroencephalography device in hospitalized elderly: A pilot study. Psychiatry and Clinical Neurosciences, 72(9), 635–642. https://doi.org/10.1111/pcn.12783
32. Soehle, M., Dittmann, A., Ellerkmann, R. K., Baumgarten, G., Putensen, C., & Guenther, U. (2015). Intraoperative burst suppression is associated with postoperative delirium following cardiac surgery: A prospective, observational study. *BMC Anesthesiology*, *15*, 61. https://doi.org/10.1186/s12871-015-0051-7
33. Ten Broeke, M., Henckens, W. P. R., Weierink, A., Speekenbrink, R. G. H., van der Palen, J., & Halfwerk, F. R. (2025). Brain Pro-TCT: a prospective, quasi-experimental study on early delirium detection with Delirium Observation Screening Scale vs. Single-channel EEG after cardiac surgery in patients aged over 70 years. *European Journal of Cardiovascular Nursing*, *24*(4), 608–615. https://doi.org/10.1093/eurjcn/zvaf024
34. Wiegand, T. L., Rémi, J., & Dimitriadis, K. (2022). Electroencephalography in delirium assessment: A scoping review. BMC Neurology, 22, 300. https://doi.org/10.1186/s12883-022-02557-w
35. Yan, E., Veitch, M., Saripella, A., Alhamdah, Y., Butris, N., Tang-Wai, D. F., Tartaglia, M. C., Nagappa, M., Englesakis, M., He, D., & Chung, F. (2023). Association between postoperative delirium and adverse outcomes in older surgical patients: A systematic review and meta-analysis. Journal of Clinical Anesthesia, 90, 111221. https://doi.org/10.1016/j.jclinane.2023.111221
36. Zhang, W., Cheng, Y., Zhang, L., Wei, Y., Xie, H., & Huang, J. (2024). Association between emergence delirium and brain status parameters in children undergoing general anesthesia: A prospective observational study. *Paediatric Anaesthesia*, *34*(2), 130–137. https://doi.org/10.1111/pan.14779
37. Zhao, L., Qiu, D., & Jia, L. (2025). Retrospective case-control study of intraoperative EEG correlates in postoperative delirium. *Frontiers in Medicine*, *12*, 1635453. https://doi.org/10.3389/fmed.2025.1635453