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Review Article

REVIEW ARTICLE

Effects of propofol- or sevoflurane-containing anaesthesia on auditory brainstem responses in children: a systematic review

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Abstract

Background: Auditory brainstem response (ABR) provides objective hearing assessment in children who cannot undergo reliable behavioural audiometry. Sedation or general anaesthesia may facilitate recording but can alter electrophysiological measurements and potentially influence diagnostic interpretation. The primary aim of this systematic review was to explore electrophysiological and diagnostic outcomes of paediatric ABR testing when at least one study condition included propofol or sevoflurane.

Methods: This Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 systematic review was prospectively registered in International Prospective Register of Systematic Reviews (CRD420261324873). PubMed/MEDLINE, Embase, and the Cochrane Library were searched from inception, with searches updated on 17 August 2026. Two reviewers independently screened the original search; one reviewer screened the later update. Because of clinical and methodological heterogeneity, findings were synthesised narratively.

Results: The database searches identified 2386 records and yielded six eligible studies. Citation checking identified one additional study, giving seven in total. Four studies reported longer wave V latency under anaesthesia than under their respective comparators, but co-administered agents and differing populations preclude drug-specific attribution. In a within-participant comparison, hearing-loss classification differed between sevoflurane and propofol; a later observational cohort found no significant adjusted association for its distinct exposure groups.

Conclusions: Four of seven studies reported longer ABR electrophysiological wave V latency under anaesthesia, but five studies had a high risk of bias. A single study with within-participant comparison found different diagnostic classifications under sevoflurane and propofol. Heterogeneous designs and exposures do not establish which anaesthesia technique best preserves paediatric ABR findings.

Keywords: ABR; anaesthesia; auditory brainstem response; hearing assessment; paediatric anaesthesia; propofol; sevoflurane

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Editor's key points

- Auditory brainstem response (ABR) is an objective test used to assess hearing in children who cannot reliably complete behavioural audiometry.
- This systematic review identified seven comparative studies of paediatric ABR measurements or diagnostic interpretation involving propofol- or sevoflurane-containing exposure.
- The available studies do not establish which anaesthetic technique best preserves paediatric ABR findings.

Auditory brainstem response (ABR), also termed brainstem evoked response audiometry, is a noninvasive electrophysiological test that records neural responses along the auditory pathway from the cochlea to the brainstem. It permits objective assessment of auditory pathway integrity and estimation of hearing thresholds in infants and children who cannot participate reliably in behavioural audiometry.[1,2]

Accurate ABR acquisition requires minimal movement and low muscular and electrical interference. Natural sleep may be sufficient in neonates and young infants, whereas older or developmentally complex children often require sedation or general anaesthesia to obtain diagnostically interpretable recordings.[2,3]

Wave V is particularly important because it remains identifiable near electrophysiological hearing threshold and is commonly used for threshold estimation. Normal ABR latency is strongly age dependent during infancy and early childhood, so comparisons must account for auditory maturation.[4]

Previous paediatric studies have evaluated propofol, sevoflurane-containing general anaesthesia, and other sedation or anaesthetic conditions using heterogeneous designs and outcomes.[5–11] Reported outcomes include wave latency, interpeak intervals, amplitude, hearing threshold, and diagnostic classification. Anaesthetic agents also differ in their effects on neural synchrony and CNS depression, providing biological plausibility for differences in ABR recordings.[12–14]

A 2026 systematic review by Lu and colleagues[15] addressed a broader question that included both the influence of anaesthetic or sedative agents on ABR waveforms and the effectiveness of different approaches for successful sedation or test completion. The present review focuses specifically on electrophysiological and diagnostic ABR outcomes and includes an updated 2026 evidence search.

Therefore, this systematic review aimed to evaluate paediatric ABR electrophysiological and diagnostic findings in comparative studies with at least one propofol- or sevoflurane-containing exposure, focusing on wave latencies, interpeak intervals, amplitudes, hearing thresholds, and diagnostic interpretation.

Methods

Study design and registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement. The protocol was prospectively registered in PROSPERO (CRD420261324873).

Eligibility criteria

Eligible primary studies included paediatric patients undergoing conventional diagnostic acoustic ABR testing in association with sedation or general anaesthesia. Under the final eligibility framework, at least one relevant anaesthetic exposure was required to contain propofol or sevoflurane. Comparators could include awake testing, natural sleep, another sedative or anaesthetic condition, or a within-participant alternative anaesthetic condition. Studies were required to report at least one electrophysiological or diagnostic ABR outcome: wave I, III, or V latency; interpeak intervals; waveform amplitude; hearing threshold estimation; or diagnostic interpretation. Prospective, retrospective comparative, crossover, and other observational comparative designs were eligible.

Studies were excluded if they evaluated only sedation success, safety, workflow, or cost without electrophysiological or diagnostic ABR outcomes; evaluated anaesthetic exposures that did not contain propofol or sevoflurane; evaluated electrically evoked ABR during auditory brainstem implant or other intraoperative monitoring rather than conventional diagnostic acoustic ABR; lacked a relevant comparator; or were reviews, editorials, conference abstracts, letters, case reports, trial registrations without results, or book chapters.

Protocol deviations

The registered protocol prioritised comparison of i.v. propofol with inhalation sevoflurane. During conduct of the review, direct head-to-head evidence proved extremely limited, and eligibility was broadened to include comparative studies in which at least one study condition contained propofol or sevoflurane and a relevant electrophysiological or diagnostic ABR outcome was reported. This allowed inclusion of comparative evidence against awake testing, natural sleep, ketamine baseline, or another sedative condition while retaining the prespecified focus on propofol- or sevoflurane-containing exposure. The protocol also specified the Cochrane risk-of-bias tool for randomised trials; because the final evidence base was predominantly non-randomised, risk of bias was instead assessed using an adapted Newcastle–Ottawa framework with explicit domain-level judgements. The planned meta-analysis was not performed because of substantial clinical and methodological heterogeneity, as documented in the updated International Prospective Register of Systematic Reviews record. The prespecified Grading of Recommendations, Assessment, Development, and Evaluation for network meta-analysis approach was not undertaken because no network meta-analysis was performed; no informal certainty categories are assigned in this report.

Information sources and search strategy

PubMed/MEDLINE, Embase, and the Cochrane Library were searched from database inception without language or publication-date restrictions. Controlled vocabulary and free-text terms addressed ABR, anaesthesia or sedation, propofol, sevoflurane, and paediatric populations. The original search was completed in February 2026, and the complete strategies were rerun on 17 August 2026. The updated searches retrieved 700 records from PubMed/MEDLINE, 1522 from Embase, and 164 from the Cochrane Library, for a cumulative total of 2386

records. Complete database-specific strategies, search dates, deduplication details, and study-level reasons for full-text exclusion are provided in Supplementary File 1.

During revision, the waveform studies included in the review by Lu and colleagues[15] were checked individually against the final eligibility criteria. This citation audit identified an additional eligible study by Mühler and colleagues.[8] The report by Duncan and colleagues[16] was excluded because its anaesthetic exposures were halothane and thiopentone, and the report by Kusakari and colleagues[17] was excluded because profound hypothermia during cardiac surgery prevented an interpretable propofol- or sevoflurane-specific comparison. Finally, Wong and colleagues'[18] report was excluded because it studied electrically evoked responses during auditory brainstem implant surgery rather than diagnostic acoustic ABR.

Study selection and data extraction

References from the original searches were imported into Rayyan (Rayyan Systems Inc., Cambridge, MA, USA). Two reviewers independently screened titles and abstracts and assessed potentially eligible reports in full text; disagreements were resolved by discussion and consensus, although some resolved decisions retained a conflict status in Rayyan because the second reviewer did not update her account. We reconciled those records against the reviewers' final decisions and the

Table 1 Domain-level risk-of-bias assessment. Low, moderate, and high denote concern within each domain; the overall judgement gives greater weight to major confounding or uncertain exposure than to the number of favourable domains. This adapted framework has not been formally validated.

Study	Selection	Comparability/ confounding	Outcome assessment	Overall	Principal rationale
Purdie and Cullen[5]	Moderate	Moderate	Low	Moderate	Small within-participant study; dose-response design is informative, but co-administered N_2O/ trimeprazine and awake-to-anaesthetised comparison limit attribution.
Kitahara and colleagues[6]	Moderate	High	Low	High	Sevoflurane was combined with 60% N_2O and compared with ketamine baseline; substantial age heterogeneity.
Norrix and colleagues[7]	High	High	Low	High	12 young children, mostly with developmental delay, compared with 12 controls aged 13–26 yr; profound age and population mismatch
Mühler and colleagues[8]	Moderate	High	Low	High	Retrospective non-randomised allocation to chloral hydrate or propofol; age significantly affected amplitude growth, and anaesthetic selection was not comprehensively adjusted.
Gundogdu and colleagues[9]	Moderate	High	Low	High	Non-randomised natural-sleep *vs* operating-room comparison; combined agents, different recording environments, incomplete depth/temperature measurement
Kandil and colleagues[10]	Low	Moderate	Low	Moderate	Within-participant comparison and blinded audiologists reduce bias, but sequence was fixed (sevoflurane then propofol), with possible period/carryover effects and uncertain depth equivalence.
Zhu and colleagues[11]	Moderate	High	Moderate	High	Retrospective non-randomised, mixed exposure groups; available-case outcome denominators; adjustment limited to ASA physical status and no independent reference measurement

study-level exclusion audit. One reviewer screened the additional records from the 2026 search update and citation audit.

For studies selected in the original paired screening, two reviewers independently extracted publication year, country, study design, number enrolled and analysed, participant age, anaesthetic exposure, comparator, unit of analysis, ABR acquisition characteristics, latency and interpeak measurements, waveform amplitudes, hearing thresholds, diagnostic classifications, effect estimates, and reported limitations; discrepancies were resolved by consensus.

Risk-of-bias assessment

For studies selected in the original paired screening, risk of bias was assessed independently by two reviewers. The adapted Newcastle–Ottawa framework covered participant selection, comparability/confounding, and outcome assessment. Numerical totals were not used to determine the overall judgement. Major unresolved confounding or exposure-classification problems were given greater weight than other domains. Overall judgements were classified as moderate or

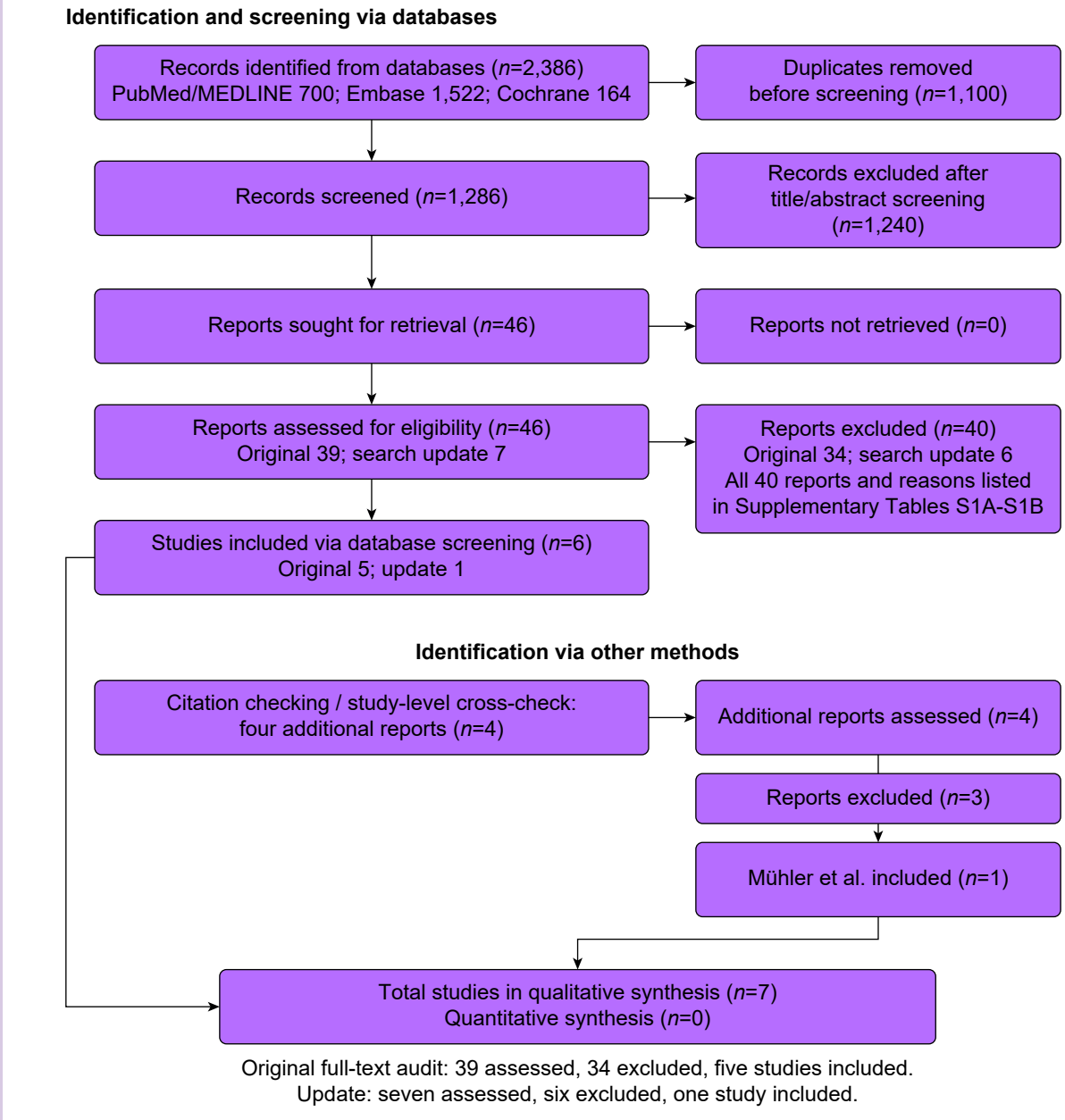

Fig 1. PRISMA 2020 flow diagram through 17 August 2026. Six studies were included from database screening and one from citation checking. The original database full-text audit comprised 39 reports (34 excluded); the update comprised seven reports (six excluded). Four additional reports were assessed in the citation audit: three excluded and Mühler and colleagues[8] included. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

high risk of bias, with study-specific rationale presented in Table 1 and full domain-level decisions in Supplementary File 2.

Data synthesis

A quantitative meta-analysis was not performed because of the small evidence base and substantial heterogeneity in participant age, anaesthetic protocols, comparator conditions, ABR stimuli, recording environments, and outcomes. Findings were synthesised narratively by latency/interpeak measures, amplitude, threshold, and diagnostic interpretation. Publication bias was not formally assessed because fewer than 10 studies were included and no pooled effect estimate was calculated.

Results

The updated database searches through 17 August 2026 identified 2386 records. After removal of 1100 duplicates, 1286 records underwent title and abstract screening; 1240 were excluded. Of 46 reports assessed for eligibility, 40 were excluded and six studies were included through database screening. The original assessment comprised 39 reports (34 excluded and five included), and the search update contributed seven further reports (six excluded and one included). Citation checking identified one additional eligible study by Mühler and colleagues,[8] resulting in seven studies in the qualitative synthesis (Fig. 1; Supplementary Tables 1A and 1B).

The seven included studies[5–11] spanned 1993–2026 and differed substantially in design, age, anaesthetic regimen, comparator, and ABR outcome. Only the report by Kandil and colleagues[10] directly compared propofol and sevoflurane within the same participants; the other studies examined distinct clinical contrasts (Table 2).

Risk of bias

Five studies[6–9,11] were judged at high overall risk of bias and two at moderate risk (Table 1). High risk reflected major population imbalance, unresolved confounding, or mixed exposure classification that substantially limited attribution to an anaesthetic condition. The domain-level rationale is presented in Supplementary File 2.

Table 2 Characteristics of systematic review included studies. Values for age and sample size are reproduced as reported by each study. ABR, auditory brainstem response; IQR, inter-quartile range; N_2O, nitrous oxide.

Study	Design/population	Anaesthetic exposure	Comparator	Primary ABR outcomes
Purdie and Cullen, 1993[5]	Prospective physiological study; 10 healthy children, 4–11 yr	Propofol target concentrations 4 and 8 μg ml^{-1}; N_2O and trimeprazine co-exposure	Awake baseline	Waves I, III, V latency; interpeak intervals
Kitahara and colleagues, 1995[6]	Prospective comparative study; 70 children, 10 per age group, 1 month to 15 yr	2.5% sevoflurane+60% N_2O	Ketamine baseline	Wave V latency, I–V interval, amplitude; age effects
Norrix and colleagues, 2012[7]	Retrospective comparative study; 12 anaesthetised children aged 29–52 months, mostly developmental delay; 12 controls aged 13–26 yr	Sevoflurane-based general anaesthesia±N_2O; midazolam premedication in some	Non-anaesthetised controls	Wave I, III, V latency; I–III, III–V, I–V intervals
Mühler and colleagues, 2013[8]	Retrospective comparative study; 46 infants aged 1–48 months	Propofol general anaesthesia; *n*=21	Chloral hydrate 50 mg kg−1 sedation; *n*=25	Chirp-evoked wave V amplitude and amplitude-growth function
Gundogdu and colleagues, 2022[9]	Retrospective comparative study; 42 general anaesthesia, 58 natural sleep; 17–95 months	Sevoflurane-based general anaesthesia with propofol/fentanyl and midazolam where applicable	Natural sleep	Wave I, III, V latency/amplitude; interpeak intervals; click threshold
Kandil and colleagues, 2022[10]	Prospective double-blind within-participant crossover; 80 enrolled, 79 analysed; mean age 3.4 (1.9) yr	Sevoflurane first, then propofol 200–250 μg kg−1 min−1 after 25–45 min washout	Within-participant alternative anaesthetic	Diagnostic interpretation, click threshold classification; five blinded audiologists
Zhu and colleagues, 2026[11]	Retrospective cohort; 403 children; median age 30 months (IQR 16–52); exposure grouping reported for 401	Sevoflurane only, *n*=98	Sevoflurane+propofol/propofol with sevoflurane induction exposure, *n*=303	Hearing-loss classification at click, 500 Hz, and 4000 Hz; ASA physical status–adjusted associations

Electrophysiological and diagnostic outcomes

Four studies[5–7,9] reported longer wave V latency under anaesthesia than under their respective comparator conditions. These comparisons involved propofol dose concentrations, sevoflurane with nitrous oxide, and non-anaesthetised control groups; co-exposures and between-group differences prevent attribution to a single agent (Table 3).

Two studies[8,9] reported comparative amplitude outcomes with different stimuli and comparator conditions. One found no significant difference in chirp-evoked wave V amplitude-growth slope between propofol general anaesthesia and chloral hydrate sedation, whereas the other reported lower amplitudes under sevoflurane-based general anaesthesia than during natural sleep (Table 3).

One study[9] reported a higher mean ABR threshold during general anaesthesia than during natural sleep; recording environment and anaesthetic management also differed between groups (Table 3).

The prospective within-participant comparison study by Kandil and colleagues[10] reported more hearing-loss classifications under sevoflurane than under propofol, with a fixed

Table 3 Numerical electrophysiological and diagnostic findings. Values are presented in the order stated in the comparison column; parenthetical dispersion measures are reproduced as reported by the source authors. Purdie values are shown in order: awake baseline, propofol target 4 μg ml^{-1}, then propofol target 8 μg ml^{-1}. aOR, adjusted odds ratio; CI, confidence interval; I–III, III–V, and I–V, interpeak intervals between the indicated auditory brainstem response waves; mid-*P*, mid-*P*-value for paired binary data; N_2O, nitrous oxide.

Study/unit	Comparison	Numerical findings	Interpretation/key limitation
Purdie and Cullen[5]; *n*=10 participants	Awake baseline; then propofol target 4 μg ml^{-1}; then 8 μg ml^{-1}	Wave V latency: baseline 5.53 (0.21), propofol 4 μg ml^{-1} 5.67 (0.30), and propofol 8 μg ml^{-1} 5.81 (0.27) ms III–V interval: 1.79 (0.16), 1.86 (0.17), and 1.96 (0.17) ms, respectively I–V interval: 3.99 (0.22), 4.10 (0.23), and 4.17 (0.22) ms, respectively	Dose-related latency/interpeak increase; small sample and co-administered agents
Kitahara and colleagues[6]; *n*=70 participants	2.5% sevoflurane+60% N_2O *vs* ketamine baseline	Wave V mean change +0.26 (0.16) ms; I–V +0.23 (0.19) ms; greater change in younger children	Numerically modest; cannot isolate sevoflurane from N_2O/ketamine effects
Norrix and colleagues[7]; one ear/participant, 12 *vs* 12	General anaesthesia *vs* non-anaesthetised control	Wave V 5.95 (0.18) *vs* 5.65 (0.12) ms, *P*=0.00005; I–III 2.44 (0.13) *vs* 2.25 (0.14), *P*=0.0008; III–V 2.05 (0.15) *vs* 1.84 (0.17), *P*=0.002; I–V 4.49 (0.19) *vs* 4.09 (0.16), *P*=0.000006	Large age/developmental-status mismatch makes anaesthetic attribution unreliable.
Mühler and colleagues[8]; *n*=46 participants	Chloral hydrate *n*=25 *vs* propofol general anaesthesia *n*=21	State-of-arousal main effect on amplitude-growth slope: $F(1,35)=0.011$, $P>0.05$; age effect significant	No detectable sedation-*vs*-general anaesthesia effect on chirp wave V amplitude growth; retrospective non-randomised comparison
Gundogdu and colleagues[9]; 42 *vs* 58 participants	Sevoflurane-based general anaesthesia *vs* natural sleep	Wave III 3.93 (0.26) *vs* 3.78 (0.18) ms; wave V 6.02 (0.32) *vs* 5.72 (0.23); III–V 2.08 (0.19) *vs* 1.93 (0.14); I–V 4.59 (0.30) *vs* 4.30 (0.21); wave III amplitude 0.463 (0.208) *vs* 0.526 (0.167); wave V 0.318 (0.141) *vs* 0.432 (0.142); threshold 15.1 *vs* 4.6 dB	Latency/amplitude/threshold differences; both thresholds normal; recording environment and anaesthetic-depth/temperature limitations
Kandil and colleagues[10]; 79 participants, 156 ears	Within-participant sevoflurane then propofol	Propofol: 13 patients/19 ears classified loss; sevoflurane: 21 patients/37 ears; ear-level McNemar mid-$P=7.24\times10^{-5}$; patient-level mid-*P*=0.0312; bilateral comparison *P*=0.0098	Clinically relevant reclassification; fixed sequence and possible carryover
Zhu and colleagues[11]; cohort 403, exposure grouping 401; available-case analyses	Sevoflurane-only *vs* mixed propofol-containing exposure	Right-ear click available *n*=387 (94 *vs* 293): aOR 0.80 (95% CI 0.50–1.31), *P*=0.376; left-ear click aOR 0.88 (0.55–1.43), *P*=0.608; other tested frequencies also non-significant after ASA physical status adjustment	Not a clean propofol-*vs*-sevoflurane comparison; residual confounding and outcome-specific missing data

treatment sequence. The report by Zhu and colleagues[11] found no significant association between its sevoflurane-only and mixed propofol-containing groups after adjustment for ASA physical status score; this comparison does not isolate a propofol-only effect (Table 3).

The numerical estimates and units of analysis are presented in Table 3; differences in comparator, stimulus, and outcome precluded a common effect estimate.

Discussion

This review identified seven comparative studies involving propofol- or sevoflurane-containing exposure and paediatric ABR outcomes.[5–11] Four reported longer wave V latency under anaesthesia than under their respective comparators.[5–7,9] However, most studies were at high risk of bias, and the comparisons do not isolate effects of individual drugs. Mühler and colleagues[8] found no significant difference in chirp-evoked wave V amplitude growth between chloral hydrate sedation and propofol general anaesthesia.

Differences in mean wave V latency across the reported contrasts ranged from 0.14 to 0.30 ms.[5–7,9] Because the studies differed in age, stimuli, anaesthetic co-exposure, and comparator setting, this range is descriptive and is not a pooled or drug-specific effect.

The report by Kandil and colleagues[10] provides the only prospective within-participant comparison of sevoflurane and propofol diagnostic classification, with interpretation by blinded audiologists. Its fixed sequence and uncertain equivalence of anaesthetic depth leave possible period and carryover effects. More recent evidence from Zhu and colleagues[11] concerns non-randomised, mixed drug exposure and cannot resolve that limitation. The authors grouped sevoflurane-only exposure against a propofol-containing group that could also receive sevoflurane during induction.[11] Adjustment was limited to ASA physical status classification, so its null association cannot be interpreted as a clean comparison of the two drugs or as a direct refutation of Kandil and colleagues.[10]

Norrix and colleagues[7] compared young anaesthetised children, most with developmental delay, with non-anaesthetised controls aged 13–26 yr. Age-dependent ABR maturation may account for part of the observed latency difference.[4] In the report by Gundogdu and colleagues,[9] groups also differed in recording environment, and anaesthetic depth and temperature were incompletely characterised.

Lu and colleagues[15] reviewed a broader set of studies, including sedation success and ABR test completion. Our narrower analysis concerns electrophysiological and diagnostic outcomes with propofol- or sevoflurane-containing exposure. Cross-checking identified Mühler and colleagues'[8] study as eligible, whereas reports from Duncan and colleagues,[16] Kusakari and colleagues,[17] and Wong and colleagues[18] did not satisfy the exposure or testing-modality criteria. The study by Zhu and colleagues[11] was identified in the updated database search.

This systematic review has notable limitations. The evidence base remains small and predominantly non-randomised. Co-administered drugs, differing comparators, and inconsistent outcomes limit interpretation. Some results were reported per child and others per ear; two ears from one child are correlated and should not automatically be treated as independent observations. The search update and citation audit were screened by one reviewer. Chloral hydrate, the comparator in the 2013 Mühler's study,[8] is unavailable or not routinely used in some settings, limiting the direct applicability of that contrast to contemporary practice.[8,19] These differences precluded meta-analysis. The broadened eligibility framework and changes to the risk-of-bias and certainty-assessment plans are documented protocol deviations.

Future studies should use prospectively defined and randomised anaesthetic sequences where feasible, explicit washout criteria, equivalent anaesthetic-depth targets, stable physiological conditions, standardised acoustic stimuli, age-stratified analyses, and blinded audiological interpretation. Reporting should include participant- and ear-level denominators, absolute latency and amplitude estimates with dispersion, hearing thresholds, and diagnostic reclassification.

Conclusion

Seven heterogeneous studies evaluated paediatric ABR outcomes with propofol- or sevoflurane-containing exposure. Four reported longer wave V latency under anaesthesia than under their respective comparators; one found no significant difference in chirp-evoked wave V amplitude growth between chloral hydrate sedation and propofol general anaesthesia. A within-participant comparison found different hearing-loss classifications under sevoflurane and propofol, but its fixed sequence limits causal attribution. Current evidence does not establish the superiority of one anaesthetic technique for preserving paediatric ABR findings.

Authors' contributions

Conceptualisation: CPB, RH
Methodology: CPB, JTM
Investigation: CPB, JTM
Data curation: CPB
Validation: JTM, RH
Writing—original draft: CPB
Writing—review and editing: JTM, RH
Interpretation of audiological findings: RH
Made substantial contributions, approved the submitted version, and agree to be accountable for the accuracy and integrity of all aspects of the work: all authors

Data availability

All data analysed in this review are derived from published studies. The extracted study-level dataset, study-level exclusions, and complete risk-of-bias decisions are provided in the Supplementary Material.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI) to assist with language editing and readability. The authors subsequently reviewed and edited the content and take full responsibility for the content of the publication.

Declaration of interests

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bjao.2026.100899.

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