Brainstem Auditory Evoked Potentials' Diagnostic Accuracy for Hearing Loss: Systematic Review and Meta-Analysis

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Abstract

Background Microvascular decompression (MVD) utilizes brainstem auditory evoked potential (BAEP) intraoperative monitoring to reduce the risk of iatrogenic hearing loss. Studies report varying efficacy and hearing loss rates during MVD with intraoperative monitoring.

Objectives This study aims to perform a comprehensive review and study of diagnostic accuracy of BAEPs during MVD to predict hearing loss in studies published from January 1984 to December 2013.

Methods The PubMed/MEDLINE and World Science databases were searched. Studies performed MVD for trigeminal neuralgia, hemifacial spasm, glossopharyngeal neuralgia or geniculate neuralgia and monitored intraoperative BAEPs to prevent hearing loss. Retrospectively, BAEP parameters were compared with postoperative hearing. The diagnostic accuracy of significant change in BAEPs, which includes loss of response, was tested using summary receiver operative curve and diagnostic odds ratio (DOR).

Results A total of 13 studies were included in the analysis with a total of 2,540 cases. Loss of response pooled sensitivity, specificity, and DOR with 95% confidence interval being 74% (60–84%), 98% (88–100%), and 69.3 (18.2–263%), respectively. The similar significant change results were 88% (77–94%), 63% (40–81%), and 9.1 (3.9–21.6%).

Conclusion Patients with hearing loss after MVD are more likely to have shown loss of BAEP responses intraoperatively. Loss of responses has high specificity in evaluating hearing loss. Patients undergoing MVD should have BAEP monitoring to prevent hearing loss.

Keywords

- ▶ evoked potentials
- ▶ auditory
- ▶ brainstem
- ▶ hemifacial spasm
- ▶ trigeminal neuralgia
- ▶ glossopharyngeal nerve diseases
- ▶ hearing loss

Introduction

Microvascular decompression (MVD) successfully treats trigeminal neuralgia (TGN), hemifacial spasm (HFS), glossopharyngeal

neuralgia (GPN), and geniculate neuralgia (GN) by relieving root exit zone) vascular compression on cranial nerve (CN) V, CN VII, CN IX, and the nervous intermedius.^{1–3} The retraction at the cerebellopontine angle or brainstem ischemia damages CN VIII

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leading to postoperative hearing loss (HL)⁴ at a rate of 1 to 23.8%.^{2,5-7} Monitoring intraoperative brainstem auditory evoked potential (BAEP) reduces postoperative CN VIII morbidity and remains the most effective method to prevent HL during MVD.⁸ The American Clinical Neurophysiology Society (ACNS) and American Society of Neurophysiological Monitoring recommend alerting the surgeon when significant changes (SCs) in BAEPs occur to prevent HL. SCs happen when wave V latency increases ≥ 1.0 ms and/or amplitude decreases $\geq 50\%$.^{9,10} Currently, no pharmacological therapeutic options are available to treat the patients based on BAEP changes. Our primary objective is to perform a comprehensive systematic review of published studies to evaluate the diagnostic accuracy of BAEP during MVD to predict HL. We calculated the sensitivity, specificity, diagnostic odds ratio (DOR), and summary receiver operating curves (SROC) to quantify diagnostic accuracy. The secondary objective was to assess heterogeneity amongst studies qualitatively using Quality assessment of diagnostic accuracy studies-2 (QUADAS-2) and quantitatively using I^2 . This information will establish BAEPs are a real-time biomarker of HL during MVD.

Methods

Literature Search and Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for a meta-analysis were followed. The PubMed/MEDLINE and World Science databases were searched systematically for articles using BAEPs to detect HL after MVD. Eligible studies were published through February 14, 2014. The following keywords and Boolean operators were used: “auditory evoked response, auditory evoked potentials, brainstem auditory evoked potentials, brainstem auditory evoked response, intraoperative monitoring, or intraoperative neurophysiological monitoring” and “microvascular decompression, or MVD” and “hemifacial spasm, HFS, trigeminal neuralgia, TGN, tic douloureux, geniculate neuralgia, GN, nervus intermedius neuralgia, or glossopharyngeal neuralgia.” Found article’s reference lists were cross-checked for additional articles. We specified search, inclusion, and exclusion criteria a priori. Two investigators independently extracted data to minimize and prevent sources of bias common in observational studies.¹¹

Study Selection

Included studies were randomized controlled trials, prospective or retrospective cohort reviews using BAEPs. All studies report hearing outcomes. The most detailed study data, or most recently published article, were chosen if studies presented duplicate data so that all cases were distinct. Excluded from this study are reviews, case reports, comments, editorials, and letters which did not report raw data. All studies with a diagnosis of HL not directly related to MVD surgery were excluded. All studies were published in English. Exclusion of non-English studies likely had no effect on the core findings and this criterion was adopted only for practical reasons with no intended bias toward international studies. Study participants were ≥ 18 years of age.

Target Conditions

TGN presents as intense pain on the ipsilateral side of the face. HFS presents as tonic and clonic contractions of the muscles innervated by the facial nerve. GPN patients suffer from severe nervous pain in the tongue, throat, ear, and tonsils. GN patients have severe pain in the deep ear, which may radiate outwards.

Data Extraction and Analysis

Two investigators (P. D. T. and G. C. C.) independently extracted relevant data from selected articles on the design and results of each study using a standardized form, which included first authors, year of publication, study population, region, BAEP use method, hearing evaluation, and methods quality. A final list of articles that met the study inclusion criteria for both the investigators was assembled. Our primary outcome for the study was HL 0 to 90 days postoperatively. We evaluated the BAEP changes during MVD to predict HL, the outcomes recorded from the studies.

We extracted data on the number of: True positives (TP), patients with postoperative HL and loss of response (LR) in intraoperative BAEPs; false negatives (FN), patients with HL, but normal BAEPs; true negatives (TN), patients without HL and normal BAEPs; false positives (FP), patients without HL but with abnormal BAEPs.

The data were used to construct 2×2 tables. For each individual study, sensitivity and specificity BAEP changes to identify HL were calculated after categorizing patients into no change, and LR or SCs. In all studies, the threshold for LR was defined as a 100% Amplitude of Wave V (AwV) loss. Our previous study categorized BAEP changes with significant benefits to sensitivity and specificity.¹² Categorical discrimination was used because BAEP waveform latency and amplitude dynamically change during MVD, secondary to the degree of retraction and/or compression affecting the auditory nerve or its vasculature. Individual study’s definition of the SC threshold was treated as valid. Studies using a threshold above the lowest value used by any study were not retroactively parsed.

Hearing Loss

Hearing loss was defined in several different ways among studies. Most studies used pre- and postoperative pure tone audiometry and/or speech discrimination scores (SDS) to determine HL. Bond et al (2010) used patient self-reporting to classify HL and Huang et al (2009) did not specify how they determined HL; in both cases, no HL was reported. Audiometric testing was not always stated as conducted by an audiologist, and in these cases, no reference to who conducted the testing was given. These two studies were excluded from the quantitative analysis. When a time frame was reported, testing occurred 2 to 90 days preoperatively and 0 to 90 days postoperatively. Among studies that reported a cutoff value for HL, the absolute value varied from 20 to 50 dB for pure tone audiometry (PTA) scores and 20 to 50% of SDS.

Assessment of Methodological Quality

The review authors used the QUADAS-2 tool to assess the included studies’ susceptibility to bias.¹³ The QUADAS-2 tool

assessed four domains: patient selection, index test, reference standard, and flow and timing. Patient selection refers to avoiding nonconsecutive or nonrandom sampling, case-control, or inappropriate exclusion. The index test refers to BAEP monitoring, which indicates continuous BAEP recording during MVD. The reference standard refers to proper testing for HL, which indicates pre- and postoperative audiogram testing. Flow and timing refer to the interval between the index and reference tests, whether all patients received the same reference test, and whether all patients were included in the analysis. If the answers to all signaling questions in a domain are “yes” then the “low” risk grade is given. If the answer to any signaling question is “no” then a “high” risk grade is given. The “unclear” category was only used where the reported data was insufficient to permit a judgment. The methodological quality of the included studies was assessed independently by two review authors and disagreement was resolved by reexamination of the primary literature.

Statistical Analysis

We used Stata 13 for the statistical analyses (Stata statistical software: release 13, StataCorp LP, College Station, Texas, United States). All p values were set at $p = 0.05$. The primary analysis of this review was to fit the data into a hierarchical SROC (HSROC) model using the bivariate model, which has been demonstrated to yield useful summary measures of diagnostic test performance.¹⁴ We were also able to obtain area under the receiver operating curve (AUROC), pooled

sensitivity, and pooled sensitivity through the same bivariate model used in generating the HSROC. For pooled estimates of DOR, we used the Der-Simonian Laird random effects meta-analysis. A Fagan nomogram was constructed to assess the positive likelihood ratio (+LR), negative likelihood ratio (−LR), positive posterior probability, and negative posterior probability.

We did not include datasets in the pooled analysis if either $TP + FN = 0$ or $TN + FP = 0$, because it was not possible to accurately estimate sensitivity or specificity. In other instances, we corrected zero cell counts by adding a 0.5 continuity correction to the study data.

Heterogeneity

The amount of heterogeneity between the included studies was quantified with the I^2 statistic. In general, $I^2 (> 50\%)$ shows that there is substantial variability or inconsistency in the results amongst the whole set of studies, whereas $I^2 (< 50\%)$ shows the included studies had consistent findings.

Results

Study Selection and Characteristics

The electronic search yielded a total of 121 publications (►Fig. 1). We rejected 94 publications as they did not meet the inclusion criteria. Of the two authors who screened the results, one author selected 25 studies for potential inclusion and one author selected 40 studies. After discrepancies were

Fig. 1 Results from searching studies for inclusion in the review.

Table 1 Summary of methodological quality

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Bond et al (2010)	+	+	?	-	+	+	?
Bricolo et al (2004)	+	+	+	+	+	+	+
Brock et al (2004)	+	-	+	-	+	+	+
Huang et al (2009)	+	-	?	?	+	+	?
James et al (2005)	+	+	-	-	+	+	+
Jo et al (2011)	+	+	+	+	-	+	+
Jo et al (2013)	+	-	+	+	+	+	+
Lee et al (2009)	+	-	+	+	+	+	+
Ramnarayan et al (2006)	+	-	+	+	+	+	+
Rizvi et al (1999)	+	-	?	?	+	+	+
Radtke and colleagues (1991)	?	-	+	+	+	-	-
Sindou et al (1992)	-	+	-	-	+	+	+
Thirumala et al (2014)	+	+	+	+	+	+	+

Note: Green, low; red, high; yellow, unclear.

discussed, the full-text copies of 27 studies were included. Of these, 14 studies were excluded for reasons stated in the flow diagram (►Fig. 1) and 13 studies met the inclusion criteria for our review since they used an appropriate index and reference test in patients having MVD surgery.

Risk of Bias within Studies and Results of Individual Studies

Radtke and colleagues (1991) included 151 unmonitored patients, which made their selection of monitored patients, used in our meta-analysis, unclear.⁸ Patient selection had a high risk of bias in Sindou et al (1992) due to nonrandom or consecutive sampling of patients.¹⁵ One study had a high patient applicability concern because some patients in the analysis did not undergo MVD.¹⁶ Seven out of 13 studies had a high-risk index test because they did not specify a threshold or a cutoff value for significant BAEP changes before surgery.^{3,5,8,17–20} One study had a high applicability concern because not all patients received intraoperative monitoring.⁸ The hearing evaluation risk of bias was unclear in three studies because no cutoff value in PTA scores or SDS was used to classify HL.^{5,18,21} The hearing evaluation risk of bias was high in two studies because they evaluated HL clinically, or did not specify their method.^{15,16} The hearing evaluation applicability was unclear in two studies because HL criteria was not reported as PTA or SDS.^{18,21} The hearing evaluation applicability was of high concern in one study because patients subjectively requested auditory tests.⁸ Flow and timing had an unclear risk in two studies^{5,18} and a high risk of bias in four studies.^{15–17,21} The high risk was due to three studies that did not include all patients in their analysis and one that did not give a hearing evaluation to all patients.

Only Thirumala et al (2014) adopted the diagnostic accuracy paradigm in their analysis and the other studies used individual cases to show BAEP change’s correlation to postoperative HL. Methodological quality is presented in ►Table 1. Characteristics of included studies are presented in ►Tables 2 and 3.

Synthesis of Results and Risk of Bias

The total incidence of HL in our study is 4.88%. The incidence of HL was 1.81% in patients with no change to BAEPs, 15.01% with any changes (92/613), 8.97% with SCs (40/446), and 31.14% with LR (52/167). These values can be deduced from ►Table 3. Alarm criteria were specified before surgery in six studies and in the seven others were determined during the course of study (►Table 2).

The first analysis was loss of BAEP responses and their relationship with HL (10 studies). The I² value was 63%. Study sensitivities ranged from 50 to 90%, and specificities ranged from 44 to 100%. Combining data from all studies using the bivariate model, loss of BAEP response exhibited strong specificity (average 95% confidence interval [CI]: 98% [88, 100%]) but weaker sensitivity (average 95% CI: 74% [60, 84%]). There was substantial heterogeneity in the whole dataset (I² = 94%). A graph of the estimated SROC along with the summary point, 95% confidence ellipse, and prediction ellipse for BAEPs is shown in ►Fig. 2A. The AUROC was 0.81 (0.78–0.84), showing that detecting loss of BAEP response had a good discriminant ability between those with and without HL. A pooled random effects estimate of the DOR for individual studies of patients with HL with loss of BAEP response was 69.3 (18.2–263).

The second analysis was loss of BAEP response or SCs (LR + SC) and their relationship with HL (11 studies). The I²

Table 2 Study profile and characteristics

Study	Study design	Condition	Alarm criteria	HL criteria	Baseline BAEP	Length of follow-up
Bond et al (2010)	Retrospective cohort	TGN	Yes, transient changes of absolute or IPL in excess of 10% baseline value	Self-reporting	Yes (after anesthesia)	Not stated
Bricolo et al (2004)	Retrospective cohort	HFS	Yes, > 0.5 ms delay in the peak of wave V, or if there were marked changes in amplitude or form of wave I or V	Mild 26–40 dB, moderate 41–55 dB, intermediate 56–70 dB, severe 71–90 dB, profound > 90 dB	Yes (after anesthesia)	Before discharge
Brock et al (2004)	Retrospective cohort	TGN	No, scores were considered abnormal if the IPL exceeded baseline by 2.5 standard deviations	Slight 20–30 dB, moderate 35–40 dB, severe hypoacusia or anacusia	Yes, (after anesthesia)	Not stated
Huang et al (2009)	Retrospective cohort	HFS	No, > 50% wave V amplitude decrease	Not stated	Yes (after anesthesia)	Not stated
James et al (2005)	Retrospective cohort	HFS/TGN/ CPA surgery	Yes, a 1.0 ms latency increase or 50% amplitude decrease of wave V	PTA cutoff 50 dB, SDS cutoff 50%	Yes (after anesthesia)	Immediately postoperative and upon discharge
Jo et al (2011)	Retrospective cohort	HFS	Yes, a 1.0 ms latency increase or 50% amplitude decrease of wave V	PTA cutoff 15 dB, SDS > 20%	Yes (before anesthesia)	3–10 d postoperative
Jo et al (2013)	Retrospective cohort	HFS	No, > 0.5 ms delay in the peak of wave V, or if there were marked changes in amplitude or form of wave I or V	PTA cutoff 15 dB, SDS > 20%	Yes (before anesthesia)	2–13 d postoperative
Lee et al (2009)	Retrospective cohort	HFS	No, 0.4 ms (watch), 0.6 ms (warn), 1.0 ms (critical) wave V latency delay, and a 50% amplitude reduction with a latency increase	Cutoff > 25 dB	Yes (after anesthesia)	3–10 d postoperative
Ramnarayan et al (2006)	Retrospective cohort	TGN	No, greater than three standard deviations over the normal mean value latency of wave V (4.77 ± 0.23 ms)	> 20 dB	Yes (after anesthesia)	48 h
Rizvi et al (1999)	Retrospective cohort	TGN	No, increase in IPL of 1.5 ms or an increase more than three standard deviations	No cutoff value, given distribution shows no major changes	Yes (after anesthesia)	N/A
Radtke and colleagues (1991)	Retrospective cohort	HFS, TGN	No, wave V latency increase ≥ 1.0 ms or rapid changes > 0.1 ms/min	> 30 dB	Yes (before anesthesia)	Immediately postoperative and 1 mo out
Sindou et al (1992)	Retrospective cohort	HFS, TGN	Yes, 1 ms in 10 min or drastic modification, for voltage a decrease in amplitude of wave V > 50%	> 20 dB	Yes (after anesthesia)	Immediately postoperative
Thirumala et al (2014)	Retrospective cohort	HFS, TGN, GN, GPN	Yes, a 1.0 ms latency increase or 50% amplitude decrease of wave V	< 50% SDS, > 50 dB PTA	Yes (after anesthesia)	1–90 d postoperatively

Abbreviations: BAEP, brainstem auditory evoked potential; CPA, cerebello pontine angle; GN, geniculate neuralgia; GPN, glossopharyngeal neuralgia; HFS, hemifacial spasm; IPL, interpeak latency; N/A, not applicable; PTA, pure tone audiometry; SDS, speech discrimination score; TGN, trigeminal neuralgia.

Table 3 Patient demographics

Study	Sample size for analysis	Patient age (average)	Hearing loss	No monitoring	No changes (HL/total)	Significant changes (HL/total)	Loss of response (HL/total)
Bond et al (2010)	119	60	0	0	0/110	0/9	0/0
Bricolo et al (2004)	84	53	9	0	1/43	3/19	5/22
Brock et al (2004)	45	55.5	8	3	1/18	3/19	4/5
Huang et al (2009)	36	N/A	0	0	0/33	0/1	0/2
James et al (2005)	130	N/A	3	0	0/78	1/22	2/30
Jo et al (2011)	1,156	48.7	46	0	22/876	12/268	12/12
Jo et al (2013)	331	N/A	4	0	1/324	1/3	2/4
Lee et al (2009)	22	61	3	0	0/8	2/8	1/6
Ramnarayan et al (2006)	75	N/A	9	0	0/50	7/12	2/13
Rizvi et al (1999)	9	N/A	4	0	0/3	3/3	1/3
Radtke and colleagues (1991)	261	53.9	9	152	3/68	2/26	4/15
Sindou et al (1992)	34	51	8	0	2/4	1/10	5/20
Thirumala et al (2014)	238	52.41	21	0	2/154	5/49	14/35
Total	2,540	51	124	155	32/1,772	40/446	52/167

Abbreviations: BAEP, brainstem auditory evoked potential; HL, hearing loss; N/A, not applicable.
Note: A N/A indicates data was not collected on age. For BAEP changes, a line—indicates data was not recorded. Several studies did not comment on transient losses and their difference from significant changes or permanent loss. In the studies by Bond et al (2010) and Huang et al (2009), no change in BAEP was recorded and therefore there can be no discrimination between BAEP change categories.

Fig. 2 SROC for HL in (A) patients with loss of BAEP response and (B) patients with a significant change of BAEP response. The size of the study estimate circle indicates study effect size. The larger circle indicates the combined effects of all studies. BAEP, brainstem auditory evoked potential; HL, hearing loss; SROC, summary receiver operator curve.

value was 42%. Study sensitivities ranged from 67 to 91%, and specificities ranged from 14 to 99%. Combining data from all studies using the bivariate model, loss of BAEP response or SC exhibited strong sensitivity (average 95% CI: 88% [77, 94%]) but weaker specificity (average 95% CI: 63% [40, 81%]). There was substantial heterogeneity in the whole dataset ($I^2 = 86\%$). A graph of the estimated SROC along with the summary point, 95% confidence ellipse, and prediction ellipse for BAEP is shown in ►Fig. 2B. Overall, the AUROC was 0.88 (0.85–0.91), showing that detecting loss of BAEP response or SCs had a good discriminant ability between those with and without HL. A pooled random effects estimate of the DOR for individual studies of patients with HL with loss of BAEP response or SC was 9.1 (3.9–21.6).

Additional Analysis

The Fagan nomogram (►Fig. 3) calculates the +LR and –LR of BAEP HL predictions for LR (►Fig. 3A) and SC + LR (►Fig. 3B). All data are reported with a 95% CI. For LR, the data indicated

reliable posttest predictability with a positive likelihood of greater than 1 (8.24 [6.27, 11]) and low negative likelihood of less than 1 (0.61 [0.53, 0.71]). The positive posterior probability was 31% (26, 38%) and the negative posterior probability was 3% (3, 4%). For SC + LR, data indicated reliable posttest predictability with a positive likelihood of greater than 1 (3.22 [2.83, 3.66]) and low negative likelihood of less than 1 (0.34 [0.25, 0.54]). The positive posterior probability was 15% (13, 17%) and the negative posterior probability was 2% (1, 2%).

Discussion

LR is used in practice to recognize patients at a high risk for HL. Patients who experience HL are 69 times more likely to have sustained an intraoperative loss of the BAEP response according to the DOR. The pooled specificity across studies was high (98%) but the sensitivity was low (74%) of BAEPs in evaluating HL after MVD. We classified patients who had

A Loss of Response

B Significant Changes and Loss of Response

Fig. 3 Fagan nomogram. The blue line represents positive tests. The red line indicates negative tests. All data are reported with 95% confidence intervals. +LR, positive likelihood ratio; –LR, negative likelihood ratio; +PP, positive posterior probability; –PP, negative posterior probability.

changes in BAEPs but no HL as false positives contributing to the lower sensitivity. Loss of BAEP response is often associated with excessive retraction of CN VIII. Increasing CN VIII axons' stretch causes wave form temporal dispersion and subsequently a loss of amplitude.²² However, if the stretch is reversible, the BAEP responses could be restored without significant histological changes similar to stretch in experimental peripheral nerves.

Experimental stresses on peripheral nerve for a prolonged time lead to histological changes and nerve injury.^{23,24} As a corollary, increasing CN VIII axons' stretch causes loss of amplitude.²² Brainstem or CN VIII blood flow changes, or direct trauma to the CN may also cause BAEP response loss,^{23–26} leading possibly to faster and irreversible changes. The higher specificity of HL in patients with BAEP loss indicates that, in some patients, recovery of BAEPs is desirable but not always achievable. Our results indicate that a loss of BAEP response can occur without loss of auditory function. Transient stretching of a peripheral nerve can result in temporal dispersion with or without conduction block resulting in a drop in amplitude of the response. These processes may have delayed recovery or degradation and may not be detected during the course of surgery.^{27,28}

SCs in the latency and amplitude of BAEPs during MVD are used in practice as an alarm so that the surgeon can be aware of the changing auditory nerve function. Patients who experience HL are nine times more likely to have sustained an intraoperative change (SC and LR) in BAEP response during MVD. The pooled sensitivity was higher as compared with LR, 88 versus 74 respectively. To prevent HL, we need a good alarm criterion which is sensitive and can be communicated to the surgical team during MVD. The current ACNS guidelines recommend as an alarm ≥ 1.0 ms or $\geq 10\%$ increase in latency of wave V and/or a decrease in the amplitude $\geq 50\%$.^{9,10} In this review, three studies alerted the surgeon at a > 0.5 ms latency delay, three used some standard deviation in latency from baseline, and the majority adopted the recommended guidelines. The varied alarm criteria adopted in clinical practice may have to be robustly evaluated to improve sensitivity. Our study found that both SC + LR and LR have +LR greater than one and –LR less than one. The +LR was higher for LR, indicating its value in predicting postoperative deficits. The –LR was higher for SC + LR, indicating its value for preventing postoperative deficits. The postoperative probability was increased from 5% in LR and SC + LR to 31 and 15%, respectively.

The overall incidence of HL in our study was 2.20%. Technical issues such as anesthetic technique, temperature of the eighth cranial nerve, lead displacement, or dislodging of the sound generator in the ear canal may cause changes in BSERs which do not reflect hearing changes and add variability to all studies. The study by Jo et al provides 1,156/2,540 patients in the study sample which includes the results of other studies in the ROC analysis. Qualitative review and individual details of published studies is included to assuage this occlusion.

Although the current study showed strengths based on a comprehensive literature review, with quality assessment using the QUADAS-2, there are several limitations that

must be addressed. Most importantly, owing to study design, our analysis is at risk of publication bias because of dependence on currently published data on the topic of investigation. Another major limitation is substantial heterogeneity in the findings of the individual studies, as evidenced by the wide variations in the sensitivities and specificities obtained. Because of high heterogeneity, a funnel plot could not be constructed. Moreover, “zero” event cells were not uncommon within this set of studies, and this precluded from reliably analyzing a few of the published studies.

Conclusions

Intraoperative of BAEPs changes are highly specific in predicting HL after MVD. Lower sensitivity is due to the therapeutic surgical pause in the MVD in response to changes in BAEPs. A loss of BAEPs during the procedure can be a specific, biomarker of perioperative HL. Patients undergoing MVD should have BAEP monitoring to prevent HL.

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