Current developments and new directions in pediatric audiology:

Frequency specific auditory brainstem response audiometry - basis for habilitation

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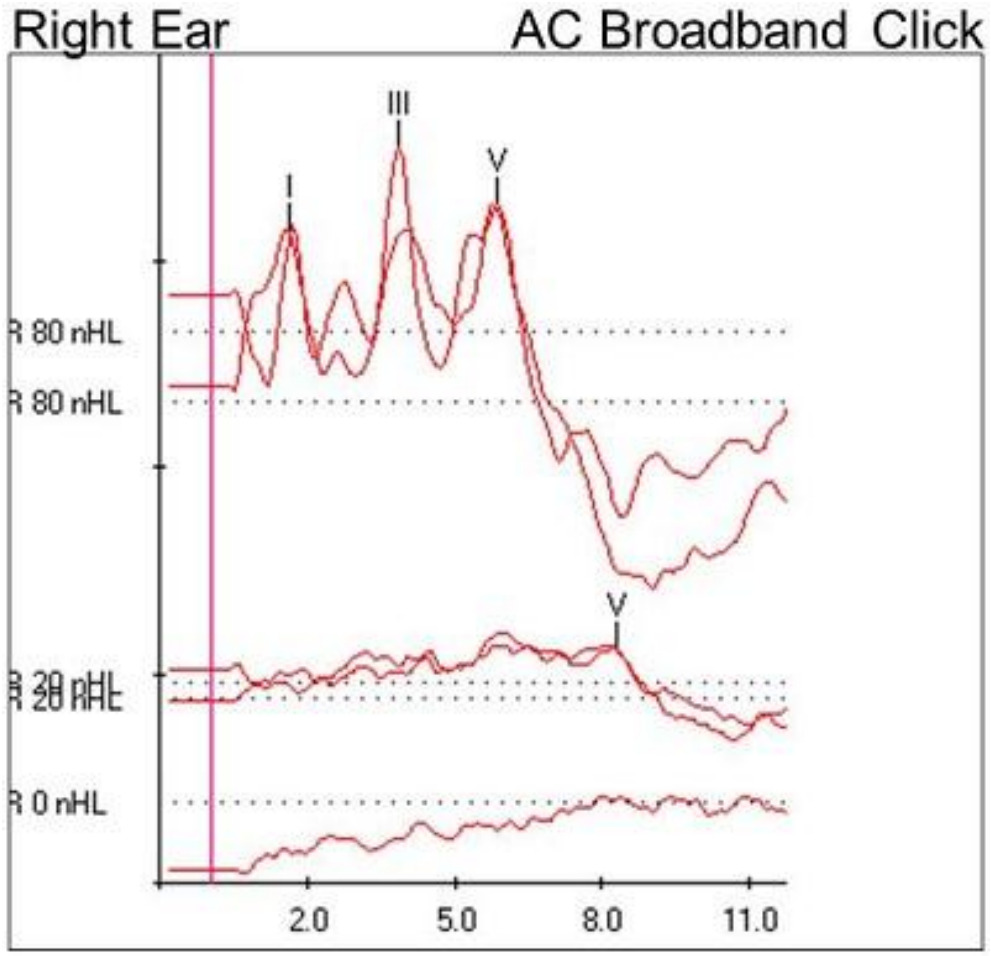
Key points

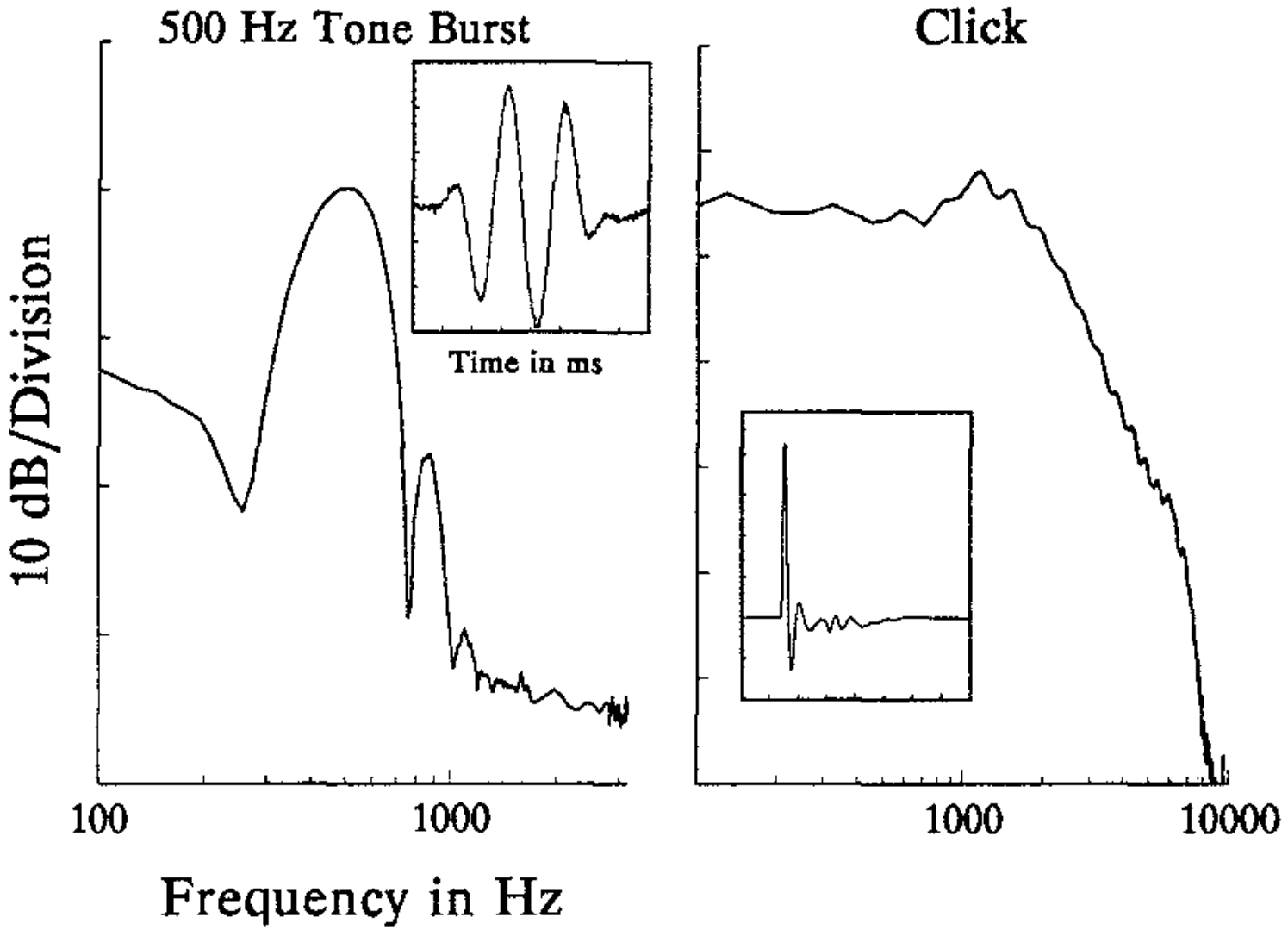
- Click ABR and excellent screening tool but not suitable for estimating hearing thresholds
- Best practice guidelines have been developed
- Need careful attention to stimulus and recording protocols, rather than accepting manufacturer default settings
- Air and bone conduction ABR needed to estimate audiogram if AC toneburst ABR indicates a hearing loss
- Erroneous results can be obtained if people do not follow guidelines for reducing noise in recordings and accurately distinguishing responses from noise



Traditional ABR approach used click stimuli to determine objective hearing threshold in infants and other children that could not be tested behaviourally

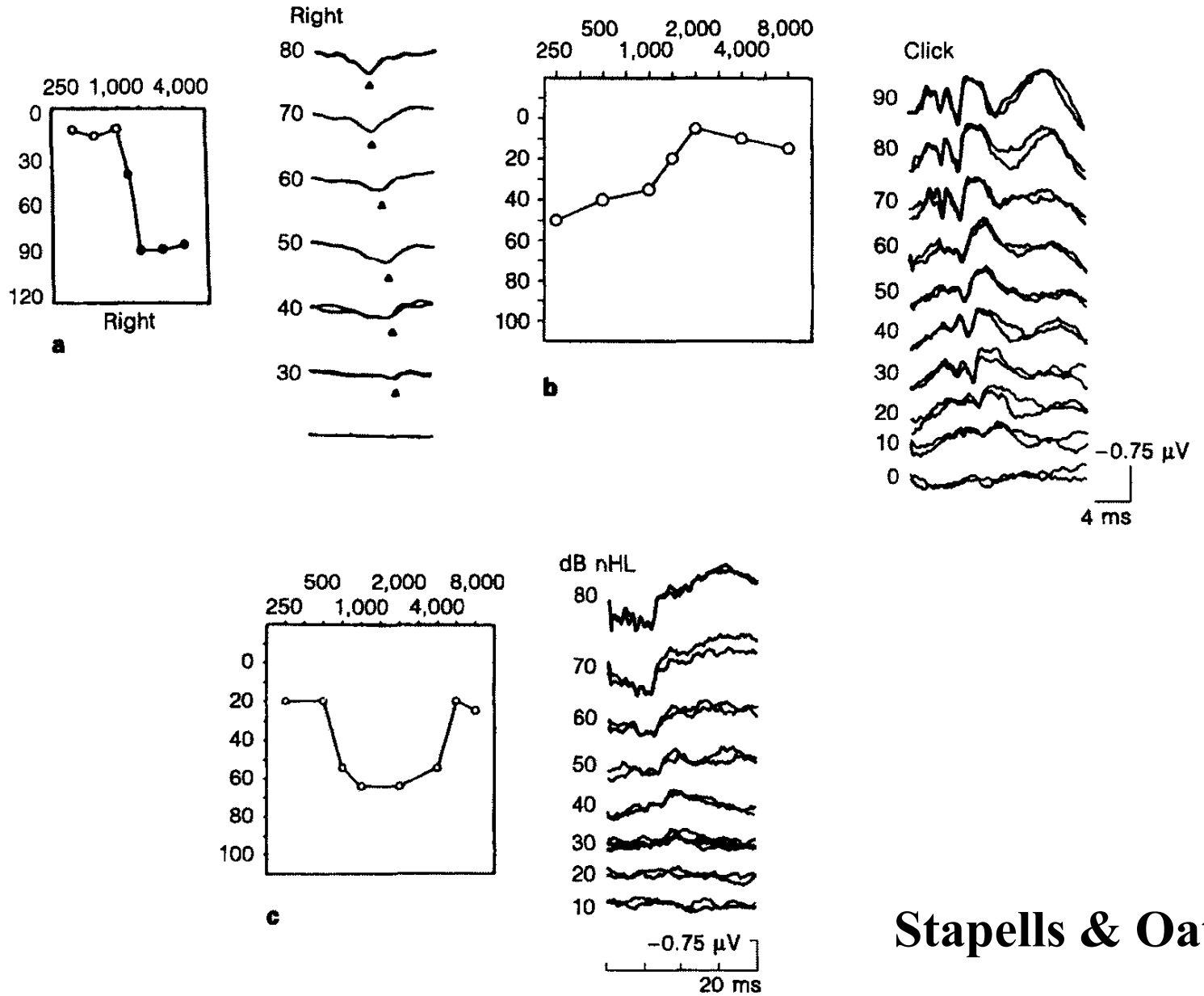
http://www.audiologyonline.com/articles/abr-illustration-auditory-dysfunction-through-12179

Click versus toneburst acoustic spectra



Sininger (1995)

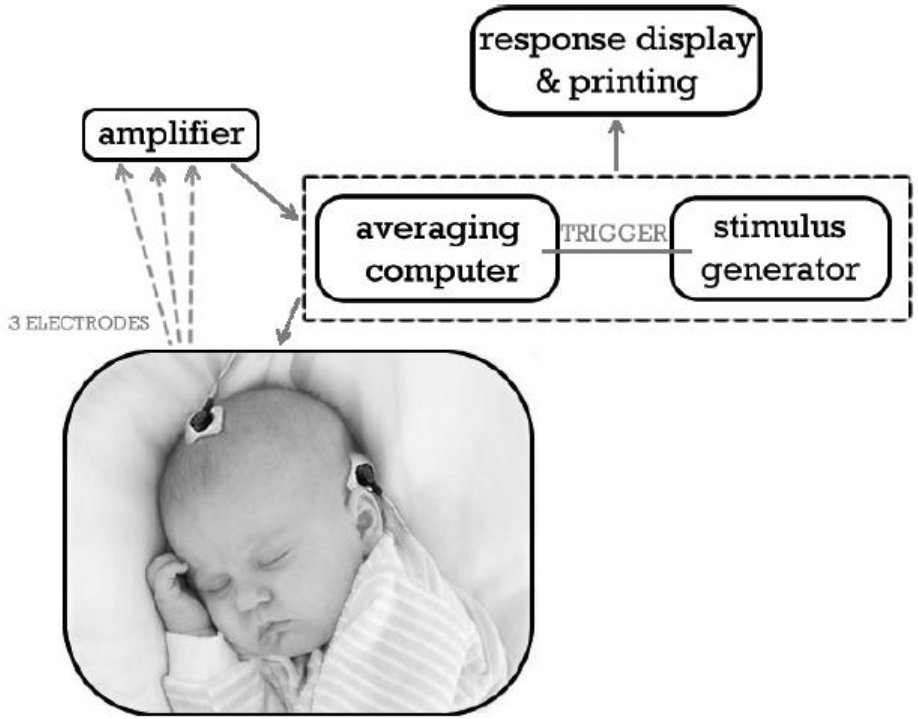
Click ABR can miss hearing loss



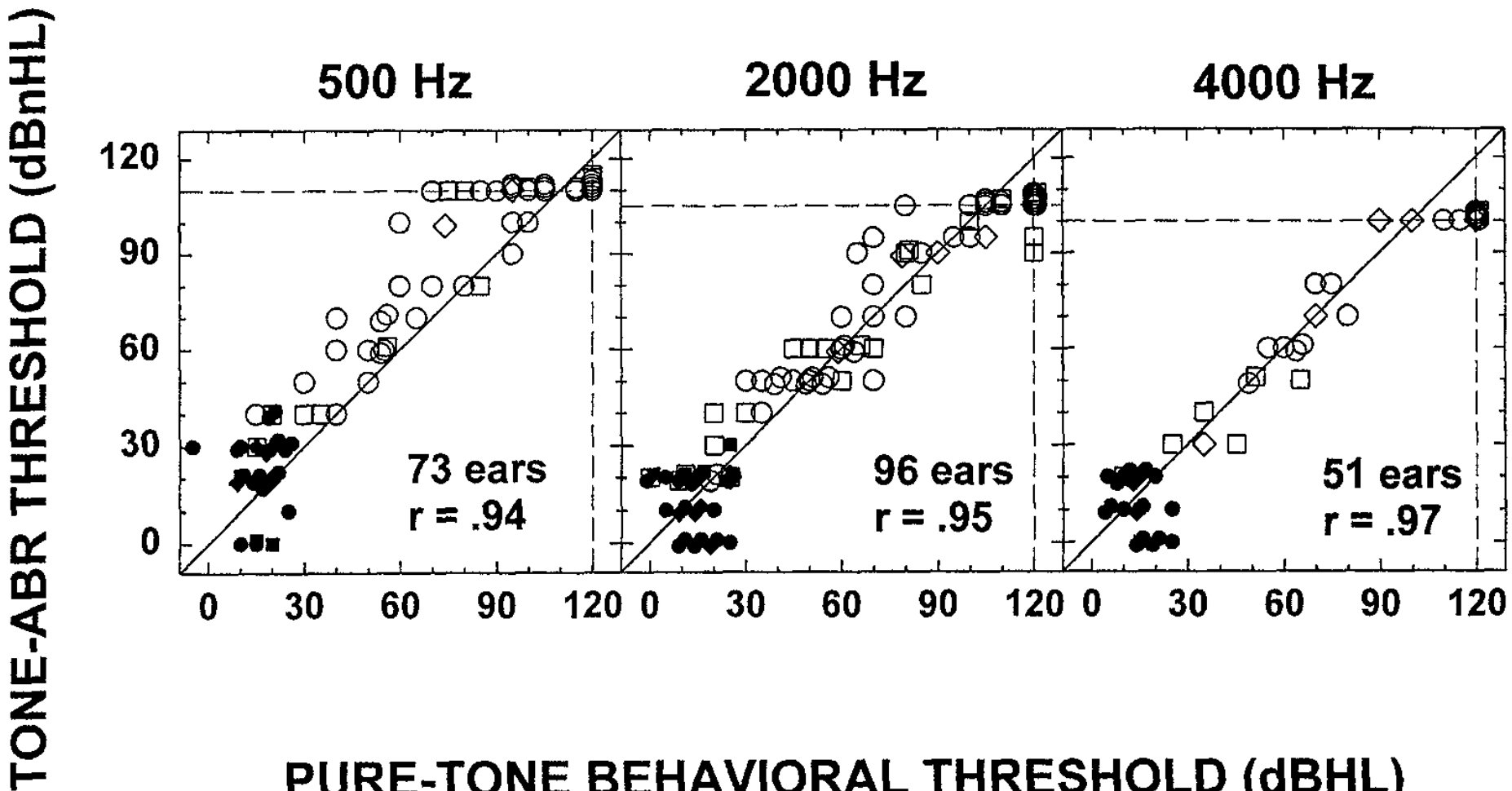
Stapells & Oates (1997)

Toneburst ABR has become the gold standard for objectively estimating hearing thresholds in children

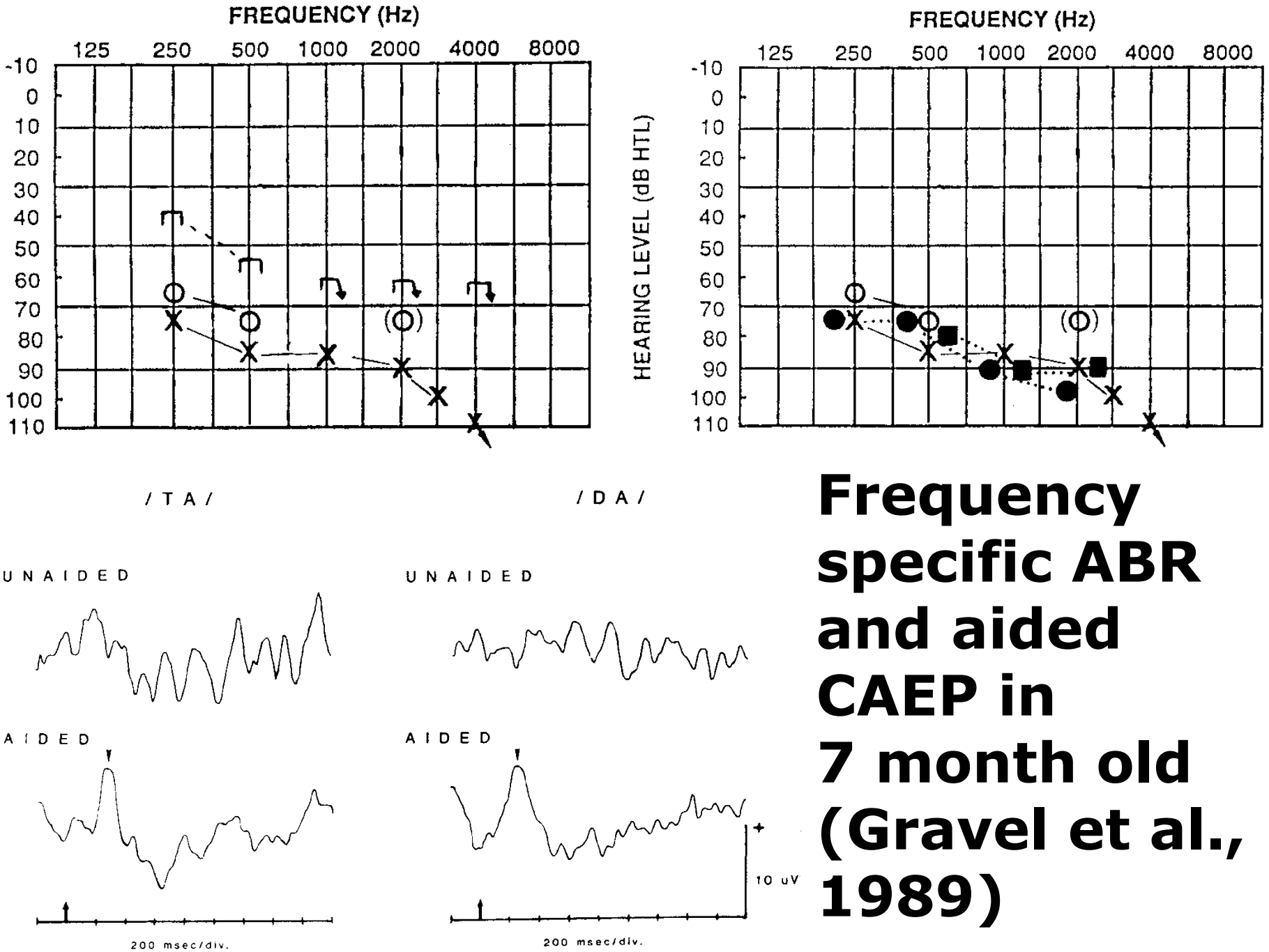
'**Auditory Evoked Response Testing in Infants and Children**' Suzanne C. Purdy and Andrea S. Kelly. Chaper 15 in J.R. Madell & C. Flexer (Eds.), *Pediatric audiology: Diagnosis, technology, and management Second edition*, New York: Thieme Medical Publishers, ISBN 978-1-60406-844-3, pp.148-163, 2014.



Relationship between toneburst ABR and behavioural thresholds



Stapells et al (1995)



Frequency specific ABR and aided CAEP in 7 month old (Gravel et al., 1989)

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Clinical Guidelines for toneburst ABR

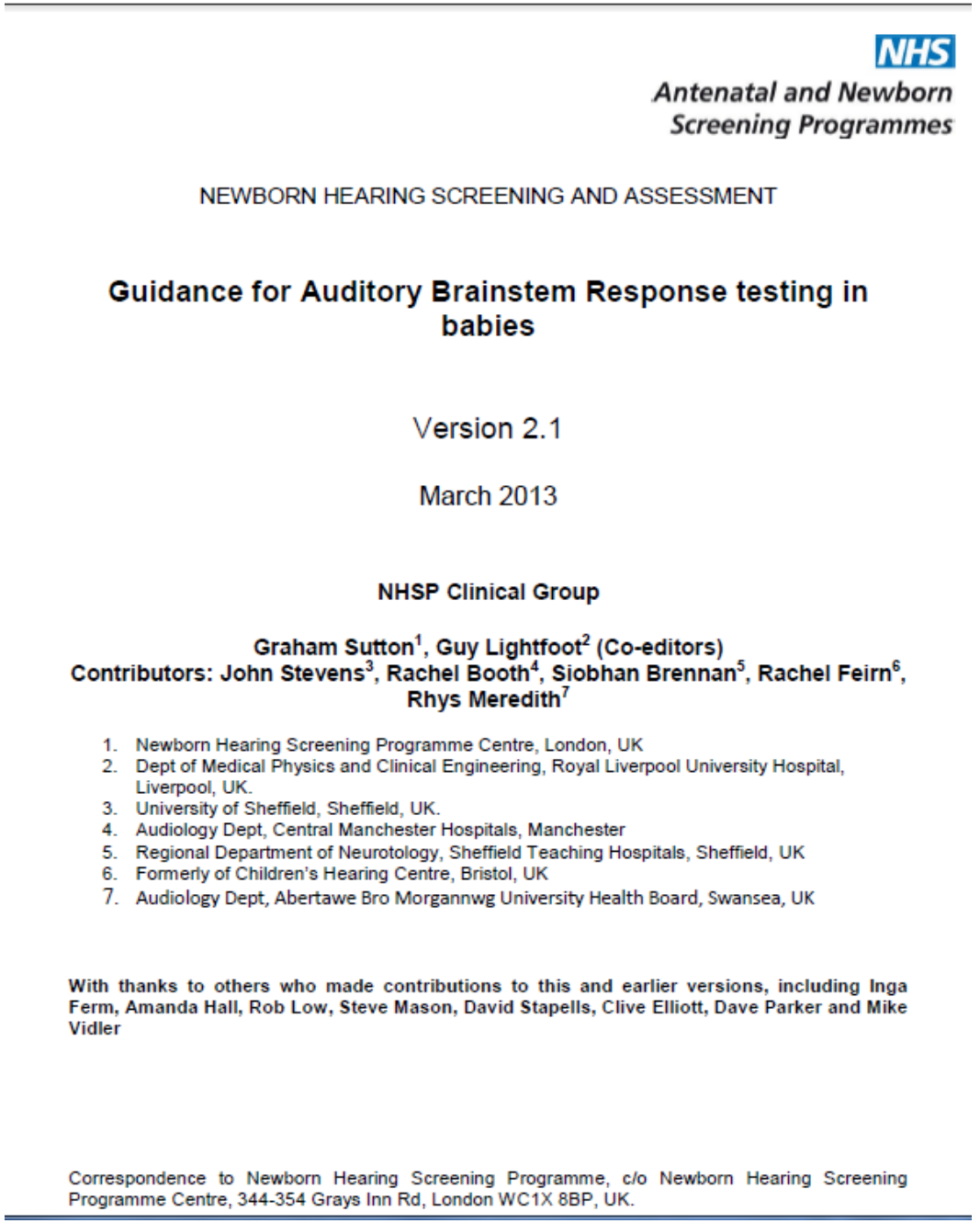
- **New Zealand** Ministry of Health Universal Newborn Hearing Screening and Early Intervention Programme National Policy and Quality Standards. Appendix F: Diagnostic and amplification protocols June 2013 https://www.nsu.govt.nz/files/UNHSEIP-appendix-F-jun13.pdf
- **British Columbia** BC Early Hearing Program Diagnostic Auditory Brainstem Response http://www.phsa.ca/NR/rdonlyres/B8B8FF59-6474-4E66-8B92-5F1EA30916FD/40120/zDiagnosticABRTrainingManualSept292008.pdf
- **ONTARIO** INFANT HEARING PROGRAM AUDIOLOGIC ASSESSMENT PROTOCOL Version 3.1, January 2008 *https://www.mountsinai.on.ca/*

Clinical Guidelines from United Kingdom

Includes sections ….

3. PATIENT PREPARATION
4. STIMULUS
5. DATA COLLECTION AND ANALYSIS ….

*hearing.**screening**.nhs.uk/getdata.php?id=19345*



NHS
Antenatal and Newborn Screening Programmes

NEWBORN HEARING SCREENING AND ASSESSMENT

Guidance for Auditory Brainstem Response testing in babies

Version 2.1

March 2013

NHSP Clinical Group

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With thanks to others who made contributions to this and earlier versions, including Inga Ferm, Amanda Hall, Rob Low, Steve Mason, David Stapells, Clive Elliott, Dave Parker and Mike Vidler

Correspondence to Newborn Hearing Screening Programme, c/o Newborn Hearing Screening Programme Centre, 344-354 Grays Inn Rd, London WC1X 8BP, UK.

Stimulus

- type
- duration
- polarity
- repetition rate
- masking
- transducer
- calibration

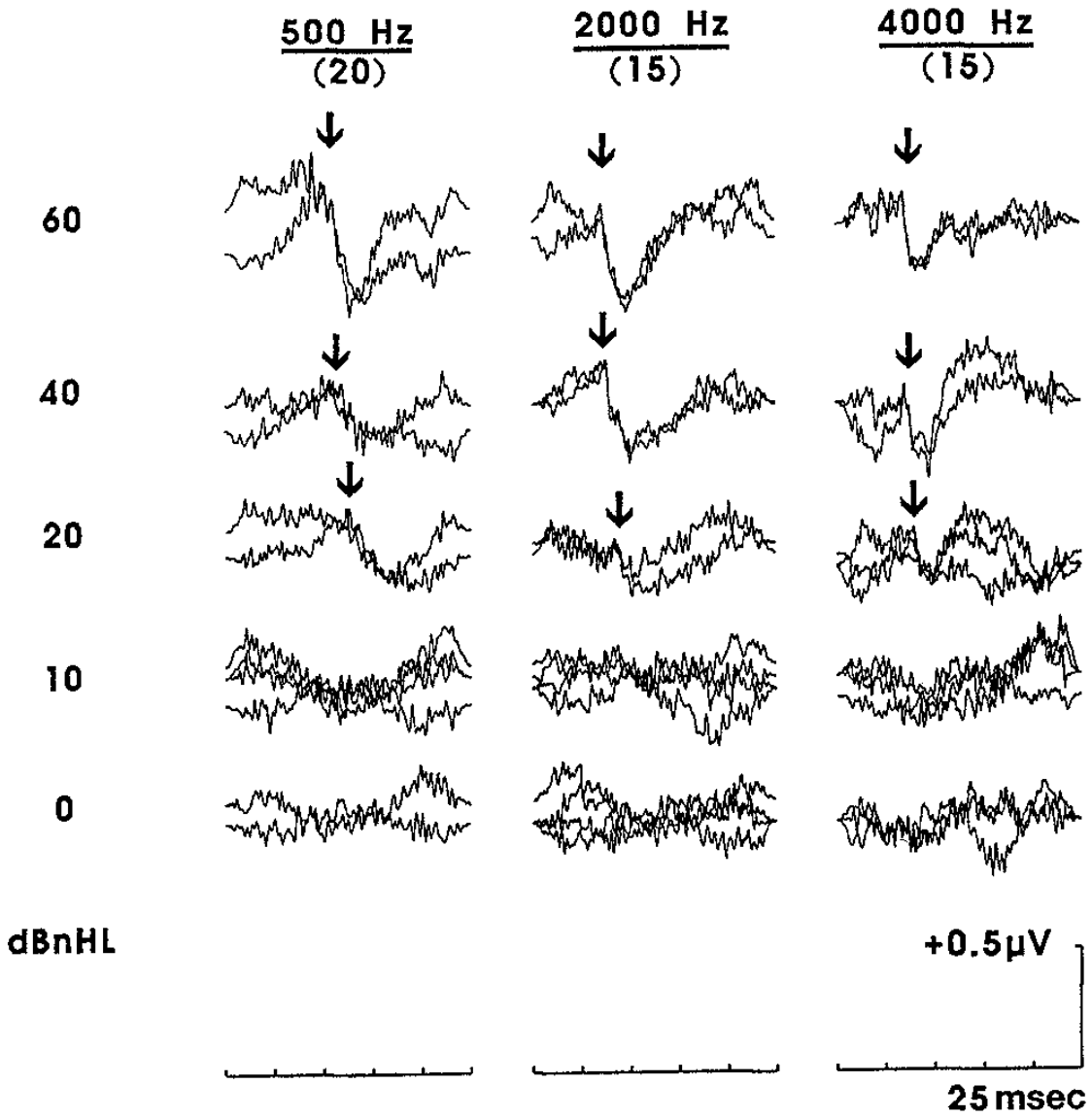
Recording

- electrodes
- time window
- bandpass filter
- number of averages
- number of repeats
- electrode positions
- number of channels
- number of repeats
- artifact reject
- gain/sensitivity
- notch filter

Recording Parameters

- Time window
  - 20-30 ms
  - Needs to be long enough to capture slow wave recovery ‘SN10’ (slow negative 10)
- Response filtering
  - Wide filter that includes low frequency energy in the response 30 - 3000 Hz
- Electrode montage
  - Vertex to enhance wave V
  - two channel for ABR to compare ipsi versus contra recordings

Tracking ABR response down to threshold

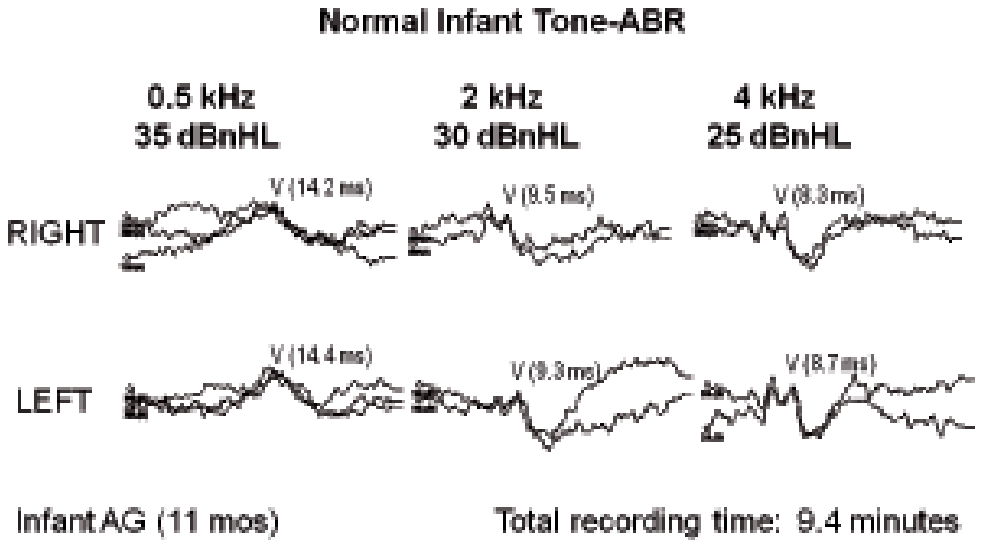


21 month old with normal hearing (behavioural thresholds at 24 months in parentheses)

Stapells et al (1995)

Janssen, Usher and Stapells (2010)

- examined several hundred ABR assessments, half of which showed normal thresholds
- average sedated sleep 58 minutes (7.6 measures)
- average non-sedated sleep 49 minutes (6.2 measures)



http://www.phonakpro.com/content/dam/phonak/gc_hq/b2b/en/events/2010/Proceedings/Pho_Chap_04_Stapells_final.pdf

Test first at levels where response is present in all infants with normal hearing: 35 dB nHL at 500 & 30 dB nHL at 1k, 2k, 4k Hz

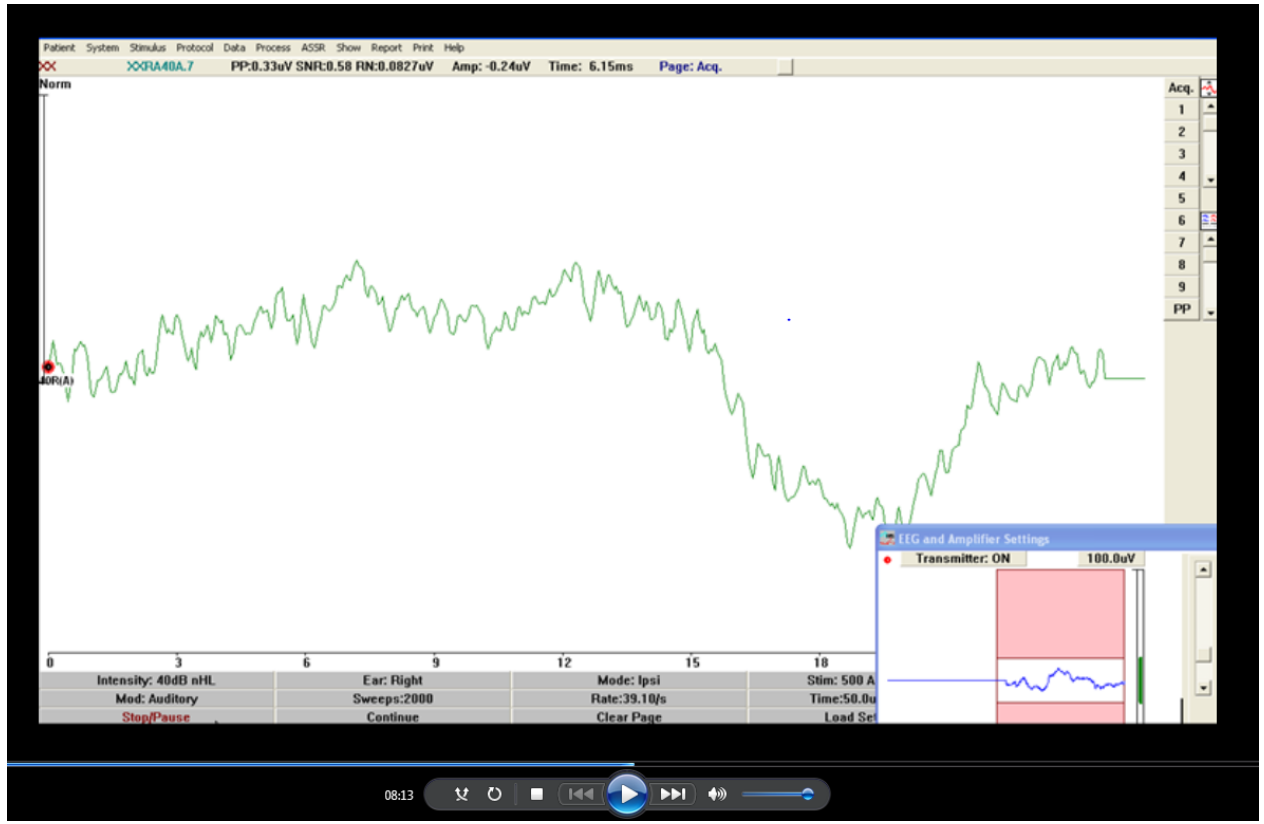
TABLE 3. Tone-ABR thresholds and detectability for normal-hearing group[a]

	Frequency (Hz)		
	500	2000	4000
Mean threshold (dB nHL)	23.6	12.9	12.6
SD (dB)	9.9	9.0	8.1
N	25	28	23
Detectability (in percent):			
≤10 dB nHL	12	50	52
≤20 dB nHL	52	96	100
≤30 dB nHL	92	100	100
≤40 dB nHL	100	100	100

[a] *Results from group with bilateral normal hearing, with data from only one ear per subject included.*

Stapells et al (1995)

Example: recording 500 Hz ABR using IHS equipment



Play video from 08:12 to 10:44

1. 40 dB nHL
2. 40 dB nHL
3. 50 dB nHL
4. 10 dB nHL

Note:

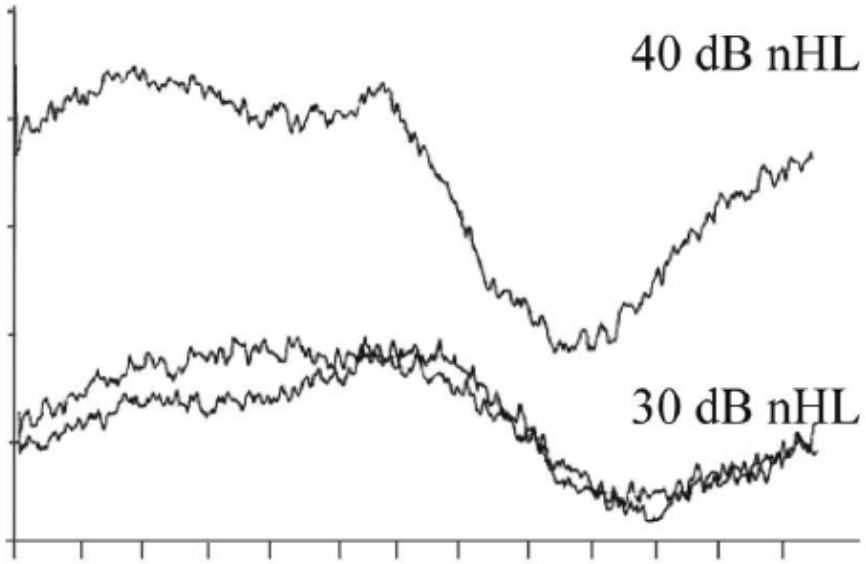
1. Replication
2. Growth
3. Baseline


Patient System Stimulus Protocol Data Process ASSR Show Report Print Help
XX
XXRA40A.7
PP:0.33uV SNR:0.58 RN:0.0827uV
Amp: -0.24uV
Time: 6.15ms
Page: Acq.
Norm
Acq.
1
2
3
4
5
6
7
8
9
PP
0
3
6
9
12
15
18
Intensity: 40dB nHL
Ear: Right
Mode: Ipsi
Stim: 500 A
Mod: Auditory
Sweeps:2000
Rate:39.10/s
Time:50.0u
Acquire
Continue
Clear Page
Load Se
EEG and Amplifier Settings
Transmitter: ON
100.0uV

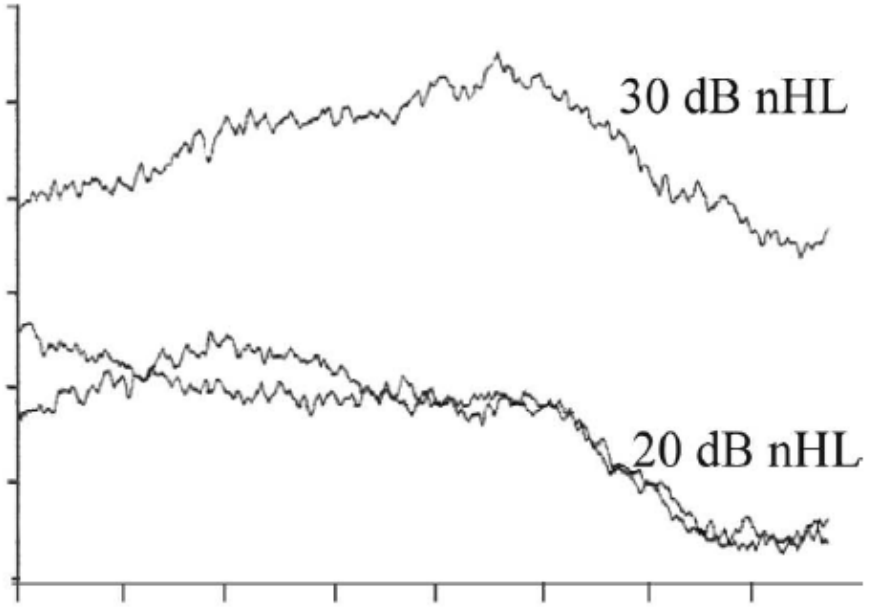
Choice of stimuli

- Unilateral refer: 2k, 500, 4k Hz, then test other ear
- Bilateral refer: 2k 1st ear, 2k 2nd ear, 500, 500, 4k, 4k

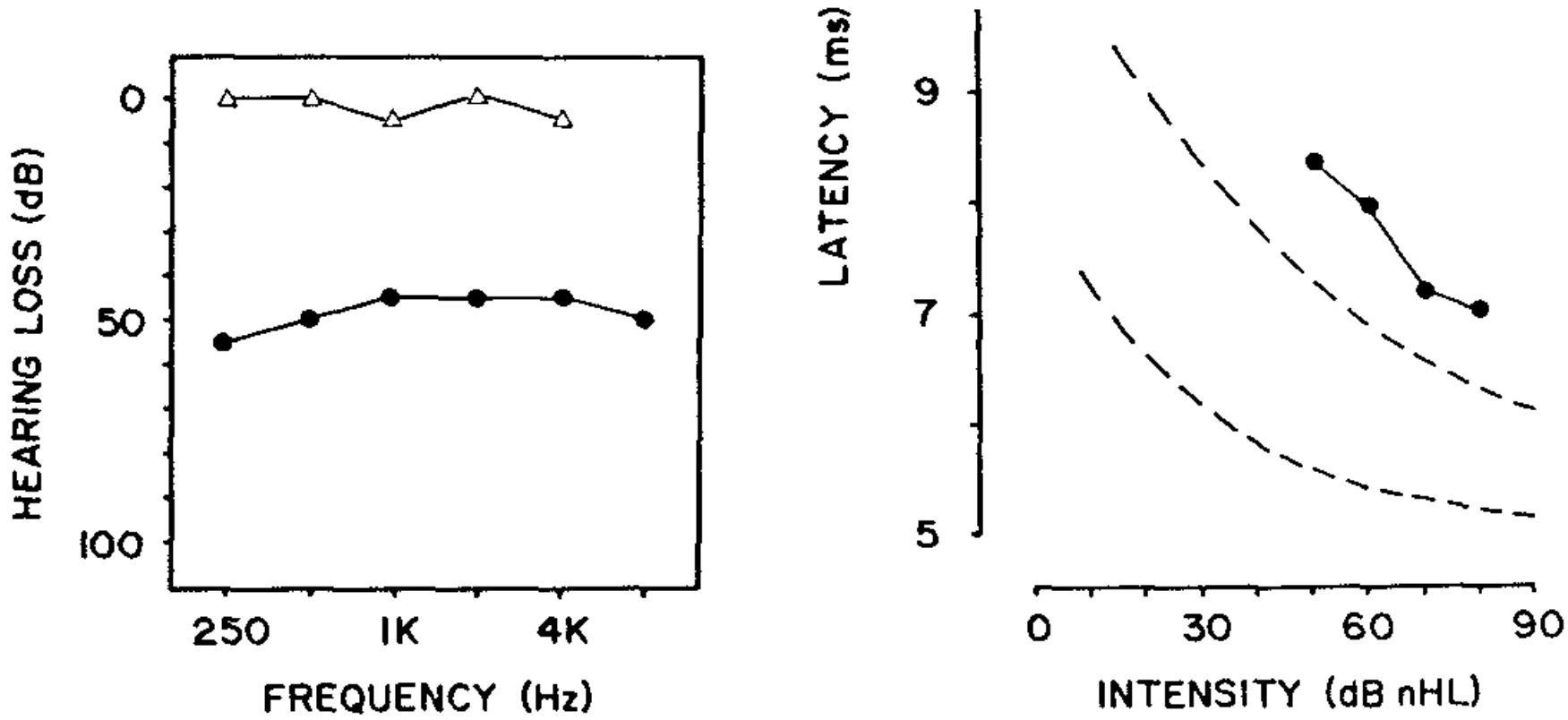
500 Hz toneburst



2000 Hz toneburst

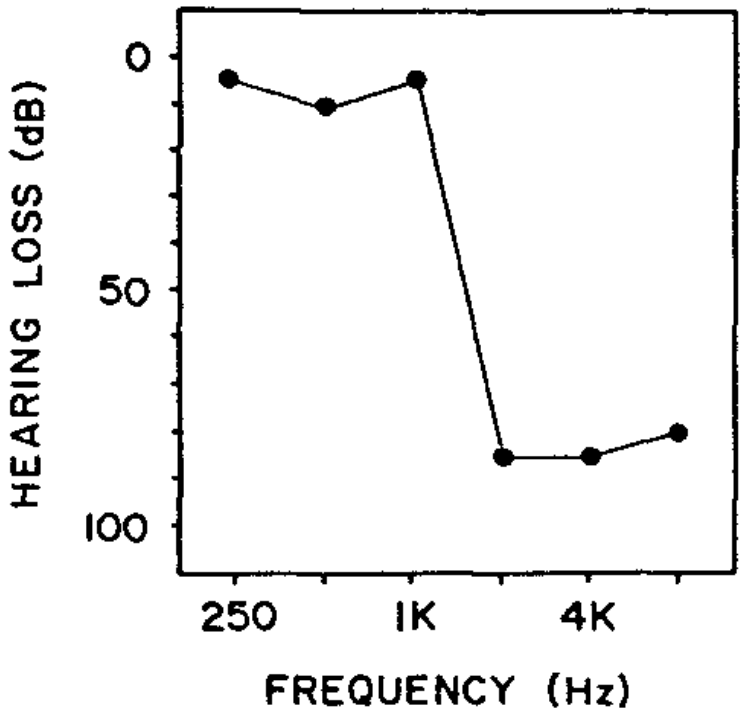


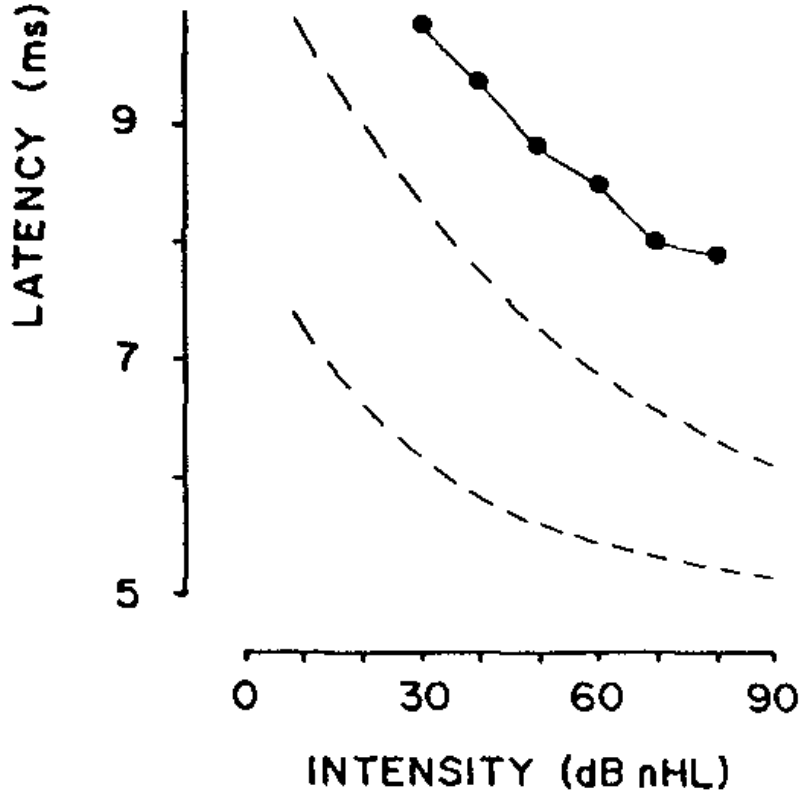
Conductive hearing loss – diagnosis should not be based on latency intensity function



Stapells et al (1985)

Steep high frequency SNHL – latency intensity function looks like a conductive loss





Stapells et al (1985)

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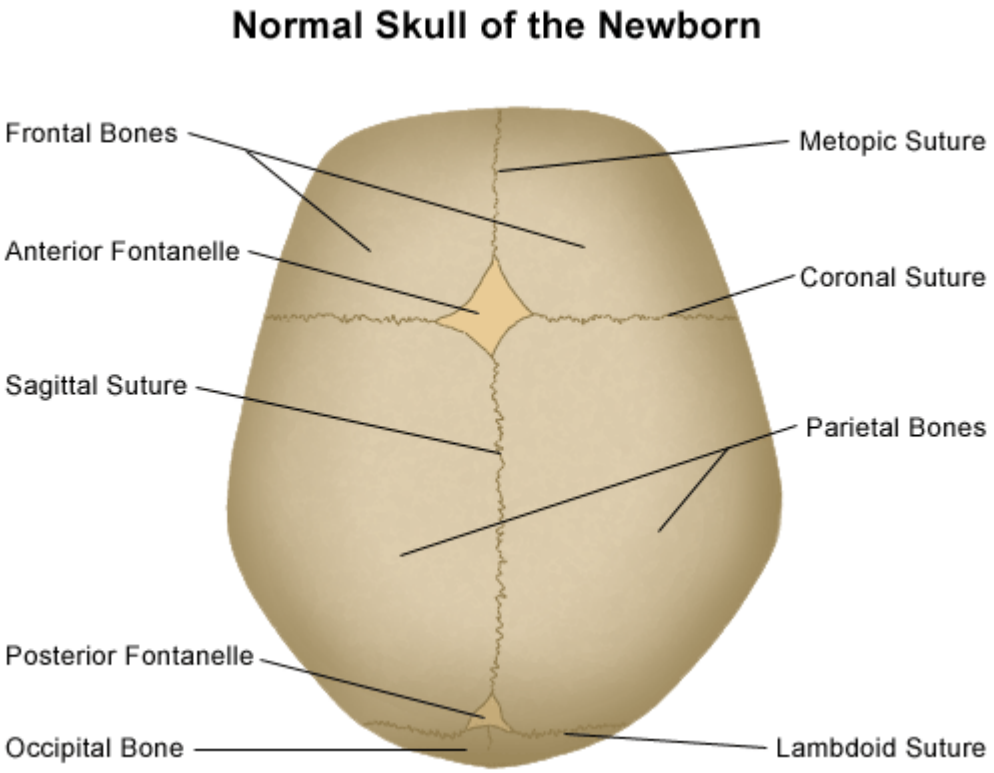
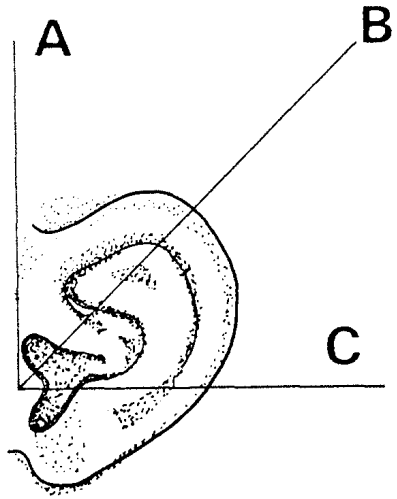
Conductive versus sensorineural hearing loss

- Immittance audiometry
- Bone conduction audiometry

Bone conduction toneburst ABR

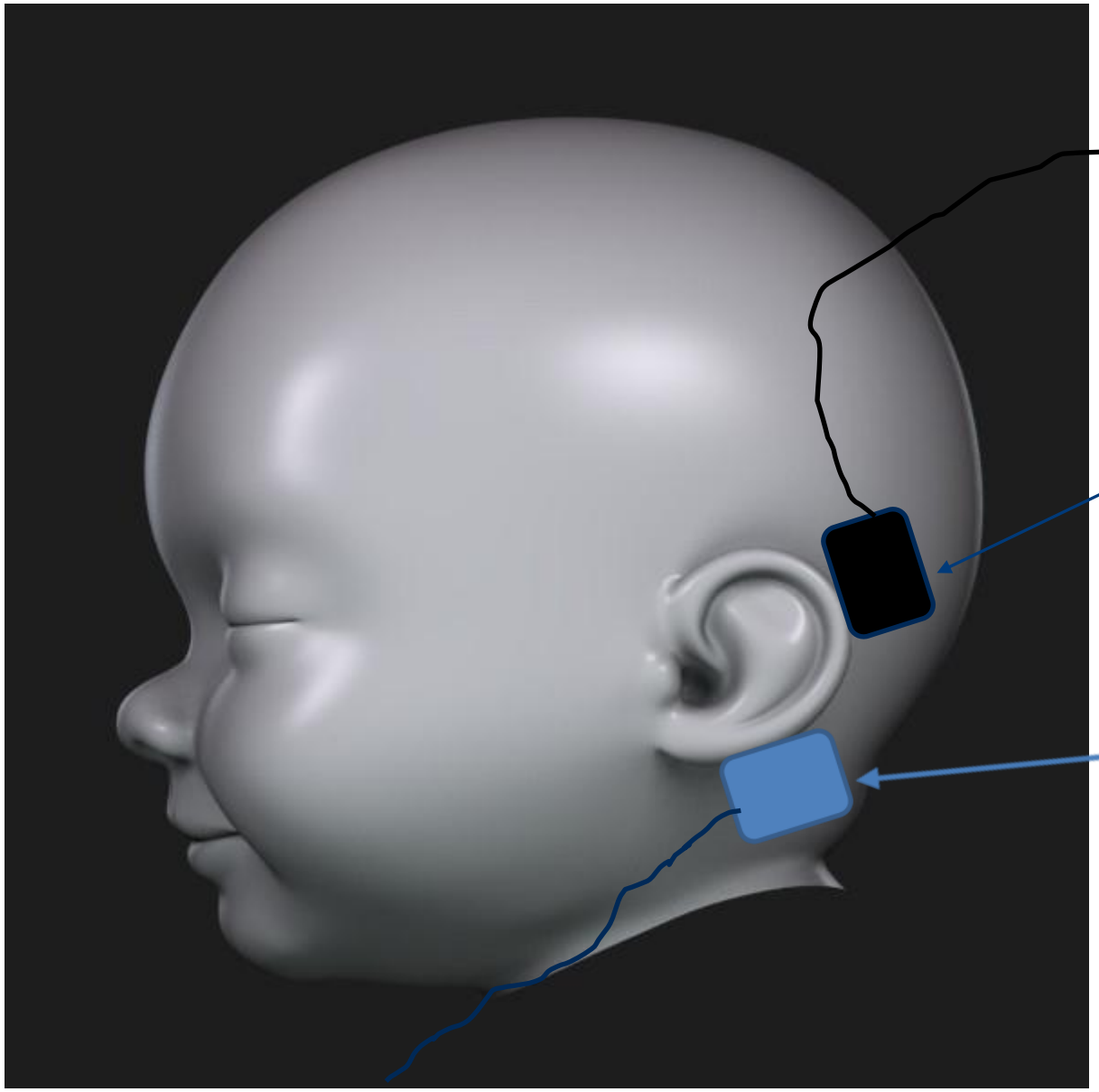




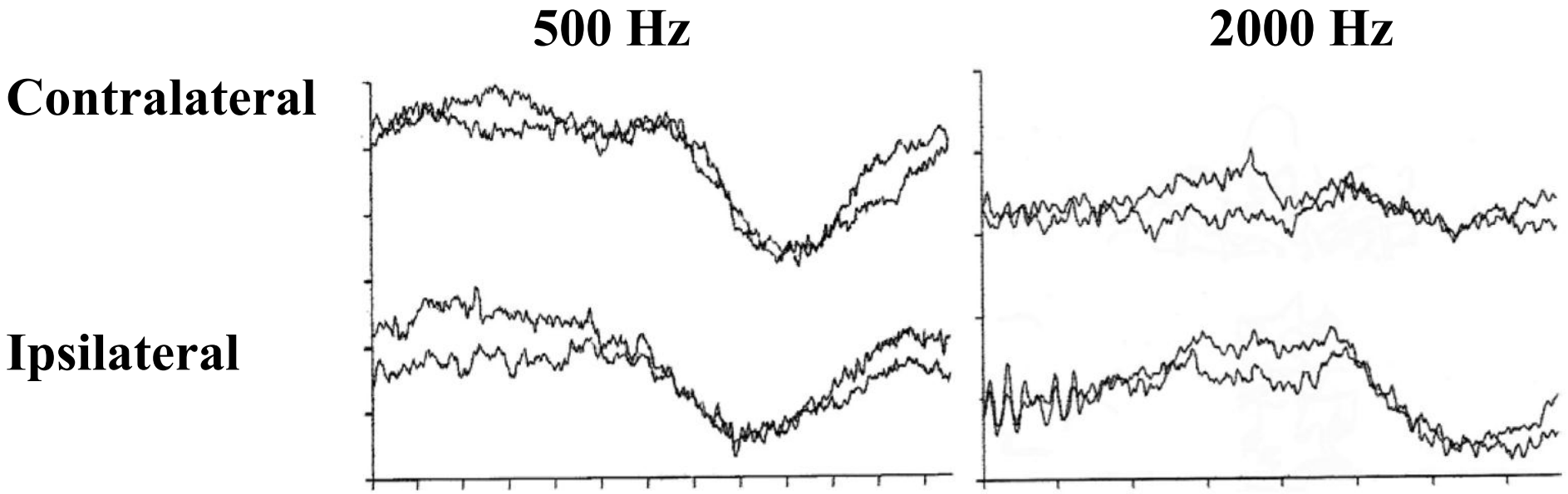
A : SUPERIOR
B : SUPERO-POSTERIOR
C : POSTERIOR

http://www.stanfordchildrens.org/en/topic/default?id=craniosynostosis-90-P02595

Stuart et al (1990)
Fox & Stapells (1993)


Bone vibrator
Electrode

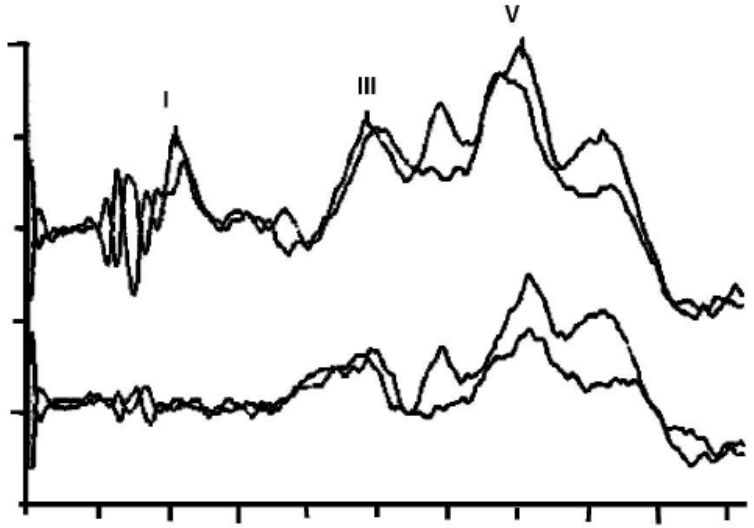
Bone conduction toneburst ABR: two-channel recording (reference to left and right mastoids)



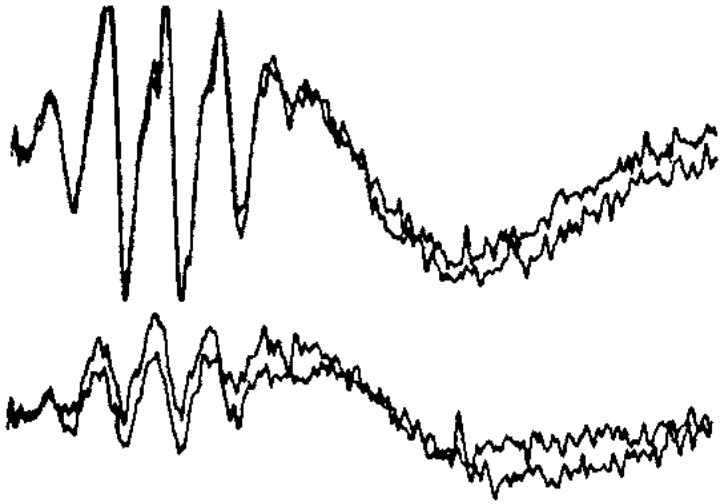
Purdy and Kelly 2014

Stimulus artifact

- Click has 100 μs duration – artifact very brief at beginning of trace
- 2-1-2 cycle (rise-plateau-fall) 500 Hz tonepip lasts 4-2-4 ms, artifact can contaminate first 10 ms of trace
- 2-1-2 cycle 2000 Hz toneburst lasts 1-0.5-1 ms, artifact can contaminate first 2.5 ms of trace
- early peaks prior to wave V difficult to identify if there is stimulus artifact – not a problem as the focus is on wave V



[air conduction click]



[bone conduction, 500 Hz]

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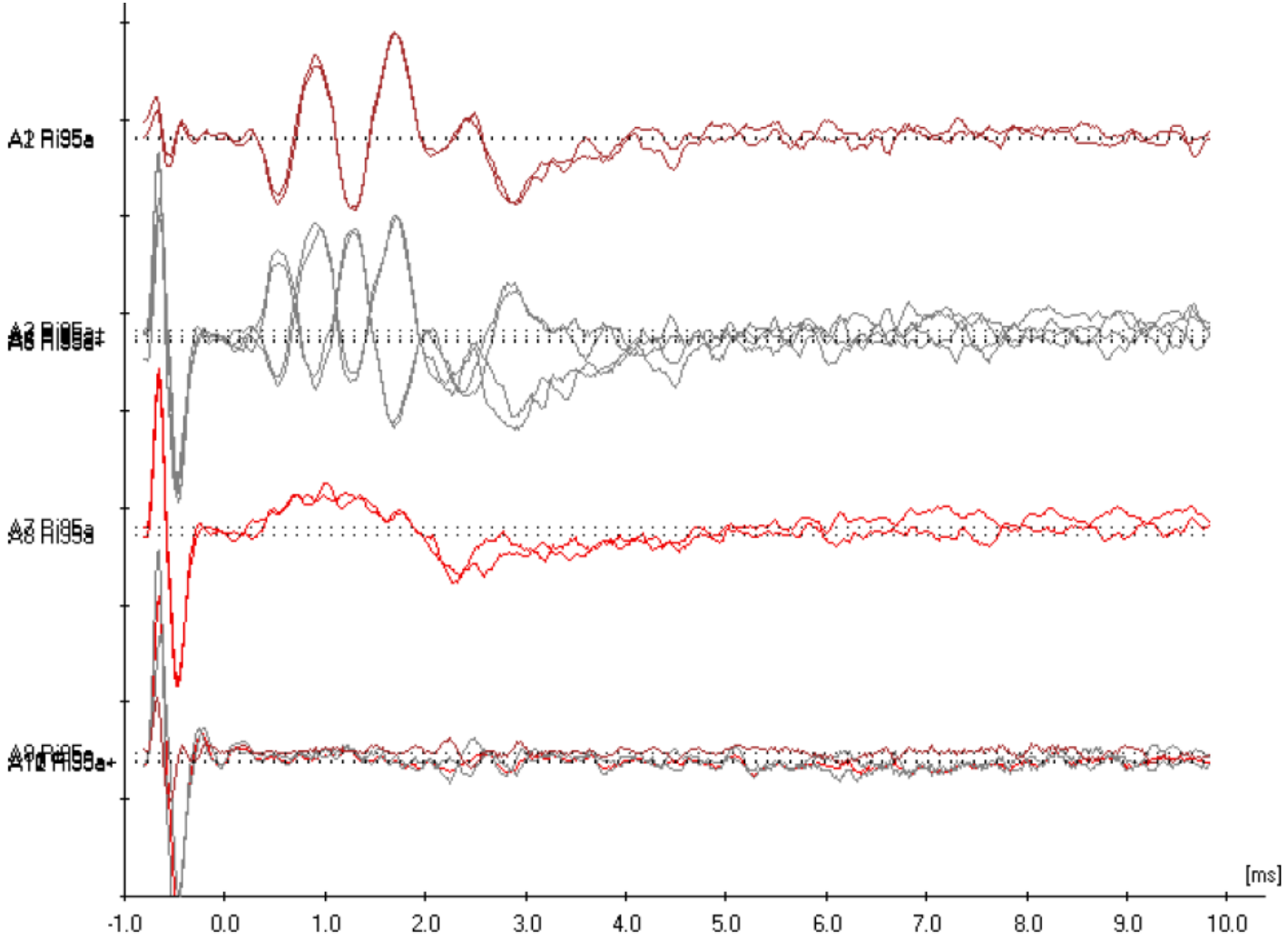
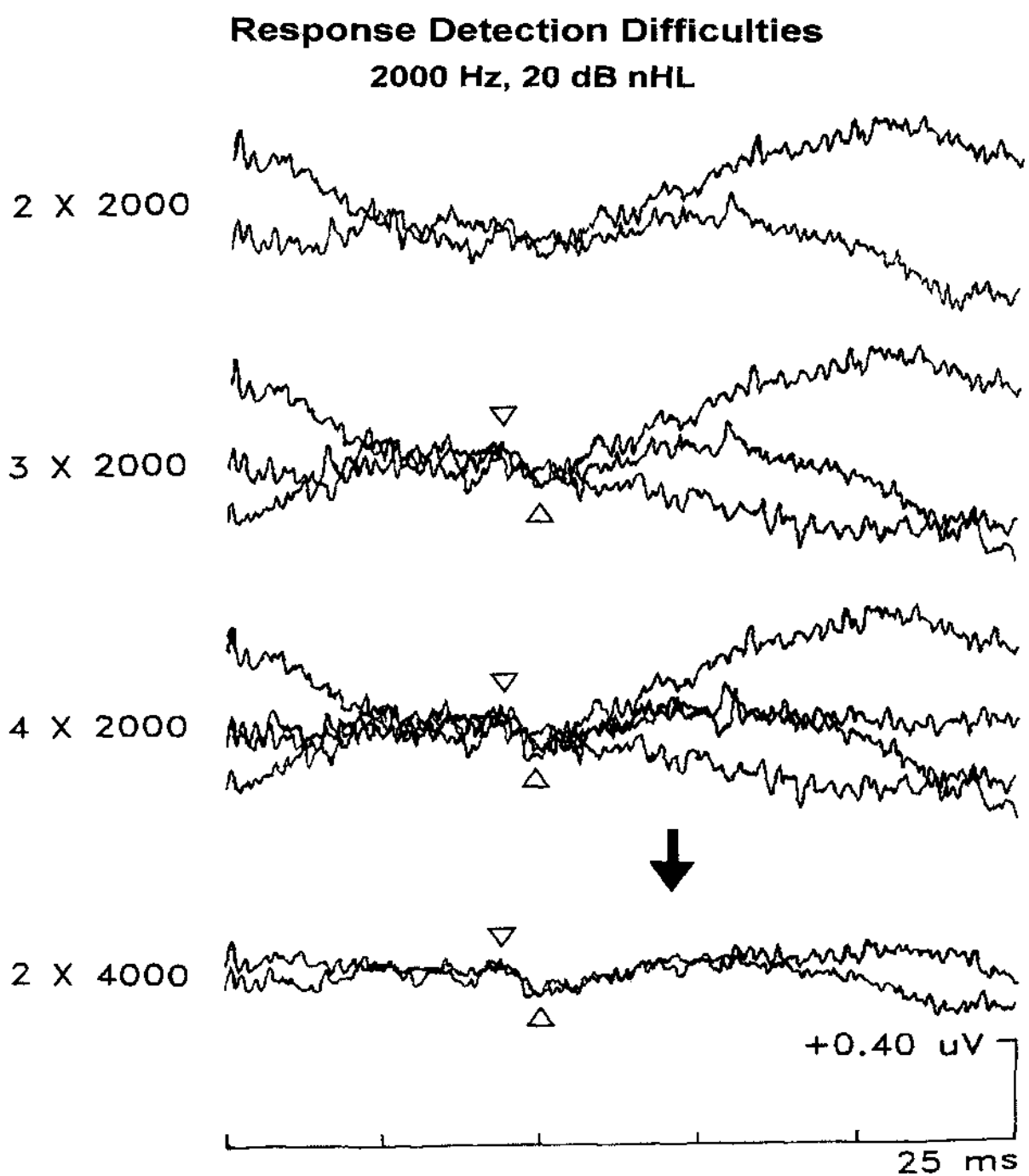
Stimulus artifact needs to be distinguished from cochlear microphonic





(Stapells 2000)

Considering the quality (noisiness) of the recording when making judgements about ABR presence

1. *United Kingdom guidelines*

Example of a clear response (*CR*), satisfying the 3 to 1 signal to noise criterion

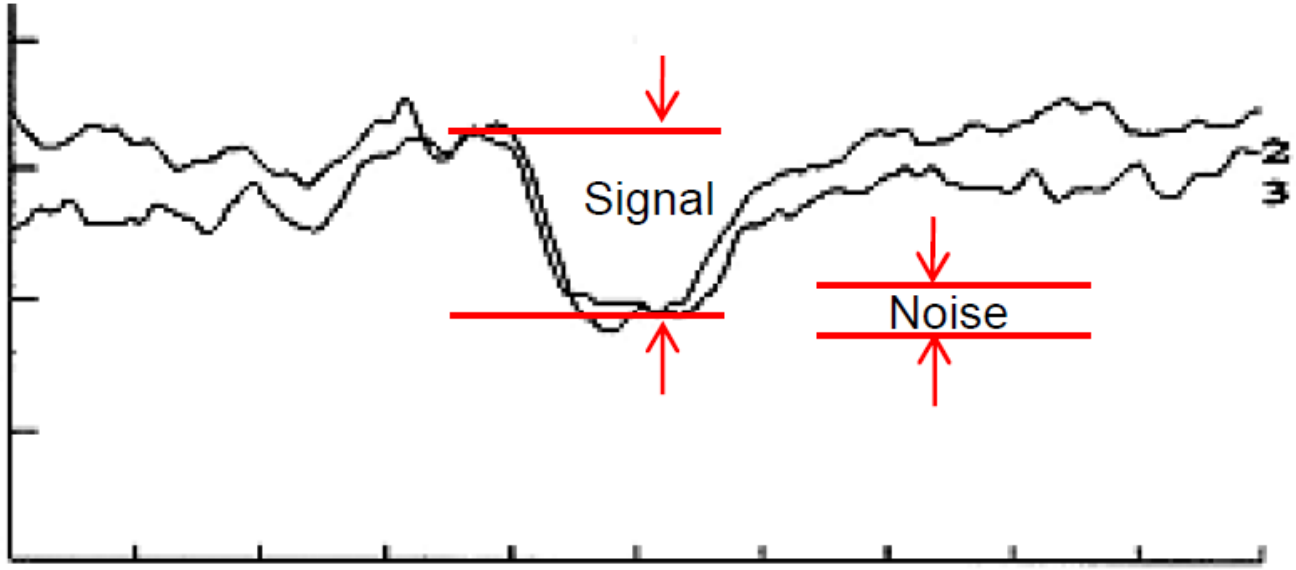
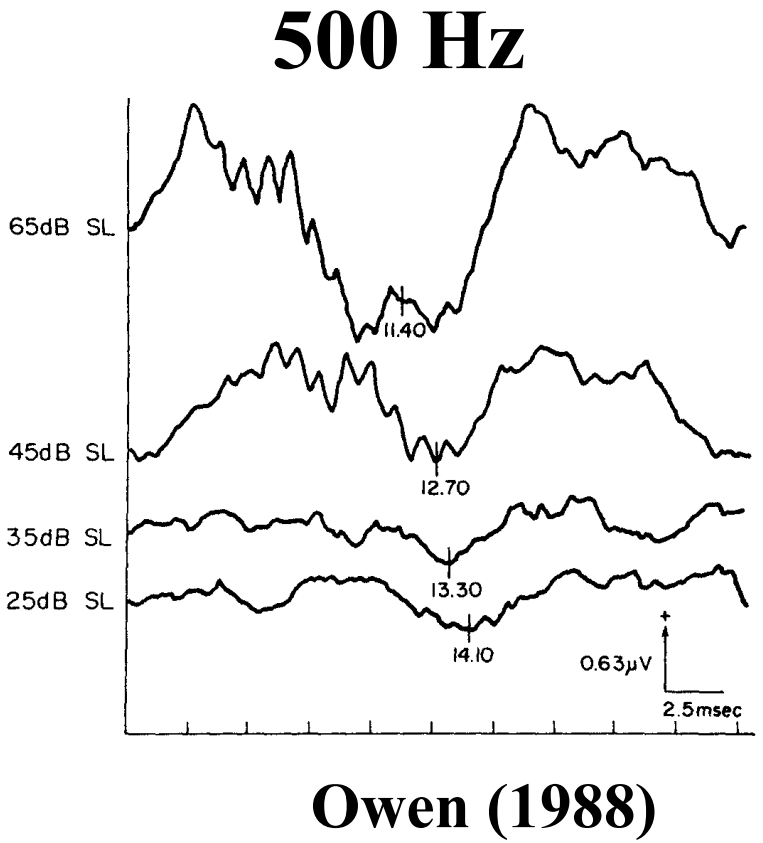


Figure 1

Scales:
150nV / div
2 ms / div

2. Ontario guidelines

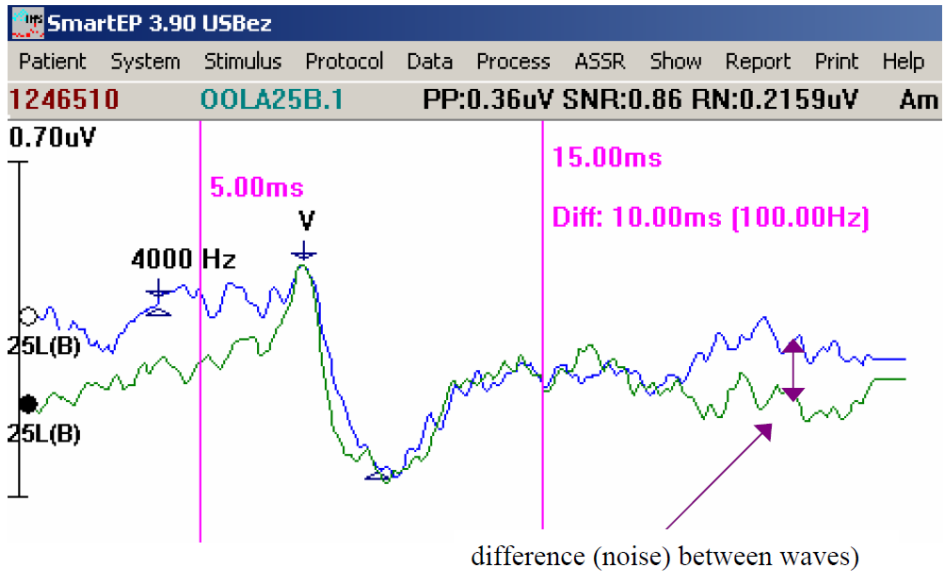
- response-positive decision may be made on basis of single average if **location & shape of the waveform are appropriate** AND the **presumed-response amplitude exceeds 250 nV** (half Y-axis mark) AND Residual Noise Level 40 nV or less.
- If any **residual noise level** (RNL) is less than 20 nV, given at least 2000 sweeps, a subjective decision about response presence or absence usually may be made with confidence.



Owen (1988)

3. British Columbia guidelines

- reasonable latency (depends on frequency and intensity)
- prominence of peak relative to fluctuations in the remainder of the average
- reproducibility
- peak-to-peak amplitude of supposed response to the residual noise level (should be 3-4 times size of residual noise)



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Calibration

ISO 389-6 standard describes method for electroacoustic and biological calibration

INTERNATIONAL STANDARD

ISO 389-6

First edition
2007-07-01

Acoustics — Reference zero for the calibration of audiometric equipment —

Part 6:
Reference threshold of hearing for test signals of short duration

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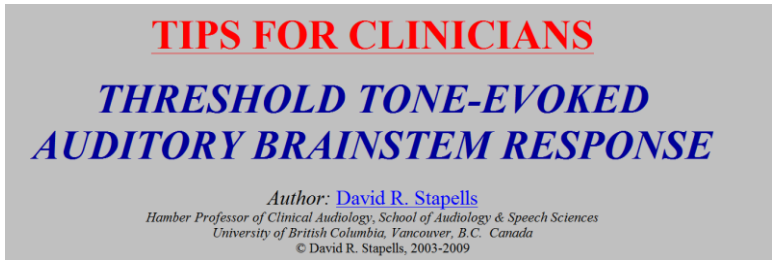
Calibration

- Regular calibration needed
- Use approved calibration facility to check peak to peak equivalent SPL – do not rely on default manufacturer settings without checking
- Normative reference threshold levels reported by Stapells http://www.courses.audiospeech.ubc.ca/haplab/ThreshABR.html


TIPS FOR CLINICIANS

THRESHOLD TONE-EVOKED AUDITORY BRAINSTEM RESPONSE

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- United Kingdom: NHSP Guidelines for ERA Equipment Calibration

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Estimating hearing thresholds from ABR thresholds *correction factor for little ears (≤3 months)

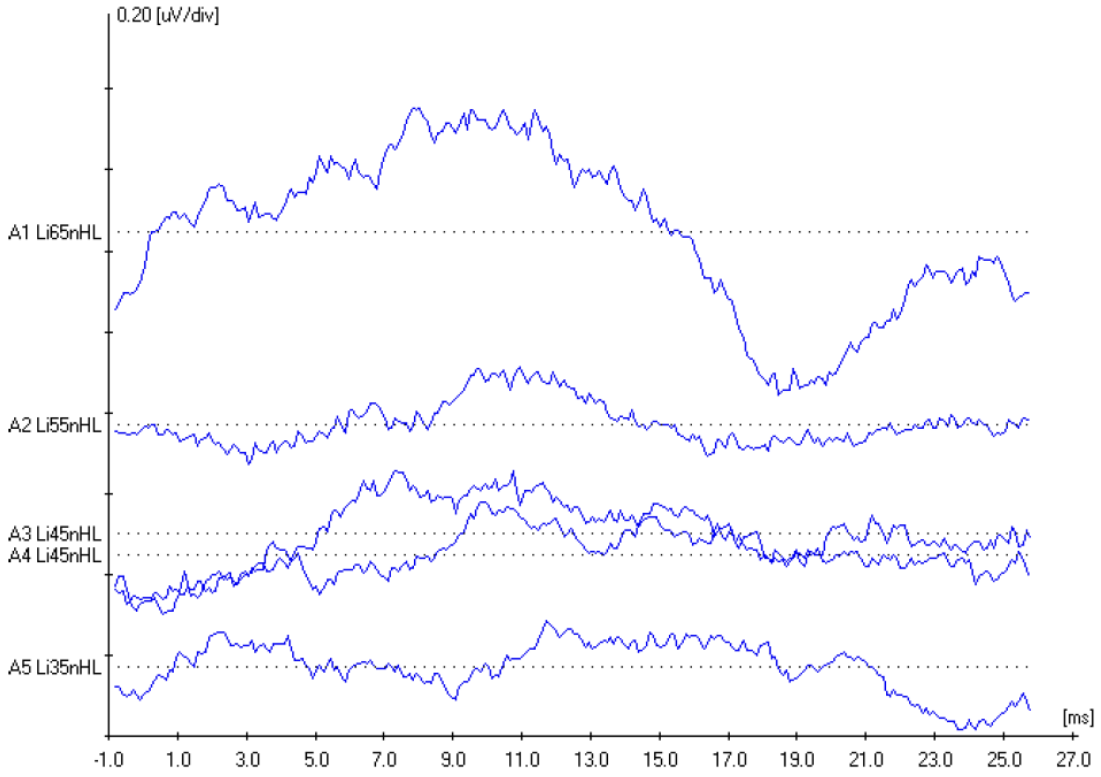
	500 Hz	1kHz	2kHz	4kHz	Units
ABR threshold	50	50	50	50	dB HL (dial)
Add 5 dB only for babies ≤ 3 months	55	55	55	55	dB HL
Correction factor to be subtracted*	*5*	*5*	*0*	*0*	*dB*
Estimated HL (HL)	50	50	55	55	dB eHL

* Subtract these values from air conduction ABR threshold in dB nHL to obtain eHL.

https://www.nsu.govt.nz/files/UNHSEIP-appendix-F-jun13.pdf

Questions to ask

- What frequency?
- Latency norms?
- System calibrated?
- Is Wave V present or is it noise?
- How old is child – what corrections needed to estimate dB eHL?
- Is this conductive or sensorineural?



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Conclusions

- If clinical guidelines are followed behavioural hearing thresholds can be reliably estimated from toneburst ABR thresholds for air and bone conduction
- Specialised training and supervision is recommended to ensure accurate results
- Partnerships between clinicians, calibration labs, manufacturers needed to ensure calibration is appropriate and standardised across clinics

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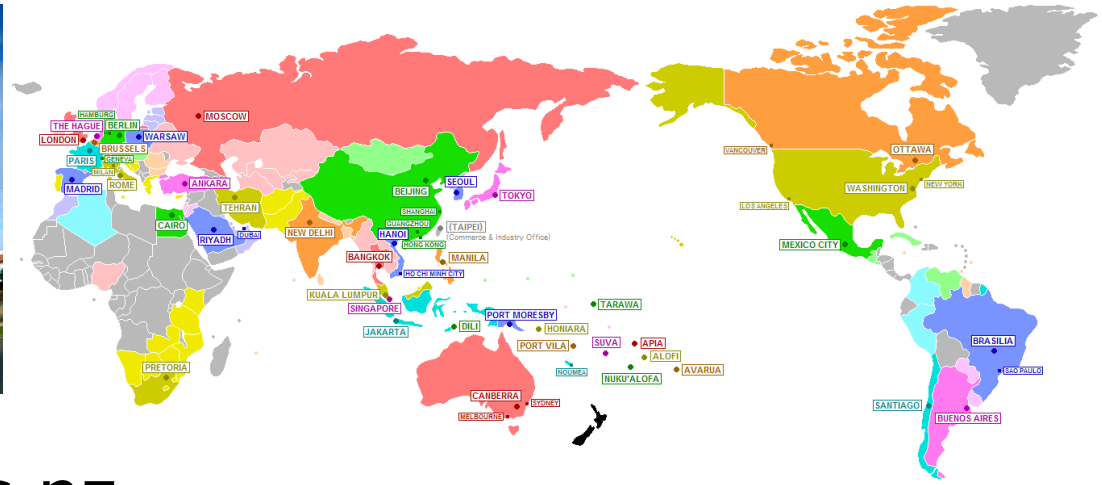
Thank you all for your participation today

謝謝你們今天的參與



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