ABR Evaluations:
Difficult Populations in Difficult Environments

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The History - 2003

• Infant Hearing and Screening Program
  – Improve standard of care for hospitalized infants
    • Add diagnostics and intervention to inpatient protocol
    • Adherence to EHDI/1-3-6 timeline
    • Carefully monitor children at risk for late onset and progressive loss (inpatient and outpatient basis)
  – Reduce LTF (Inpatient and Outpatient)
  – Compassion based care and counseling for families
The Good Times and the Bad
Comparison of Auditory Brainstem Response Systems in the NICU Population

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ABSTRACT

Completing auditory electrophysiologic recordings in preterm infants while in a NICU environment is a challenging procedure. Completion of a QI project can assist in determining whether investment in new technology is cost-effective. This project revealed that the Vivosonic Integrity obtained lower threshold levels in this noisy environment, and was comparable to the Bio-logic NavigatorPRO in classifying type and degree of hearing status.

INTRODUCTION

The Neonatal Intensive Care Unit (NICU) is an electrically hostile environment, with electrical signals in the frequency range of the Auditory Brainstem Response (ABR) which is much lower in the NICU environment, in the presence of noise sources. The NICU is also acoustically hostile, and the infant produces myogenic activity as well as respiration and vascular noise, which all can interfere with ABR recordings, particularly at low stimulus intensities.

METHODS

Participants: 28 infants tested in NICU with one or both instruments
20 ears provided click thresholds for both instruments
5 ears provided tone burst thresholds for both instruments at 1, 2, or 4 kHz

Hearing Status Categories (in ears):
- Normal = 11
- Mild = 6
- Moderate = 2
- Severe = 1
- Profound = 2

Procedures: All tests were performed by an audiologist with over 10 years of experience assessing infants in the NICU with threshold ABR. Thresholds were independently verified by a second investigator. ABR protocol for the two systems is as follows:

<table>
<thead>
<tr>
<th>Vivosonic Integrity</th>
<th>Bio-logic NavigatorPRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicks: 2000 Hz</td>
<td>Clicks: 2000 Hz</td>
</tr>
<tr>
<td>37.14 kHz Response Filter:</td>
<td>37.14 kHz Response Filter:</td>
</tr>
<tr>
<td>100-500 Hz</td>
<td>100-500 Hz</td>
</tr>
<tr>
<td>Tone: 4000 Hz</td>
<td>Tone: 4000 Hz</td>
</tr>
<tr>
<td>37.14 kHz Response Filter:</td>
<td>37.14 kHz Response Filter:</td>
</tr>
<tr>
<td>1000-5000 Hz</td>
<td>1000-5000 Hz</td>
</tr>
</tbody>
</table>

RESULTS

Mean Threshold (dB nHL)

Inter-Test Agreement for Bio-logic and Vivosonic:
- Within 10 dB: 15/20 (75%)
- >10 dB, less than 20 dB: 5/20 (25%)
- >20 dB: 0

Qualitative Advantages of Vivosonic Compared to Bio-logic:
- Reduction of electrical artifact
- Ease of achieving acceptable impedances
- Waveform integrity maintained with infant movement
- Ability to test in lighter sleep states compared to Vivosonic

Qualitative Disadvantages of Vivosonic Compared to Bio-logic:
- Inability to switch between ears during testing
- Lack of split screen option
- Need a better neonatal electrode – smaller with flexible material
- Need more options on protocol settings – starting intensity, timing, waveform selection after 30 zero intensity testing
- Cannot delete selected epochs of waves while testing
- Internally selected – both in protocol screen and test screen
- Lengthy software initialization

CONCLUSION

- the number of thresholds obtained for Bio-logic and Vivosonic were equivalent for clicks and tone bursts.
- Threshold averages were significantly better for the clicks using Vivosonic compared to Bio-logic. Similar trends were shown for tone bursts but not to small to show a difference.
- Correlation between Bio-logic and Vivosonic thresholds for clicks was high (R = .79).
- Majority of hearing status conclusions were within 10 dB (75%).
- 10-20 dB threshold differences occurred in 25% of ears.
- In 45% cases, Vivosonic showed lower (better) thresholds.
- Infants were in an NICU environment and thus limited time was available for full head to head comparison at all frequencies.
- Time and electrical artifact often precluded a full test with both instruments, therefore, head-head data on the same infant is limited.
- Bone conduction testing was lower priority due to environment and critical status.

ACKNOWLEDGEMENTS

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REFERENCES

There’s Got To Be A Better Way - 2011

• Head to head testing in NICU with standard signal averaging vs Integrity system (Kahlman weighting, Blue tooth technology, amplitrode)
• Thresholds were similar or better for clicks with Integrity
• Could obtain toneburst data with Integrity
• Excellent in electrically hostile environment with noisy infants
• Preferred old system for some “user issues” like printing waves
Introduction
The Joint Committee on Infant Hearing (JCIH 2007) recommends newborn hearing screening by one month of age, and access to intervention services by six months of age in order to maximize communication and educational capabilities.

Loss to follow-up (LTF) rates from newborn hearing screening (NHS) programs continue to be a challenge with only 45% of infants receiving a complete diagnostic evaluation by 3 months of age (CDC 2009).

Aim
The purpose of this quality improvement retrospective chart review was to:
1) determine what percentage of the time a complete ABR was obtained at the initial test session
2) identify LTF trends for infants requiring more than one ABR
3) determine the median age of definitive diagnosis for infants requiring more than one ABR evaluation
4) determine appropriate interventions to reduce LTF rates at this facility based on study findings

Method
The authors hypothesized that infants requiring more than one ABR appointment have higher than average LTF rates and receive a definitive diagnosis at greater than 3 months of age

- A chart review was completed for 764 infants who were referred to a large children's hospital audiology clinic due to abnormal NHS results
- Infants received ABR evaluations between May 2010 and May 2011
- ABRs were completed by audiologists experienced in evoked potential evaluations utilizing Biologic Navigator Pro ABR systems

Method (cont.)
- Charts were divided into the following categories:
  - normal hearing after initial ABR
  - permanent hearing loss after initial ABR
  - infants who required more than one ABR due to the following: poor sleep state, middle ear pathology, and technical difficulties or equipment malfunction
  - LTF rates were analyzed for each group requiring more than one evaluation.
  - Age of definitive diagnosis was analyzed for all infants

Results
After initial ABR evaluation:
- 72% of infants were found to have normal hearing
- 17% had suspected middle ear pathology with incomplete/inconclusive ABR results
- 9% of infants could not be evaluated due to poor sleep state
- 4% were identified with permanent hearing loss
- <1% had incomplete results due to equipment malfunction

Infants Requiring >1 ABR
- LTF 48%

Infants with poor sleep state (9%)
- 63% LTF rate for infants who did not sleep at first ABR
- Scheduling a follow-up appointment before the family left the audiology clinic significantly reduced the LTF rate

Technical Difficulties or Equipment Malfunction (<1%)
- LTF 50%

Age of Definitive Diagnosis
- Infants requiring more than one ABR
  - >3mo at age of diagnosis = 41%
  - Median age = 6 months
  - Range = 2 to 13 months
- Infants with complete evaluation at initial ABR
  - >3mo at age of diagnosis = 8%
  - Median age = 1 month
  - Mean age = 1.4 months
  - Range = 2 weeks to 4 months

Results (cont.)
Infants with middle ear pathology (17%)
- 45% LTF rate
- LTF rates were higher, 68%, if the ABR was not attempted due to suspected middle ear pathology (flat tympanograms) compared to 32% LTF when ABR was attempted
- LTF rates were significantly reduced when a follow-up appointment was scheduled before the family left the audiology clinic

Quality Improvement
Interventions:
- Audiologists educated regarding LTF rates for infants with incomplete ABR evaluations at first appointment
- Follow-up appointments scheduled before the family leaves the clinic for all infants who do not sleep for first ABR
- ABR attempted for all infants at first visit regardless of tympanometry results and middle ear status
- Bone conduction ABR or a statement as to why it could not be completed included for all abnormal ABRs
- Parents receive written results and recommendations for all incomplete/abnormal ABRs

Follow-up Data
Chart review completed for infants receiving ABR evaluations following QI Interventions (n=75)
- 91% of infants normal at first evaluation
- 4% with definitive diagnosis of SNHL or CHL at initial ABR
- 3% Undetermined type of HL (follow-up scheduled)
- 1% ABR not attempted due to poor sleep state (LTF at this time)

Conclusions
The results of this study indicate the following:
- LTF rates for infants requiring more than one ABR test session are higher than the national average (48% vs. 45%)
- 41% of infants in this group are greater than 3 months of age at diagnosis
- Scheduling a follow-up appointment for the family before they leave the audiology clinic reduces loss to follow-up rates
- Attempting an ABR even when middle ear pathology is present improves LTF rates
- QI studies can be effectively utilized to identify and ameliorate weaknesses in clinic procedures that contribute to increased LTF rates

References
3. May 2010 and May 2011
4. May 2010 and May 2011

Acknowledgements
We wish to acknowledge Dora Murphy and the audiologists at CCHMC for their assistance and support of this project
2011 Outpatient Quality Review

The Effects of Inconclusive ABR Results on Loss To Follow Up

• ABRs at six outpatient centers (n=764)
• 9% did not achieve adequate sleep state (standard signal averaging) (n=71)
• 63% of those were lost to follow up
• 17% had suspected fluid with incomplete ABR due to inability to complete BC ABR
• 45% of these were lost to follow-up
• For infants needing more than one, ABR average age of ID for PHL was 4.3 months
2014 Outpatient Quality Review

• 3 Outpatient Centers utilizing standard signal averaging
• 3 Outpatient Centers utilizing Vivosonic Integrity
• n=274
• Standard Signal Averaging
  – 11% incomplete due to sleep or no BC
• Vivosonic
  – 2% incomplete due to infant state
Case Studies
Case #1: Multiple Risk Factors

- Infant Boy born at 35 weeks gestation
- Congenital Diaphragmatic Hernia (CDH)
- ECMO (7 day cannulation)
- Congenital CMV
- Pulmonary hypertension
- Multiple courses of gentamicin, lasix, and valgancyclovir
- Tested at 48 weeks AA / 3 months CA
Case #1:

- Click 60 dBnHL
- 4KHz 20 dBnHL
- 520 Equivalent Sweeps

RN = 0.86
Case #1

1040 Sweeps

RN = 0.025  CC = 0.54
Case #1

4512 Sweeps

RN = 0.014  CC = 0.71
Case #1:

2KHz at 20 dBnHL
1432 Sweeps

RN = 0.16  CC = 0.71
Case #1:

1000 Hz at 25 dBnHL
3096 Sweeps
Case #1:

500 Hz at 30 dBnHL
2544 Sweeps
Case #1:

Time Study

- Awake but quiet, calm baby
- Click and 4 frequencies
- Screen shots
- 24 minutes
Case #1: The Baby Who Won’t Sleep

- A sleeping baby is **ALWAYS** best!
- Patience!! Avoid the temptation to accept noisy waveforms.
- Longer averaging and longer test time
- Utilize residual noise measurement and correlation coefficient to verify visual identification of waveform
- Look at the EEG not the baby!!!
Case #1: The Baby Who Won’t Sleep

Please, please, please don’t take garbage!!

Use all of the tools available: latency norms, residual noise, correlation coefficient!!!
Case #1: The Baby Who Won’t Sleep

Please, please, please
Don’t try to cheat
the correlations!!
Case #2: Bone Conduction ABR

- Infant Girl
- Born at 36 weeks GA
- Treacher Collins Syndrome
- Micrognathia
- Bilateral aural atresia
- Tested at 37 weeks GA
Case #2: Bone Conduction ABR

- CT scan of IAC
- **Bilateral Enlarged Vestibular Aqueducts**
Case #2: Bone Conduction ABR
Case #2: Bone Conduction ABR
Case #2: Bone Conduction ABR

Because the latencies and amplitudes are the same, you can be sure that both are ipsilateral recordings.
Case #2: Bone Conduction ABR

4000 Hz BC Ipsi
Contra

1000 Hz BC Ipsi
Contra
Case #2: Bone Conduction ABR

- Superior posterior placement
- Alternating polarity
- Mask, utilize second channel, or obtain a wave I to know response is from the ipsilateral side
Case #3: Brainstem Dysfunction

- Infant Boy
- Born at 33 weeks GA
- Dandy Walker Malformation
- Severe brainstem and cerebellar hypoplasia
- Lissencephaly
  - “Smooth brain”
- Neurosurgery requested a brainstem study
- Infant intubated and on bili lights
- No gag reflex or purposeful movement
Case #3: Brainstem Dysfunction
Case #3: Brainstem Dysfunction

- Utilized a 7.6 click rate
- Delayed wave I in left ear only at 80dBnHL
- Flat tympanograms bilaterally
- Absent DPOAEs bilaterally
- Severe brainstem dysfunction and possible cochlear hearing loss
Case #3: Brainstem Dysfunction

• Don’t waste time chasing tone burst thresholds on infants with brainstem dysfunction!!!
• Always assess neural transmission in NICU infants. Especially infants with myelomeningocele, hydrocephalus, IVH and VP shunts!!!
• Don’t forget to slow down the click rate
• OAEs will be critical in these cases
• If neural component is going to resolve, will typically see normalized ABR about 8 weeks post shunt.
• This is not ANSD!!!
Case #4: Monitoring of Older Infants

- Infant Boy
- Born at 36 weeks gestation
- Presented to ED in January 2015
- Low grade fever x 4 days
- Poor weight gain
- Neuromuscular weakness, respiratory distress
- Imaging revealed multiple brain tumors
- Diagnosed as CNS Atypical teratoid/rhabdoid tumor
Case #4: Monitoring of Older Infants

- ATRT is a rare aggressive brain tumor occurring most often in children under age 3
- Tumor resection followed by chemotherapy
Case #4: Monitoring of Older Infants
Case #4: Monitoring of Older Infants

• Always worth it to attempt natural sleep with older children who can’t/won’t complete behavioral testing.
• Always risks with anesthesia.
• Careful counseling with parents. Everyone must be on the same page.
• Will not always be successful.
• Distractors critical (iPad, quiet toys, books, pictures, games on cell phone).
Take-home Message

• ABRs must be accurate!!
• Don’t be tempted to take garbage!!
• Utilize all available tools for cross check of thresholds
• Don’t over manipulate the correlations!!
• Not all children will be able to be tested without sedation/anesthesia, but it should be utilized as an absolute last resort!!
Lessons Learned

- Audiologists don’t like change in general
- Have to utilize technology that provides the best outcomes for patients vs what is comfortable
- Training is KEY
- Need manufacturers that will work with us