Validity of various methods of pure tone audiogram averaging in diagnosing hearing impairment in a hearing conservation programme

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Introduction

• Noise-induced hearing loss (NIHL) is a permanent, non-reversible occupational disease which affects nearly 16% of workers in Malaysia. As there is currently still no treatment for NIHL, the mainstay of its management is prevention, structured over the years into a comprehensive hearing conservation programme (HCP). One of the main components of the hearing conservation programme is the annual pure tone audiogram (PTA), designed to detect workers with NIHL early and to subject them to subsequent interventions that hopefully might arrest the progression of further deterioration of the hearing thresholds.
DIAGRAMMATIC REPRESENTATION
OF COMMON SOUNDS

FREQUENCY (Hz)

INTENSITY (dB HL)

Whisper
Normal Speech
Shout
Painfully Loud
Objective

• To calculate the
  – sensitivity
  – specificity
  – positive predictive value
  – negative predictive value

of the current methods of calculating PTA average from PTA thresholds obtained via HCP
Methodology.. (cont.)

- Cross sectional study: workers from palm-oil mills around Kuantan
- Calculated sample size: 300 workers
- Study period: from June 2010 – September 2011
- Sampling technique: purposive sampling
- They were subjected to
  - interview questionnaire
  - otoscopic examination
  - tympanometry (GSI Tympstar)
  - diagnostic pure tone audiometry (DOSH-certified sound-proof room ANSI 20, GSI 61 with TDH 39 head-phone and bone-transducer).
Methodology..(cont.)

• Exclusion criteria
  – No consent
  – Workers with conductive hearing loss
  – Workers with PTA configurations suggestive of other underlying causes of sensorineural hearing loss
  – Female (only one – odd job) as the operative workforce in the palm-oil mills are exclusively male
Methodology..(cont.)

• The PTA averages that are used for analysis include:
  – 0.5, 1, 2 and 3 kHz (used currently by DOSH)
  – 0.5, 1, 2 and 4 kHz (used currently by the Irish)
  – 1, 2, 3 and 4 kHz (used currently by BSA)
  – 2, 3 and 4 kHz (used currently by DOSH to define standard threshold shifts, where an average shift of more than 10 dB cf to baseline audiogram)
Proper instruction is VERY important
Proper placement of the head-phone is also important.
Methodology..(cont.)

- The right and left ear is considered individually.
- Each of the PTA configuration is then analysed clinically and a diagnosis of either normal hearing or NIHL is made.
Severity of Hearing Loss

- Normal ± 20 dBHL
- Mild 21 – 40 dBHL
- Moderate 41 – 70 dBHL
- Severe 71 – 90 dBHL
- Profound > 90 dBHL

- Nb – cf to DOSH’s criteria (average of 0.5, 1, 2, 3 kHz > 25 dBHL – hearing impairment)
Diagnosis of NIHL

- History of loud, chronic* exposure to noise of > 85 dBA
- SNHL
- Typically bilateral
- Notch around the 4kHz region
NIHL – how long is ‘chronic exposure’

- Pathophysiologically
  - Apoptosis was noted in animal subject as early as 20 days after exposure
  - In humans, evidence of NIHL (noise notch) was noted as early as 6 weeks post exposure

- Legally
  - 6 months into the occupation*
  - Not stated in black and white [not in FMA (noise regulations) 1989]
Diagnosis of NIHL

- History of loud, chronic* exposure to noise of > 85 dBA
- SNHL
- Typically bilateral
- Notch around the 4kHz region
WORKER'S BIODATA
Name of Employee: Operation
Name of Employee: 
Workstation: Operation
Employment Date: 06/07/2002
Work Duration: 5y 7m 27d

Date of Birth: 07/02/1969
Age: 48y 5m 26d
Gender: Male
IC No.: 590657-11-3321
Designation: Operator

TECHNICAL DATA
Audiometer: Amplifon Italy
Serial Num: MA310046004
Model: Amplaid A311
Calibration Date: 29/01/2008
Max Level: 120dB

HISTORY
Past Medical History: Nil
Present Medical History: Nil
Personal Hobbies: Nil
Drugs/Protective Equipment: Ear plug

SOUND LEVEL METER
Sound Level Meter: Larson- Davis
Model: 824
Calibration Date: 11/12/2007
Serial Num: 0858

Average Hearing Level
Left: 34.5 dBHL
Right: 13.5 dBHL
Test Date: 29/01/2008

Background Noise Levels in Audio Test Room:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Level</td>
<td>20</td>
<td>18</td>
<td>18</td>
<td>16</td>
<td>14</td>
<td>18</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

PURE TONE AUDILOGRAMS

No baseline established as yet

PTA configuration is suggestive of established NIHL.
PPE is advocated. Yearly audiogram is recommended.

Tested By: June Asmanita
Reviewed By: 

LOSS (NIHL)
I-IUM HEARING CONSERVATION PROGRAM

WORKER'S BIODATA
Name of Employee: [Redacted]
Name of Employee: [Redacted]
Workstation: Operator
Employment Date: 05/07/2002
Work Duration: 5y 7m 27d

Date of Birth: 07/08/1969
Age: 48y 6m 26d
Gender: Male
IC No: 590307-11-5021
Designation: Operator

TECHNICAL DATA
Audiometer: Amplifon Italy
Serial Num: MIA3110046004
Model: Amplaid A311
Calibration Date: 29/01/2008
Max Level: 120dB

HISTORY
Past Medical History: Nil
Present Medical History: Nil
Personal Hobbies: Nil
Drugs/Protective Equipment: Ear plug

SOUND LEVEL METER
Sound Level Meter: Larson- Davis
Model: 824
Calibration Date: 11/12/2007
Serial Num: 0856

AVERAGE HEARING LEVEL
Test Date: 29/01/2008

Background Noise Levels in Audio Test Room:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>250</th>
<th>500</th>
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<th>2000</th>
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<th>4000</th>
<th>6000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Level</td>
<td>20</td>
<td>18</td>
<td>16</td>
<td>16</td>
<td>14</td>
<td>18</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>

PURE TONE AUDIOGRAMS

No baseline established as yet

Results: Annual
Baseline

Tested By: June Asmanita
Reviewed By: [Signature]
Results
The total number of workers selected as sample is 300. The average age of the sample is 37 years old with the eldest being 55 years old and the youngest 19.
Summary of the **clinical diagnosis** of the workers’ pure tone audiogram is as shown below:

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>338</td>
<td>56.3</td>
</tr>
<tr>
<td>NIHL</td>
<td>262</td>
<td>43.7</td>
</tr>
<tr>
<td>Total</td>
<td>600</td>
<td>100</td>
</tr>
</tbody>
</table>
Calculation of the sensitivity and specificity of each PTA averaging method in NIHL screening is shown in the table below. Mc Nemar’s test done shows that there are significant differences in the proportion of pass and refer cases between PTA and the different methods of PTA averaging techniques used.

<table>
<thead>
<tr>
<th>PTA from clinical diagnosis</th>
<th>Normal / negative (n=168)</th>
<th>NIHL / positive (n=132)</th>
<th>Total</th>
<th>McNemar’s p-value</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass / negative</td>
<td>338</td>
<td>196</td>
<td>534</td>
<td>&lt; 0.001</td>
<td>25.2%</td>
<td>100%</td>
<td>100%</td>
<td>63.3%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>66</td>
<td>66</td>
<td></td>
<td>0%</td>
<td>25.2%</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Pass / negative</td>
<td>338</td>
<td>163</td>
<td>501</td>
<td>&lt; 0.001</td>
<td>37.8%</td>
<td>100%</td>
<td>100%</td>
<td>67.5%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>99</td>
<td>99</td>
<td></td>
<td>0%</td>
<td>37.8%</td>
<td>16.5%</td>
<td></td>
</tr>
<tr>
<td>Pass / negative</td>
<td>338</td>
<td>138</td>
<td>476</td>
<td>&lt; 0.001</td>
<td>47.3%</td>
<td>100%</td>
<td>100%</td>
<td>71%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>124</td>
<td>124</td>
<td></td>
<td>0%</td>
<td>47.3%</td>
<td>20.7%</td>
<td></td>
</tr>
<tr>
<td>Pass / negative</td>
<td>338</td>
<td>117</td>
<td>455</td>
<td>&lt;0.001</td>
<td>55.3%</td>
<td>100%</td>
<td>100%</td>
<td>74.3%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>145</td>
<td>145</td>
<td></td>
<td>0%</td>
<td>55.3%</td>
<td>24.2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PTA from clinical diagnosis</td>
<td>McNemar's p-value</td>
<td>Sensitivity</td>
<td>Specificity</td>
<td>PPV</td>
<td>NPV</td>
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<tr>
<td></td>
<td>Normal / negative (n=168)</td>
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<tr>
<td></td>
<td>NIHL / positive (n=132)</td>
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<td></td>
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<td>100%</td>
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<tr>
<td></td>
<td>100%</td>
<td>74.8%</td>
<td>89.0%</td>
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<td></td>
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<tr>
<td>Refer / positive</td>
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<td>66</td>
<td>66</td>
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<td></td>
<td></td>
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<td></td>
<td>.0%</td>
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<td>11%</td>
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<td>37.8%</td>
<td>100%</td>
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<tr>
<td></td>
<td>100.0%</td>
<td>62.2%</td>
<td>83.5%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>99</td>
<td>99</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>.0%</td>
<td>37.8%</td>
<td>16.5%</td>
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<td>100%</td>
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<tr>
<td></td>
<td>100.0%</td>
<td>52.7%</td>
<td>79.3%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>124</td>
<td>124</td>
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<tr>
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<td>100%</td>
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</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>44.7%</td>
<td>75.8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0</td>
<td>145</td>
<td>145</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>.0%</td>
<td>55.3%</td>
<td>24.2%</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
• The sensitivity, specificity, PPV and NPV for the current averaging method used by HCP endorsed by DOSH and SOCSO currently are 25.2%, 100%, 100% and 63.3% accordingly. The rest of the PTA averaging method also yielded low sensitivity.
<table>
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<tr>
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<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5123 Pass / negative</td>
<td>338 (100%)</td>
<td>196 (74.8%)</td>
<td>534</td>
<td>&lt; 0.001</td>
<td>25.2%</td>
<td>100%</td>
<td>100%</td>
<td>63.3%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0 (0.0%)</td>
<td>66 (25.2%)</td>
<td>66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5124 Pass / negative</td>
<td>338 (100.0%)</td>
<td>163 (62.2%)</td>
<td>501</td>
<td>&lt; 0.001</td>
<td>37.8%</td>
<td>100%</td>
<td>100%</td>
<td>67.5%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0 (0.0%)</td>
<td>99 (37.8%)</td>
<td>99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1234 Pass / negative</td>
<td>338 (100.0%)</td>
<td>138 (52.7%)</td>
<td>476</td>
<td>&lt; 0.001</td>
<td>47.3%</td>
<td>100%</td>
<td>100%</td>
<td>71%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0 (0.0%)</td>
<td>124 (47.3%)</td>
<td>124</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>234 Pass / negative</td>
<td>338 (100.0%)</td>
<td>117 (44.7%)</td>
<td>455</td>
<td>&lt;0.001</td>
<td>55.3%</td>
<td>100%</td>
<td>100%</td>
<td>74.3%</td>
</tr>
<tr>
<td>Refer / positive</td>
<td>0 (0.0%)</td>
<td>145 (55.3%)</td>
<td>145</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Conclusion

• When compared to the clinical diagnosis of the air conduction PTA, the current method used now which is an average of 0.5, 1, 2, and 3 kHz is not sensitive (25.2%) although highly specific (100%).

• The use of 2, 3 and 4 kHz has shown the highest sensitivity (55.3%) amongst all the other pure tone averages, with 100% specificity as well. The other two pure tone averaging methods has lower sensitivity when compared to the 2,3 and 4 kHz averaging, although much higher when compared to the current average PTA method.
Conclusion (cont.)

• The current method of using PTA averaging is not a sensitive tool to use for NIHL screening, although it is very highly specific with very high PPV. We therefore recommend looking into new techniques or screening NIHL in HCP.
Limitations of study / Points to Ponder

• Reliability / validity of clinical diagnosis
  – Good repeatability
  – Very sensitive

• High specificity is misleading – remember exclusion criteria of sample
Reference

• Factories and Machinery Department Malaysia. (1989) Factories and Machinery (Noise Exposure) Regulations 1989
THANK YOU