Abstract

Previous studies have suggested larger magnitudes and lower thresholds in ipsilateral acoustic reflexes when compared to contralateral acoustic reflexes. This pilot study explored these effects by measuring how sound is transmitted through the middle ear. Middle ear absorbance was measured in the ipsilateral and contralateral conditions with and without activation of the acoustic reflex in normal hearing adults. Data showed that ipsilateral acoustic reflex thresholds (ART) were approximately 5 dB lower than contralateral ARTs. The magnitude of the acoustic reflex was shown to be larger in the ipsilateral condition. Results suggest that there is an evident contrast between ipsilateral and contralateral absorbance values. When considering elevated or absent acoustic reflexes in children with auditory processing disorder (APD) and the role of the acoustic reflex on speech perception in the presence of noise, it is important to investigate this contrast with regards to current clinical diagnostic tests.

Introduction

The acoustic reflex is an involuntary contraction of the stapedius muscle of the middle ear in response to high-level acoustic stimuli (McGregor et al., 2018). The fact that the acoustic reflex is elicited only by high intensity sounds has led to the theory that the acoustic reflex may act to protect the middle ear from damage due to excessive acoustical stimulation, although this is unlikely to be its primary function (Lutman & Martin, 1979). Alternatively, it has been suggested that this contraction increases middle ear impedance, adjusting sound transmission over a range of stimulus levels, modifying input to the cochlea in frequency-selective manner (Borg, 1968). Because its effect is frequency-selective, it may assist in improving speech perception in the presence of noise. The activation of the acoustic reflex controls the attenuation of low frequency speech sounds (de Andrade et al., 2011), thus acting like a high pass filter and favoring the perception of high frequency sound which is important for speech perception.

Difficulty understanding speech in the presence of noise is a common complaint from children with suspected auditory processing disorder (Saxena, 2014). The American Speech-Language-Hearing Association (ASHA) defines auditory processing disorder (APD) as deficits in the neural processing of auditory information in the central auditory nervous system not due to higher order language or cognition, as demonstrated in poor performance in one or more of auditory discrimination, temporal processing, and binaural processing. (ASHA, 2022). Current clinical practices for diagnosing APD may include behavioural and objective tests, in which it is essential that these tests are accurate.

An objective test that can be performed on children with APD involves measuring acoustic reflex thresholds (ART). The ART is defined as the minimum stimulus intensity at which contraction of the stapedius muscle can be measured from changes in middle ear impedance (Saxena, Allan, & Allen, 2017). It is considered the most common acoustic reflex parameter used for clinical and research purposes (Awang et al., 2019), especially valuable in the diagnosis of middle ear and retrocochlear disorders (Guest et al., 2019). This test can be performed ipsilaterally (uncrossed; stimulus and measurement in the same ear) or contralaterally (crossed; stimulus and measurement in opposite ears). Many children with APD show abnormalities in ARTs and often have elevated or absent reflexes, outlined in a study by Allen & Allan (2014). They determined that these abnormalities were most often reported in the crossed condition, which may suggest potentially weaker pathways crossing the lower brainstem.

Other studies have also reported larger reflex magnitudes and lower reflex thresholds in ipsilateral acoustic reflexes when compared to contralateral acoustic reflexes. A study by Hall (1982) discovered that in all participants, acoustic reflex amplitude was larger in the uncrossed condition than in crossed condition. More recently, Saxena, Allan, & Allen (2015) measured crossed and uncrossed acoustic reflex growth functions (ARGF) in normal hearing adults, typically developing children, and children with suspected APD. They determined that ARGF slopes tended to be shallower in the crossed compared to the uncrossed condition. Another study by Causon et al. (2020) looked at the role of the acoustic reflex as a research tool in clinical environments and reported acoustic reflex thresholds to be on average 5 dB lower in the ipsilateral compared to the contralateral condition. It may be worthwhile to consider the differences between ipsilateral and contralateral acoustic reflex activation with respect to current accepted clinical practices.

Measuring absorbance through the middle ear with regards to an individual's ART is one method that can be used demonstrate the effect of acoustic reflex activation on middle ear function. Middle ear absorbance provides an estimate of the sound energy being absorbed by the middle ear across frequency (Saxena, 2014). It can be used to describe how effectively acoustic energy is transmitted through the middle ear, with relation to the acoustic energy of the incident sound. Because of this, measuring the change in absorbance after the activation of the acoustic reflex can be used as a method to inspect middle ear function.

This pilot study is based on the final study in the PhD dissertation of Udit Saxena (Saxena, 2014), which investigated the effect of acoustic reflex activation on middle ear functioning at different reflex activator intensity levels (ART, ART + 5 dB, ART + 10 dB). In that study, absorbance and resonant frequency were measured contralaterally through a frequency range of 226-4000 Hz while activating the acoustic reflex in normal hearing adults, typically developing children, and children with suspected auditory processing disorder (APD). It was determined that there was a decrease in absorbance between 226 and 1000 Hz, a small increase in absorbance between 1000 and 2000 Hz, and little or no change in absorbance above 2000 Hz (Saxena, 2014). Although stapedial muscle contraction is bilateral, even when the stimulus is presented in a single ear (Meneguello et al., 2001), due to technical limitations only the contralateral, potentially weaker, reflex was investigated. This pilot study will build upon the previous study, by examining the effect of both contralateral and ipsilateral acoustic reflex activation on absorbance in the middle ear for the purpose of determining potential differences between the two conditions.

Methods

Participants

Participants included 4 normal hearing adults (including the author and fellow lab members, 21-26 years of age). All participants had normal otoscopic examination and normal hearing thresholds, as well as no history of neurological disorder.

Procedure

Absorbance was measured in both ears at a baseline resting state and at a threshold level where the acoustic reflex was determined. Absorbance was then recorded in the presence of the acoustic reflex activator at 5 and 10 dB above the threshold, resulting in three absorbance measures (ART, ART + 5 dB, ART + 10 dB). An admittance change in middle ear reflex amplitude of 0.02 mL or greater was recognized as the standard for establishing the ART. In all conditions, ARTs were elicited using a wide band noise from 250-4000 Hz, performed in ascending 5 dB steps using the TITAN middle ear analyzer (Interacoustics, 2013). Prior to the study, the TITAN was professionally calibrated according to industry standards by Electro-Medical Instrument Company (EMI Canada, 2016). The measures were sequenced using MATLAB software on a Microsoft Surface laptop, which was used in accordance with the TITAN to actively test absorbance. The stimulus was presented through probe inserts, which were attached directly to the TITAN. In all participants, absorbance was measured in the left ear for both ipsilateral and contralateral conditions. The data was validated by repeating the measures twice at each intensity level. The intensity level was not increased above 100 dB SPL for any measurement, meaning participants with reflexes above this level were not included in the study. If participants felt uncomfortable at a certain intensity level, the measurements were restricted and were only performed below that level to prevent discomfort.

Absorbance measured without activation of the acoustic reflex was considered baseline absorbance. Absorbance measured at three different reflex activator intensity levels (ART, ART + 5 dB, ART + 10 dB) was considered contracted absorbance because of the contraction of the stapedius muscle resulting in the acoustic reflex. For each intensity level, the effect of the acoustic reflex on absorbance was calculated by subtracting the baseline absorbance value from the contracted absorbance value.

Results

Measurements in all participants were obtained at the intensity level in which the acoustic reflex was first activated (ART). Figure 1 shows the change in absorbance over a frequency range in both conditions at each of the three intensity levels (ART, ART + 5 dB, ART + 10 dB). Group average change in absorbance is represented by the dark blue lines, whereas individual absorbance values are represented by the light blue lines.

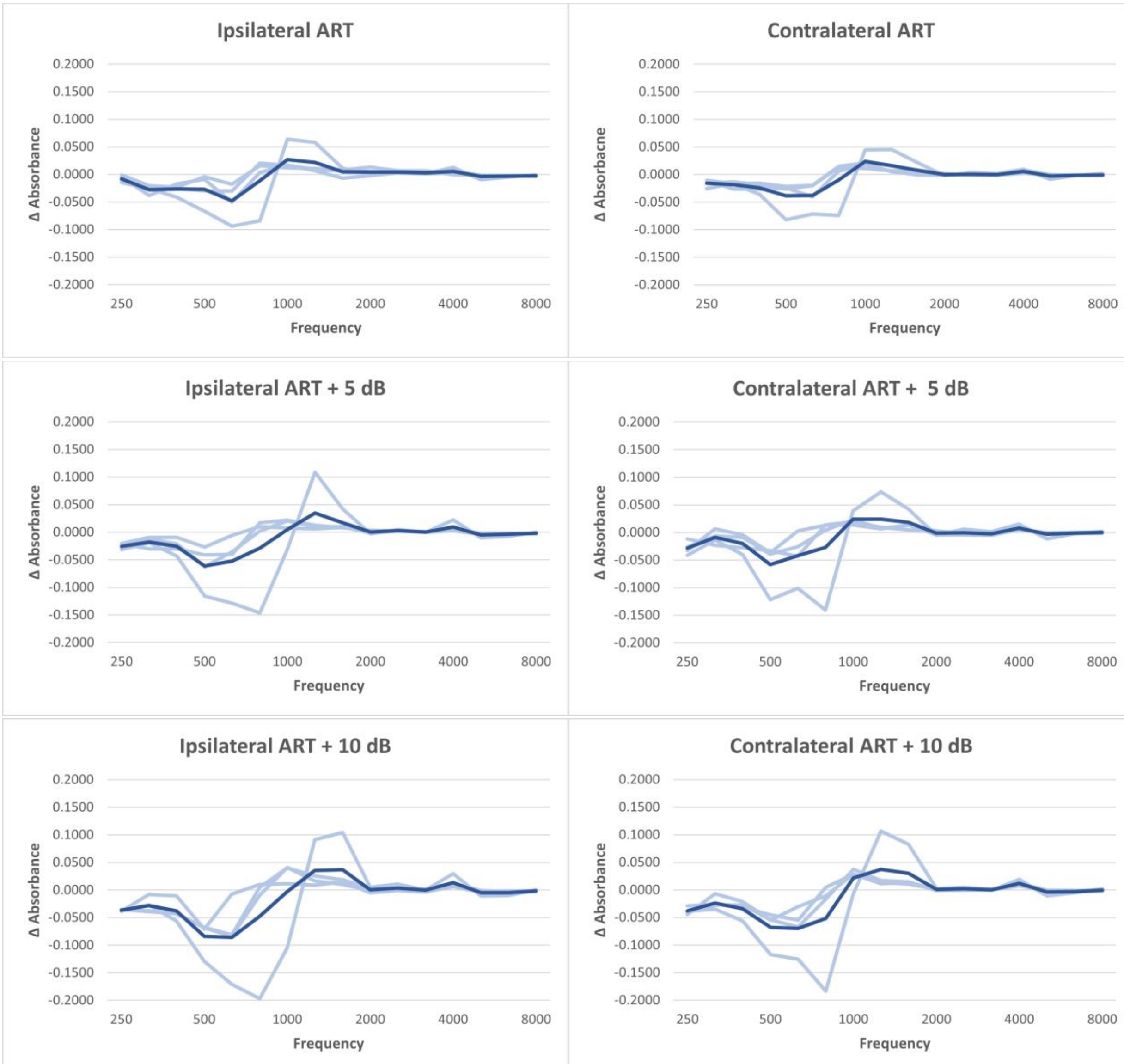

Figure 1: Average change in absorbance measured with and without activation of the acoustic reflex in the ipsilateral (uncrossed) and contralateral (crossed) conditions. Group average change in absorbance is represented by the dark blue line, whereas individual data with light blue lines.

Although statistical analysis was not completed, average data estimated that acoustic reflex activation caused a decrease in absorbance between 250-750 Hz, an increase in absorbance between 750-2000 Hz, and little or no change above 2000 Hz.

Figure 2 shows the average difference between ipsilateral and contralateral absorbance values for each of the three ART threshold levels. The lines shown are reflective of the dark blue lines in Figure 1, as they show a subtraction of average contralateral absorbance values from average ipsilateral absorbance values.

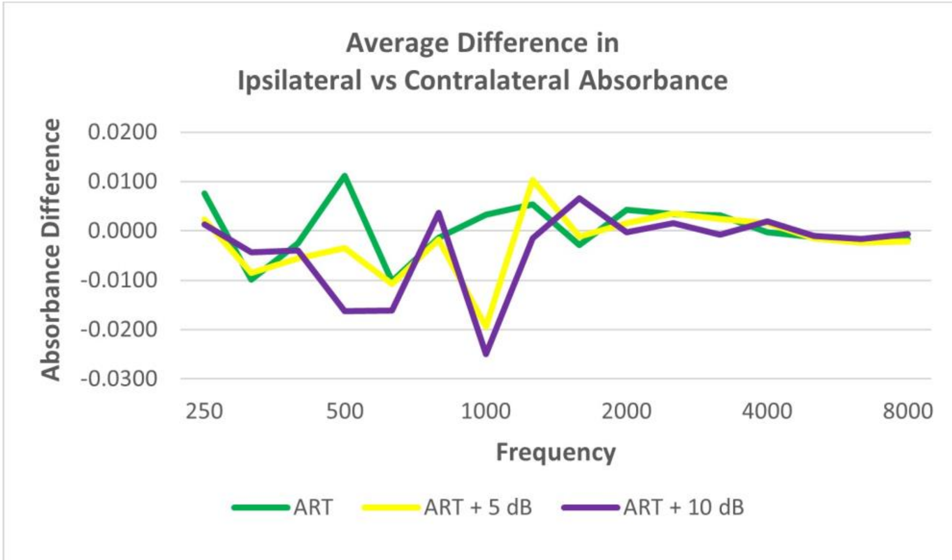

Figure 2: Average difference between ipsilateral and contralateral group average change in absorbance values for each of the three acoustic reflex threshold intensity levels.

Although statistical analysis was not completed, Figure 2 shows a clear difference between the group average difference in ipsilateral and contralateral absorbance values.

Figure 3 shows the magnitude of the group average change in absorbance. This shows that the magnitude of the ipsilateral acoustic reflex is larger than contralateral acoustic reflex.

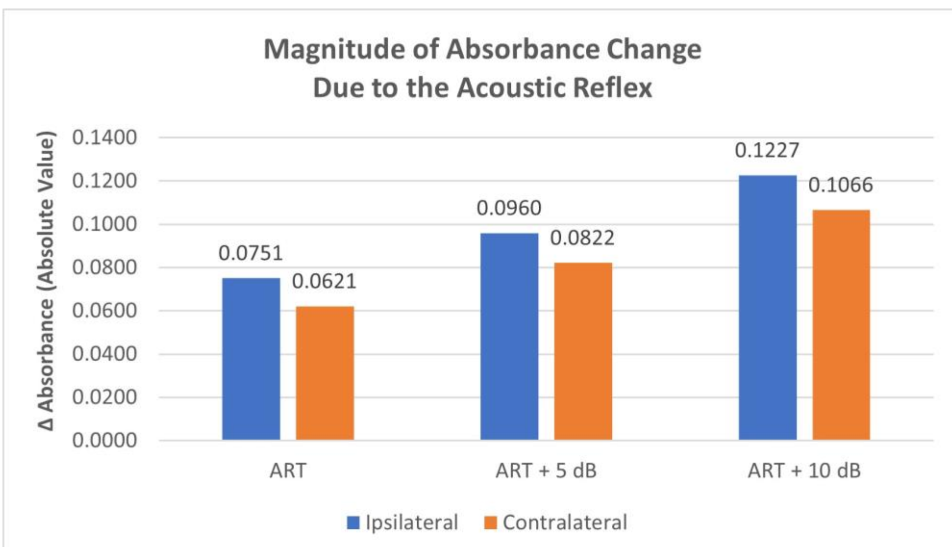

Figure 3: Absolute value of the magnitude of absorbance change in both conditions for each of the three acoustic reflex threshold intensity levels.

Discussion

The effect of acoustic reflex activation on change in absorbance in the middle ear was investigated to determine how the activation of this reflex affects middle ear function. It was determined that the activation of the acoustic reflex affects middle ear absorbance in a frequency-specific manner. After examining the data, it can be estimated that absorbance decreased from 250-750 Hz, increased from 750-2000 Hz, and showed little or no change above 2000 Hz. A decrease in absorbance due to the acoustic reflex at low frequencies may benefit speech perception, as noise is prevalent at low frequencies. The decrease in absorbance at low frequencies results in an increase in reflectance, improving the signal to noise ratio and subsequently reducing the extent to which sound energy is transmitted to the oval window of the cochlea. Although the observed values are estimates, they are somewhat consistent with the previous study (Saxena, 2014) in which this pilot study is based. It can be prudently surmised that future data may closer resemble the results of the original study, as data from this study was drawn from a small sample size.

Changes in middle ear absorbance due to the acoustic reflex were examined in both ipsilateral and contralateral conditions. Pilot data showed that at each of the three reflex activator levels, ipsilateral ARTs were approximately 5 dB lower than their contralateral counterparts, which is consistent with previous studies. Figure 1 outlined the change in absorbance over a frequency range in both conditions and all three reflex activator levels while showing the average change in absorbance of the group. The absolute value of this group average change in absorbance was plotted in Figure 2 to show the average difference between the ipsilateral and contralateral conditions. Results showed that there was an observable difference in absorbance values between both conditions as the value of this difference was not zero. The magnitude of the acoustic reflex can be explained by the absolute value of the absorbance change over the frequency range. Data in Figure 3 demonstrated a larger acoustic reflex magnitude in the ipsilateral condition in all three reflex activator levels. Although statistical analysis was not completed, the magnitude difference between both conditions was similar through all activator levels. This relationship may become stronger when the full study is completed and there is a larger sample size. Pilot data displayed a notable contrast between ipsilateral and contralateral middle ear absorbance values as a result of the acoustic reflex, consistent with previous studies.

Conclusion

This pilot study showed the differences in the activation of ipsilateral and contralateral acoustic reflexes with regards to resultant changes in middle ear absorbance. It was determined that on average, ipsilateral acoustic reflexes have a larger magnitudes and lower ARTs than contralateral acoustic reflexes and ARTs. Although testing was only completed on a small sample size, this study illustrated the differences in both conditions, an important thought when considering the literature suggests the contralateral reflex is weaker. An ethics application pertaining to this pilot study is currently being prepared which will allow a full study to be completed in the future. The results shown portray many avenues in which acoustic reflex thresholds can be compared between ipsilateral and contralateral conditions. The overall success of this pilot study on normal hearing adults opens the idea of completing this study on typically developing children, children with suspected APD, and children with APD. This will allow data to be collected within the same cohort in which the presence of APD most frequently is discovered. The correlation between acoustic reflexes and speech perception along with known reflex abnormalities in children with APD show the need for comprehensive acoustic reflex testing in clinical environments for this population.

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