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INFLUENCE OF CONTRALATERAL ROUTING OF SIGNALS ON SOUND LOCALIZATION ON ADULT MALES WITH SINGLE SIDED DEAFNESS

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Abstract

Single-sided deafness (SSD) is a situation of profound hearing loss on one side, with normal contralateral or proximal hearing. SSD presents a myriad of unique and specific listening challenges, sound localization, and speech intelligibility in background noise with a great risk to quality of life and social development. The objective of the paper is to determine the influence of Contralateral Routing of Signals (CROS) on sound localization adult males with SSD in Lagos State, Nigeria. The evaluation process consisted of an application of a checklist, the conduction of conventional clinical audiological evaluation and sound localization using the Spatial Hearing Questionnaire as well as the Bern Benefit in Single Sided Questionnaire. A significant positive gain in sound localization and auditory performance was observed through effective use of CROS. The study concluded that effective deployment and usage of CROS can efficiently improve the auditory performances and enhance the quality of life of individuals with SSD.

Keywords: Single-sided deafness, contralateral routing of signals, sound localization, auditory performance

Background

Single-Sided Deafness (SSD) is clinically defined as normal hearing or close to normal hearing in one ear and a hearing loss in the contralateral ear, ranging anywhere between mild to profound in degree, which may be sensorineural, conductive or mixed. Single-sided Sensorineural Deafness (SSD), is an example of the most extreme asymmetrical hearing loss configuration, i.e. where the poorer ear presents with profound sensorineural deafness, and the contralateral ear displays normal hearing or close to normal hearing thresholds (i.e. up to a mild hearing loss with pure-tone average, PTA, thresholds of 40dB HL or less) in the better ear. It has been estimated by Prieve, Dalzall, Berg, Bradley, Cacace and Campbell, et al, (2000) that SSD occur in 0.83/1,000 newborn children while approximately 9% of the adult population are affected by SSD (Agrawal, Platz & Niparko, 2008). Single-sided deafness (SSD) is in most cases caused by Ménière's disease, trauma or sudden sensorineural hearing loss of unknown origin. According to Schreiber, Agrup, Haskard, et al., (2010), the most common etiologies associated with profound unilateral sensorineural deafness are ototoxicity, inner ear infection, Ménière's disease, inner ear otosclerosis, trauma to the ear/head; disorders of the circulatory system, genetic or hereditary factors including certain syndromes, and acoustic neuroma. Unilateral deafness often remains a hidden disability which is undetected or ignored because it is possible for individuals to cope in most listening conditions by using a variety of strategies, i.e. choosing where to sit or stand, avoiding noisy situations, turning the better ear toward the target sound, and others (Gray, Kesser, & Cole, 2009; Wie, Pripp, & Tvete, 2010). However, in spite of normal hearing in one ear and the ability to understand speech in most quiet conditions, individuals with unilateral deafness experience significant disabilities in many situations. This is particularly evident if communicating in competing background noise where speech arrives at the poorer ear (Wie, Pripp, & Tvete, 2010). An inability to identify the location of sound and the loss of binaural advantages gained from binaural summation, binaural squelch and the head shadow effect add to the difficulties for a unilateral listener (Hol, Kunst, Snik, & Cremers, 2010; Flynn, Sammeth, Sadeghi, Cire, & Halvarsson, 2010). Common everyday situations where the need to have the better ear directed toward the speaker (or sound source) are challenging such as in a restaurant, an automobile, train, at a meeting, school classroom, at a party or simply engaging in normal conversations with a small group of friends. Taking advantage of usually available speech-reading cues (visual cues) in difficult listening situations is compromised when attempts to improve understanding are made by naturally turning the better ear toward the speaker (Wie et al. 2010). All of these functional disabilities can lead to fatigue in listening and impact psychosocial factors such as self-esteem, self-confidence, feelings of security (e.g. being surprised when approached at the poorer hearing side), feelings of safety (e.g. cycling, recognising oncoming traffic, crossing the street, jogging etc), feelings of exclusion and perceived diminished quality of life (Wie et al. 2010; Borton, Mauze, & Lieu, 2010).

As noted by Távora-Vieira, Boisvert, McMahon, Maric, and Rajan (2013), patients with single-sided deafness who cannot benefit from hearing aids have been historically left without the benefit of binaural hearing. They usually report difficulties understanding conversation coming from the poorer-hearing side, especially in noisy environments, and they have no ability to localize sounds. These difficulties experienced by persons with single-sided deafness are due to the lack of binaural effects (head shadow, squelch, and summation effect (Vermeire & Van de Heyning, 2009). Interestingly, overcoming the challenges posed by single-sided deafness has been the core of researchers in recent time with research trials with hearing aids, counseling as well as helping patients develops ability to manage and live with the better contralateral ear. However, Peters, Smit, Stegeman and Grolman (2015) stated that current rehabilitation options for SSD include the contralateral routing of signal (CROS) or bone conduction devices (BCD) CROS systems transfer sounds from a microphone on the deafened ear to an open fit hearing aid on the opposite, normal-hearing ear.

The system may be connected either with cables or wireless technology (Dillon, 2001). The contralateral routing of signal system picks up sounds arriving at the impaired ear using a remote microphone and presents those sounds to the non-impaired ear through a wired or wireless link (Harford and Barry, 1965). A CROS conducts signals from the hearing field of the poor ear via a wire (or FM/Bluetooth) to an output transducer in the ear canal of the better ear such that sound awareness is restored. The primary function of the system is therefore to overcome the acoustic shadow cast by the head and, in doing so, to improve access to sounds on the impaired side. As a result of the dwindling auditory performances and its associated effects on psychosocial wellbeing as well as quality of life of persons with SSD, researchers such as (Hol et al, 2010; Peters, Smit, et al. 2015; Punch, 1988) have presented the fitting of contralateral routing of signal (CROS) as a traditional approach to the rehabilitation of individuals with SSD. The use of a CROS system has been found to improve the perception of speech in noise compared to the unaided condition when the most favourable signal-to-noise ratio is available at the impaired ear; that is, with speech on the impaired side and the noise from the front or speech from the front and noise on the non-impaired side (Bosman, Hol, Snik, Mylanus & Cremers, 2003 Niparko, Cox & Lustig, 2003; Hol, Bosman, Snik, Mylanus & Cremers, 2004; Lin, Bowditch, Anderson, May, Cox, & Niparko, 2006).

Use of a CROS system has also been associated with a reduction in self-reported difficulty with background noise, communication, and reverberation (Baguley, Bird, Humphriss & Prevost, 2006). However, the indiscriminate routing of sounds from the impaired ear to the non-impaired ear can produce undesirable results. For example, the perception of speech in noise can degrade with CROS use compared to the unaided condition when a background noise is located on the impaired side (Hol et al., 2010). However, studies of Hol et al. (2010) and Niparko, Cox and Lustig (2003) pointed that a few patients benefit from these options. In previous studies, only 25–40% of SSD patients chose an implantable BCD or CROS hearing aid after a short trial period (Andersen, Schroder & Bonding, 2006; Hol et al., 2010). Most patients found it unpleasant to have an earmold with partial occlusion in their hearing ear or to have an abutment in their skull that required diligent care.

Although these treatments options have their merits in improving speech perception and providing subjective benefits (Yuen, Bodmer, Smilsky, Nedzelski & Chen, 2009; Wazen, Van Ess, Alameda, Ortega, Modisett & Pinksy, 2010) but binaural hearing is not achievable (Hol et al. 2010). A recently published review found that there are no high level evidence studies comparing CROS and BCD for single-sided deafness (Peters et al., 2015). The authors of the review could only include studies with low to moderate levels of evidence, and they found that CROS and BCD did not improve speech perception in noise or sound localisation, although patients did benefit in speech communication subjectively. Presently, major studies on the implication of CROS among persons with SSD have been engaged in among are patients in high resource settings where noise and its associated hazard are kept in the barest minimum while there is a dearth of such studies in low resource settings like Nigeria where levels of noise pollution is daily on the rise (Nduka, Aitafo, & Nduka, 2019). Unfortunately, thousands of individuals with SSD in Nigeria still lives with the enigma and psychosocial trauma associated with the condition, there is clearing of an urgent need to search for probable solution to balance auditory signals and lead a comfortable life. Therefore, this study determined if patients with single sided deafness fitted with CROS would have improved sound localization and auditory performance.

Research question

Will sound localization abilities and auditory performances of adult males with single sided deafness be improved with the use of Contralateral Routing of Signals (CROS)?

Materials and Method

The study adopted a purposive sampling technique with three patients A, B and C. The study participants were male, ages 52, 63 and 60 respectively. All study participants were screened presented for single sided deafness using the otoscope, tympanometer and diagonistic audiometer. An otoscopic examination was conducted on the ear canals and the eardrum so as to ascertain the presence or absence of any occluding substance in the ear canals. An objective test of the middle ear function was performed with the aid of a tympanometer. The procedure of the tympanometry involves the presentation of a tone of 220 Hz into the ear canal, where the sound waves strikes the tympanic membrane, causing vibration of the middle ear, which in turn results in the conscious perception of hearing. A Pure Tone Audiometry (PTA)(air and bone conduction test) was carried out on each patient using a diagnostic audiometer (name of the audiometer and its number) with standard headphones for air conduction testing while a mastoid bone vibrator is used for bone conduction testing. Further investigation of the Patients hearing mechanisms were conducted using the Otoacoustic Emissions (OAEs). The Otoacoustic Emissions (OAEs) is an objective assessment tool that determines sensorineural hearing loss of cochlear origin. The Otoacoustic Emissions (OAEs) test procedure that reveals the level sound emitted by the cochlea either spontaneously or as all echo or other sound evoked by an auditory stimulus, related to the functions of the outer hair cells. All the objective examinations were clinically conducted to ascertain unilateral deafness without any other complications in the hearing mechanisms in the other ear.

Specifically, Patient A, a 52 year male was presented with gradual deterioration in hearing acuity with pulsating tinnitus in right ear with occasional wobbling and inbalance of movement sometime in 2009. There was also a complaint of fullness in the right ear. Due to his busy schedules,

Patient A ignored the symptoms until 2011 when the condition got really disturbing with a significant negative impact on job performances. Audiological evaluation showed severe to profound hearing loss more at the higher frequencies. MRI and CT scans showed the presence of a tumor (Acoustic Neuroma) at the stage that it was large enough pressing on the brainstem. Surgery was conducted to remove the tumor after which a post-surgical audiogram showed profound SNHL (**R**) which made it difficult for Patient A to localize sounds and communicate efficiently with others. In other to ameliorate the difficulties experienced in effective auditory-verbal communication, Patient A was fitted with WIDEX WIRELESS CROS D.CIC and D-FS (Monaural discrimination of 80%; Binaural discrimination of 100%) using the WIDEX GPS software.

Patient B, a 63 years old man who presented a deteriorating hearing acuity in the Right ear, he was referred by the ENT Surgeon for audiological assessment and MRI/CT scans. MRI did not show any abnormality, but the audiological evaluation revealed high frequency progressive SNHL. Patient B experienced difficulty in localizing sounds in the Right ear. He was particularly worried as he could not enjoy music. After series of subjective and objective tests, Patient B was fitted with Phonak Audeo CROS system.

Patient C, a 60-year-old male noticed a sudden deterioration in his hearing acuity on the left ear. Audiological evaluation was conducted to ascertain the severity of the deterioration of the hearing acuity in 2004 but advised to avoid excessive exposure to loud noise. The patient was placed on routine audiological assessment as follow-up twice every year. MRI tests showed absence of a tumor. However, follow-up audiogram continued to show further deterioration in hearing sensitivity when in 2014, the patient took up a higher responsibility in the public service that required attendance and presiding of several meetings. In other words, it became quite difficult for him to converse with his superiors, colleagues or whoever sits and speaks to him from his left side. To ameliorate these challenges, the patient was fitted with a completely in the canal CIC hearing aid in the left ear in 2006 with a matrix 117/55/10 with a peak fall on Gain of 57.7dB with little improvement in the hearing acuity from the left ear. Subsequently, the patient was fitted with PHONAK CROS solution using CROS 312 half shell on the left ear and Microphone on Cassia model 312 UZ on the Right Ear. Fitting was done using Phonak Target firm version 1.2.1.0. Discrimination was 95dB and 100dB on the Right and left ear respectively.

Based on the report of the objective assessment of hearing, a subjective test, the Bern Benefit in Single Sided Questionnaire (Kompis, Pfiffner, Krebs & Caversaccio, 2011) and Spatial Hearing Questionnaire (Tyler & Perreau, 2009) was presented to the participant before and after fitting of the contralateral routing of signals (CROS). The Bern Benefit in Single Sided Questionnaire (BBSS) is a 10-item questionnaire that measures the perceived benefit of amplification devices (CROS) on the auditory performances of persons with single-sided questionnaire. The BBSS is a closed ended questionnaire that allowed the respondent to choose from options which ranges from "Much easier without the aid", "…Somewhat easier", "Similar with and without" as well as "Much easier with the aid". The Spatial Hearing Questionnaire (SHQ) was designed in a closed response format of 'Very Difficult'' and "Very Easy" to assess spatial hearing abilities. The 24-item (SHQ) was SHQ was administered to the patients before and after of the contralateral routing of signals. Data collection and further evaluation was done 12 weeks after the fitting of CROS through the Bern Benefit in Single Sided Questionnaire and the Spatial Hearing Questionnaire. Data generated through the questionnaires was analysed using a descriptive statistics involving p-plot graph and a radar chat.

Results

Figure 1 revealed the audiogram pattern of the study participants on air and bone conduction test. It showed that participants A and C had profound to severe hearing loss on the left ear while participant B is shown to have profound to severe hearing on the right ear when examined with the Air conduction test.

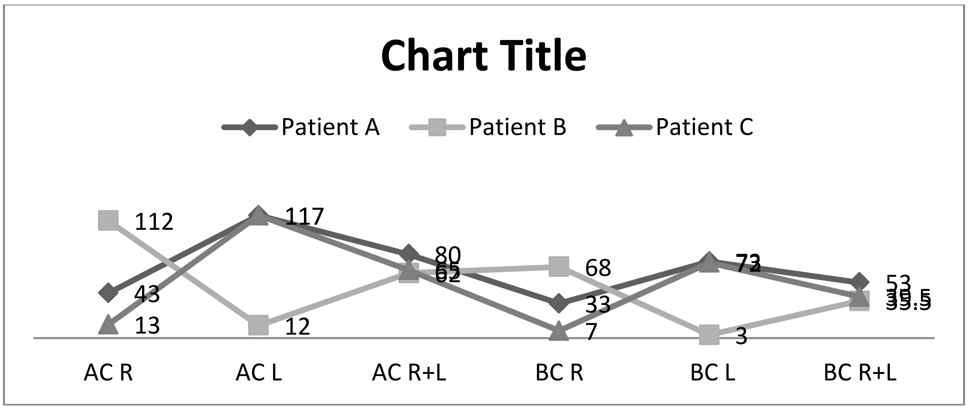

Figure 1: Pure tone audiometry of the patients with SSD
Where AC R = Air conduction (Right ear)
AC L = Air conduction (Left ear)
AC R+L = Air conduction (Right and Left ear)
BC R = Bone conduction (Right ear)
BC L = Bone conduction (Left ear)
BC R+L = Bone conduction (Right and Left ear)
Figure 1: Pure tone audiometry of the patients with single sided deafness

Research Question: Will sound localization abilities of persons with single sided deafness improve with the Contralateral Routing of Signals (CROS)?

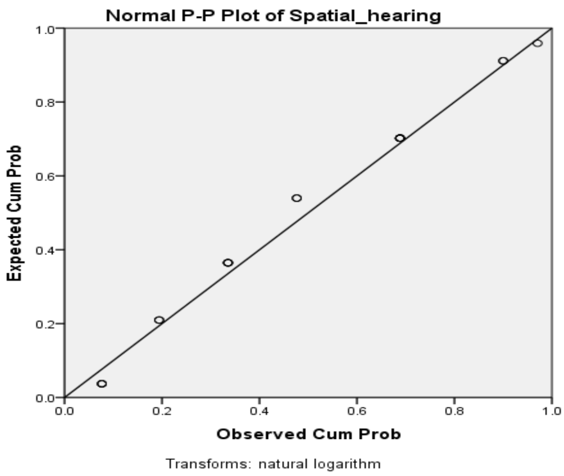

Figure 2a: Observed spatial hearing acuity before fitting of CROS on patients with single sided deafness.

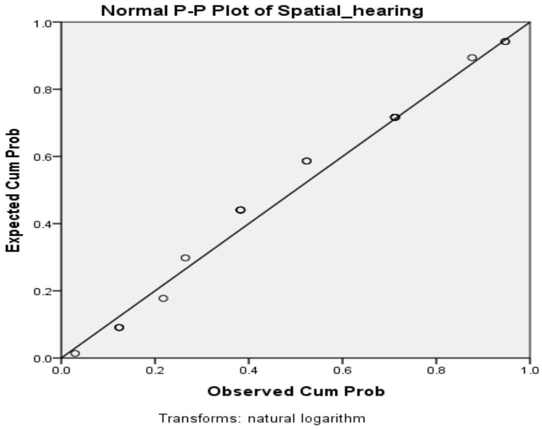

Figure 2b: Observed spatial hearing acuity after fitting of CROS on patients with single sided deafness. The P-Plot in figure 2a revealed that participants in this study perceived relatively fewer sound signals from the impaired ear before fitting of CROS. However, participants perceived substantial sound signals from the impaired ear when fitted with CROS. In Figure 2b, there were more elements of sound signals on the plot than it was before the fitting of CROS. This implies that participants fitted with CROS perceived, localized and responded to appreciable sounds stimulus compared to pre-fitting of CROS.

Discussion

Patients observed in this study prior to CROS fitting experienced significant challenges with sound localization with increased effort to respond to auditory-verbal signals that is directed to the impaired ear. Thus SSD had a most negative impact on the psychosocial adjustment and impaired quality of life. However, this study showed that CROS has positively influence on sound localization with an improvement on auditory performance as well as quality of life of persons with single sided deafness. In other words, study participants fitted with CROS showed increased and effortless abilities to locate and discriminate sound sources coupled with improved self-esteem, social connectedness and an overall positive quality of life. This finding supports Dillion (2001) and Hol et al. (2010) who stated that CROS can significantly improve perception of speech in noise with a reduction in self-reported difficulties with background noise, communication and reverberation. The finding in this study is in tandem with a previous study by Hol et al. (2004) who stated that the perception of speech in noise can degrade with CROS use compared to the unaided condition when a background noise is located on the impaired side. However, these present findings does not conform with that of Nawaz, McNeill, and Greenberg (2014) who reported a case of a postlingually single-sided deaf adult patient who was managed with a counter routing of signal (CROS) hearing aid, then an osseointegrated bone conduction system (OBCS) and finally a cochlea implant (CI), as previous methods did not improve his chief complaint of difficulties with sound localization.

Conclusion and recommendation

This study had successfully brought to the fore the implication of contralateral routing of signals (CROS) as an effective device to improve the auditory performances of individuals with single-sided deafness in Nigeria. This study therefore concluded that the use of contralateral routing of signals can significantly improve auditory performance and thus influences the quality of life of individuals with single-sided deafness. In the absence of compelling clinical evidence of benefit of contralateral routing of signal, clinicians are therefore advised to proceed with caution the fitting of contralateral routing of signal to individuals with single-sided deafness. More importantly, individuals with single-sided deafness should be well counseled on the benefit of effectiveness and efficient use of the device.

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