Efferent Pathway

Clinical Evaluation of Efferent Auditory pathway. *Ajith Kumar U, MSc (Sp. & Hg.), Doctoral Student, Department of Audiology, All India Institute of speech & Hearing, Mysore, India.*

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In humans, role of the ear is extremely important. It is one of the most important links in the human speech chain, which enables proper communication. All the information from the peripheral receptor organ is carried to the central organ, the brain for analysis, by means of afferent auditory pathway. The higher organs have control over the peripheral receptor, the cochlea, by means of efferent feedback pathways (Huffman & Henson, 1990). These efferent auditory pathways can be found in all classes of vertebrates (Roberts & Meredith, 1992). The efferent auditory system has two main segments.

1. Cortex and rostral brainstem system
2. Olivocochlear system.

Cortex and rostral brainstem system: Two efferent systems emerge from the cortex. One projects to medial geniculate body and the other to various auditory nuclei in brainstem and to sensory cells of cochlea. However, little is known about the physiology of these fibers. Much of the research has been focused on olivocochlear bundle, located in the caudal pons in the region of superior olivary complex (Warr & Guinan, 1979; Rasmussen, 1946).

Olivocochlear bundle: The following section is aimed at providing a brief overview of functional anatomy of olivocochlear bundle (OCB). More detailed description can be found else where (e.g., Warr, 1992; Guinan, 1996). The olivocochlear bundle was first described by Rasmussen in 1946, as the group of nerve fibers originating from the superior olivary complex, crossing the midline at the level of fourth ventricle and innervating the cochlea. In 1960, he supplemented his findings through the discovery of an uncrossed bundle of nerve fibers originating from superior olivary complex and terminating at cochlea. Later, by aterograde tracing technique, Warr and Guinan (1979) and Guinan, Warr and Norris (1983), showed that there are two main groups of olivocochlear efferents: Lateral and Medial. The lateral olivocochlear bundle (LOCB) originates from the small nuclei in and around the lateral superior olivary complex and have unmyeilinated fibers. These fibers terminate on the afferent fibers of auditory nerve beneath the inner hair cells. The medial olivocochlear bundle (MOCB) originates from nuclei in and around medial superior olivary nucleus. These fibers are myelinated and terminate directly on outer hair cells. Medial olivocochlear innervation is largest near the center of the cochlea where as lateral efferent innervation is equally biased towards base and center of the cochlea (Liberman, Dodds & Pierce, 1990). In most of the species, LOCB is large and projects mostly to the ipsilateral ear where as MOCB projects predominantly to contralateral ear. Because medial efferents are myelinated they are far more readily stimulable than non myelinated LOCB. Hence, almost all efferent physiological knowledge available is derived from medial efferents and very little is known about the functioning of lateral efferents.

Although the existence of efferent innervation to the mammalian cochlea was described more than fifty years ago, the functional role and clinical relevance of these fibers remain unclear. Outer hair cells (OHC) are anatomically located post-synaptically to medial efferents. There fore, OHC are in a unique position, where they can be directly modulated by medial efferent system. The discovery of otoacoustic emissions (OAE) (Kemp, 1978) has provided a direct means to study OHC and hence to monitor the effects of efferent stimulation on cochlear micromechanics. As the efferent fibers constitute a part of the intercochlear loop, stimulation of the one cochlea modifies the functioning of the opposite cochlea too. The efferent fibers can be stimulated through electrically by shocks at the floor of fourth ventricle or acoustically by presenting the noise to the ipsilateral/contralateral ear. Hence, monitoring the OAE, by stimulating the efferent system through binaural, ipsilateral or contralateral noise provides an objective and noninvasive tool to test the efferent system. Because of certain methodological and instrumental limitations, most of the clinical studies have used contralateral stimuli to excite the efferent system. When medial olivocochlear bundle is activated through contralateral acoustic stimuli, the effect observed is a reduction in the amplitude of OAE. This effect is called contralateral suppression of OAEs. This effect is expressed in dB and is measured by subtracting the OAE amplitude without contralateral stimuli from OAE amplitude with contralateral stimuli. A suppression value of less than 0.5 is considered to be indicative of dysfunction of efferent auditory pathways (one **software** is available to measure the suppression OAE using ILO instruments) However, accessing the efferent auditory pathway through OAE requires the presence of normal functioning of outer hair cells. This poses a problem in evaluating the efferent auditory pathway in individuals with cochlear hearing loss. Recently, two other alternate approaches have been suggested which can be used in the evaluation of efferent system in individuals with hearing impairment (Kumar &Barman, 2002; Kumar &Vanaja, 2004). Kumar and Barman (2002) reported the changes in acoustic reflex threshold (ART) and amplitude upon the stimulation of efferent system through contralateral stimuli. In normal hearing subjects on an average ART increased by 4 dB and 3.5 dB at 1 KHz and 2 KHz respectively. Acoustic reflex amplitudes measured at 10 dB SL (w.r.t. ART) was reduced by 0.06 and 0.03cc at 1 KHz and 2 KHz respectively, when noise was presented to other ear. This suppression effect was greater with contralateral broad band noise than with the narrow band noise. This suppression had significant positive correlation with contralateral suppression of evoked otoacoustic emissions (Kumar, 2002) suggesting that both the mechanisms are mediated through medial efferent olivocochlear bundle.

Another approach to evaluate the efferent system makes use its antimasking property. Kumar and Vanaja (2004a) reported the improvement in speech identification scores in noisy environment when efferent system was activated by contralateral noise. This improvement had a significant positive correlation with other two measure of efferent system, i.e., contralateral suppression of OAE and acoustic reflex. This improvement in speech perception was not present in children with learning disability. These children also exhibited less suppression of OAE and acoustic reflex (Kumar, 2002; Kumar and Vanaja, 2004b).

Clinical protocol for the evaluation of efferent auditory system using above mentioned methods may be as follows

Method I: In individuals with good OAE, contralateral suppression of OAE can be used as measure of efferent functioning. Suppression can be measured by following three step paradigm suggested by Muchink, Roth, Jebara, Katz, Shabtai & Hildesheimer, (2004).

Step1 – Two successive TEOAEs without contralateral broad band noise (Q_1)

Step2 – Two successive TEOAEs with contralateral broad band noise (N_1)

Step2 – Two successive TEOAEs without contralateral broad band noise at 30 dB SL (Q_2)

Obtain $Q_1 - N_1$ (suppression 1) and $Q_2 - N_2$ (suppression 2). Average of suppression 1 and suppression 2 gives the amount of contralateral suppression. If this value is more than 0.05 (Veuillet, Kahalf & Collet, 1999) indicates the clinically significant suppression.

Method II: In individuals with no or weak emissions, acoustic reflex can be used to evaluate the efferent system. The following four step protocol can be used evaluate efferent system using acoustic reflex (Kumar & Barman, 2002)

Step1 – Measure the acoustic reflex thresholds at 1 KHz and 2 KHz.

Step2 – Measure the amplitude of acoustic reflex at ART + 10 dB SL without contralateral broadband noise (at 30 dB SL) in two successive recordings (Q_1).

Step3 – Measure the amplitude of acoustic reflex at ART + 10 dB SL with contralateral broadband noise (at 30 dB SL) in two successive recordings (N_1).

Step4 – Measure the amplitude of acoustic reflex at ART + 10 dB SL without contralateral broadband noise (at 30 dB SL) in two successive recordings (Q_2).

Obtain $Q_1 - N_1$ (suppression 1) and $Q_2 - N_2$ (suppression 2). Average of suppression 1 and suppression 2 gives the amount of contralateral suppression. If this value is more than .03 (Kumar, 2002) indicates the clinically significant suppression.

Method III: In individuals, who complain of difficulty in understanding speech in noisy environment efferent system can be assessed using fallowing behavioral technique (Kumar and Vanaja, 2004).

Step1 – Measure the speech identification scores using a standard test material in presence of ipsilateral signal to noise ratio of +10 dB.

Step2 – Repeat the measurement with the addition of 30 dB SL (reference: Threshold of noise) broad band noise in the contralateral ear.

The difference in the speech identification scores between two conditions gives the antimasking effect of efferent system. If the improvement in speech identification scores upon the presentation of contralateral noise is less than 10% is indicative of dysfunction of olivocochlear bundle (Kumar and Vanaja, 2002).

Efferent Auditory System Functioning in Clinical populations:

1. *Auditory Neuropathy:* It has been reported that patients with auditory neuropathy do not show efferent suppression of OAE (Starr, Picton, Sininger, Hood & Berlin, 1996). But it is difficult to interpret the results of efferent functioning in these populations because lack of suppression of OAE could be because of abnormal medial olivocochlear feedback or may be due to inability to access efferent system via dysfunctional afferent auditory pathways. Unilateral auditory neuropathy patients teach us that lack of efferent suppression is primarily due to dys-synchronous afferent firing. Lack of efferent suppression is also reported in other retro cochlear pathologies such as acoustic neuroma (Prasher, Rayn & Luxon, 1994). In patients with vestibular neurectomy suppression is either reduced or absent (Zeng, Martino, Soli, & Linthicum, 1997).

2. *Auditory processing disorder:* It has been shown that in children with auditory processing disorders contralateral suppression values are reduced than normal age matched children (Kumar & Vanaja, 2004b; Muchink et al., 2004). These children also failed to show the improvement in speech perception in noise upon the addition of contralateral noise. This reduction in antimasking effect of olivocochlear bundle at least in part may contribute to their difficulty to understand speech in presence of noise.

3. *Tinnitus:* EOAEs in ears with tinnitus have been found to show less suppression by contralateral acoustic stimulus compared to ears presenting similar hearing loss but without tinnitus. Contralateral suppression of DPOAE at the frequency of tinnitus is reported to be abnormal at least in one ear.

4. *Other populations:* Efferent suppression is reported to be abnormal in subjects who are obligate carriers of genes for deafness. Increased activity of olivocochlear bundle is reported in musicians, patients with hyperacusis, and children with autism. Musicians are reported to have binaural suppression of 4-7 dB compared to 2-3 dB in age and gender matched normal subjects.

   To summarize, evaluation of efferent auditory bundle in clinical set up is not a difficult task. It can provide a great deal of information regarding the patient's performance in noisy situation and susceptibility to noise. This would in turn help in patient education, counseling and in planning the management strategies.

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