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Review Article

Outcome Measures of Cochlear Implantation

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Abstract:

Early Diagnosis of and intervention for hearing loss as early as possible is very critical as early intervention is linked to better communication outcomes and good performance of children at school. Cochlear implantation is considered the most effective rehabilitation for individuals who are suffering from profound hearing loss and aren't responsive to hearing aids. However; patients vary in their outcome and satisfaction after cochlear implantation. So, outcome measures for evaluation of performance with cochlear implantation is very important as adequate hearing is linked to improved communication school performance, development of speech and language, improve speech perception and discrimination in different environmental conditions and even enable CI users to use their cell phone. A successful cochlear implant program involves many steps starting by hearing screening and extend to postoperative rehabilitation. Good performance and positive outcomes of cochlear implantation can be carried in many manners as speech, reading, speech perception, and word learning skills.

Keywords: Cochlear implant (CI), Cochlear implantation, Rehabilitation, outcome, Evaluation.

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Introduction

Hearing loss occurs in about 1-3 live births per 1,000. Discovering hearing loss as early as possible and dealing with it is serious since early intervention is linked to improved communication outcomes, school performance, and acquisition of language and speech discrimination in different environmental circumstances. (1)

Ramsden reported that cochlear implantation (CI) is the most important invention in the rehabilitation of profound hearing loss since the invention of the hearing aid. It considered the most effective rehabilitation for individuals who are suffering from profound hearing loss and aren't responsive to hearing aids .(2)

It is well recognized that hearing within normal range is a requirement that is linked directly to the development of speech and language, so CI has a very important role in restoration of hearing in individuals who are either born deaf or those who developed significant hearing loss later on. Early stimulation of the central auditory pathway, especially in pre-school ages, leads toimproved acoustic memory and sound discrimination. (3)

Choo and Mienzen Derr said that a successful program of cochlear implantation should include many steps starting by neonatal hearing screening up to post-operative rehabilitation, to guarantee the greatest outcome. (4)

II-Physiology of hearing and cochlear implantation:

When Sound is applied it is collected by auricle, an acoustic pressure wave passes through the external auditory canal and tympanic membrane, transformed to mechanical vibrations in the middle ear. Ossicles in the middle ear travel these mechanical vibrations to the oval window, whose motility generates pressure waves that cause in the perilymph, that correlate to the auditory signal's frequency. This leads to basilar membrane vibration, which lead to deflection of the hair cells attached to it. The hair cells' deflection generates signals that lead to a neuronal impulse that travels to the auditory nerve, and ultimately to the auditory cortex .(5)

If there is a problem in the process of transformation of auditory signals into neuronal impulses, there will be hearing loss. For instance, when diseases, certain medications or hereditary conditions damage hair cells, pressure waves in the perilymph can't be transformed into neuronal impulses, and auditory signals are no longer be perceptible. (CI) restore hearing by stimulating the auditory nerve directly, and bypassing any obstacles that affect conversion of auditory signals into neural impulses .(6)

III-Definition of cochlear implant:

It is a biomechanical device which is placed in the cochlea and provides electric stimulation of the auditory nerve directly .(7)

IV-Cochlear implant Design:

CI has two components figure1, external part worn behind the ear, and an internal part that is implanted surgically in the mastoid. (8)

The external component has a microphone to detect acoustic signals and convert it into electrical signals, a speech processor to encode the electric signal with a battery and a coil that bio communicates the speech processor with the surgically inserted internal component .(9)

The internal component has a receiver to receive and decode the collected information, then sends these decoded data to the implanted electrode. The implanted array has the main job of the system and it composed of of a flexible silicone carrier with a variable number of electrodes. This electrode array is implanted in the Scala tympani of and stimulates directly the residual auditory fibers .(10)

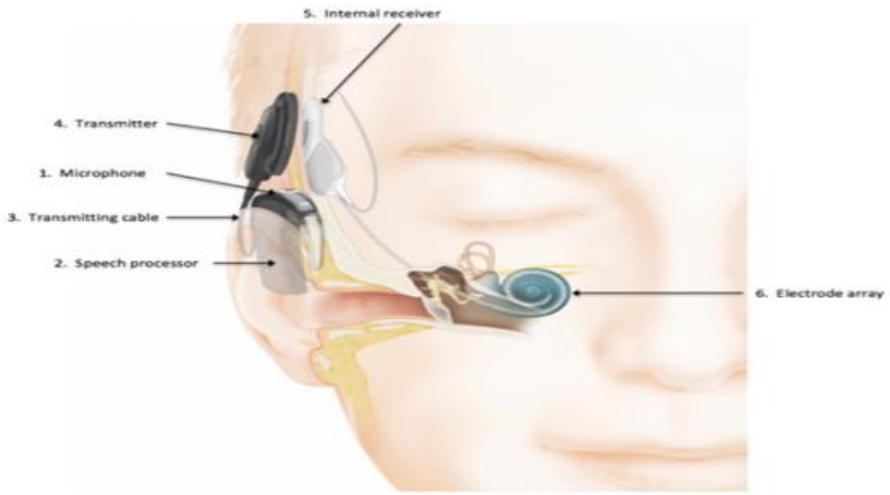

Fig.1. Parts of cochlear implant.

V-Cochlear implant processing: Microphones capture sound; pass it to the speech processor, where the acoustic signal is decoded. These signals are then sent by the external coil to a receiving coil placed beneath the skin. These electrical signals are then sent to the implanted array. The electrodes induce electric field by biphasic current pulses that stimulate the cochlear nerve fibers .(11)

According to the place of the stimulated electrode, different cochlear nerve fibers are stimulated and different frequencies can be received and hence different specific auditory sensation .(12)

VI-Candidate:

Individuals with substantial hearing loss, who cannot hear adequately by hearing aids even the powerful ones and are unable to enhance their oral communication skills even by regular and continuous speech therapy. (13)

1- Adults. (14)

- Age: 18 years old or older.
-Bilateral moderate to profound sensorineural hearing loss.
-Restricted benefit from hearing aids; preoperative scores ≤ 50% sentence recognition in the ear to be implanted and ≤60% in the other ear or binaurally.

2- Children (2-17 Years). (15)

-Bilateral Severe to profound hearing loss.
-Restricted benefit from binaural hearing aids.
-Multisyllabic Lexical Neighborhood Test (MLNT) or Lexical Neighborhood Test (LNT) scores ≤ 30%.

3- Children (9-24 Months). (15)

-Bilateral Profound hearing loss.
-Restricted benefit from binaural hearing aids.

VII-Exclusion criteria .(8)

1-Absolute:

-Congenital absence of the cochlea.
-Congenital absence of cochlear nerve.
-Severe mental retardation.
-Acute/chronic otitis media and mastoiditis without eradication of the disease**.**

2-Relative:

-Associated abnormal medical condition (e.g. pulmonary, cardiac, and hematologic).
-Epilepsy (if not controlled).
-Not offered postoperative rehabilitation.

VIII-Candidacy evaluation:

Complete evaluation; medical, audiological, and radiological evaluation, neurological in addition to evaluation of speech and language .Also patient /family counseling is a key component, it is important to make clear to patient/ family benefits from CI and to have realistic explanation. (16)

1-Audiological evaluation:

a- Visual reinforcement audiometry and auditory evoked response audiometry are the primary methods for determining hearing sensitivity as the age of implantation decreases.

b- FrequencyspecificAuditory brainstem response and auditory steady state response. [17]

c- Speech/auditory perception tests according to the age and linguistic ability of the child; includes closed set measurements of prosodic features, word identification, and speech feature identify-cation in addition to it vary from open set word and sentence recognition .[18]

d- It's possible to monitor a child's development overtime and scale their ability along a contin-uum by employing tests that are appropriate for their age and language level, speech recognition criteria include limited benefit from binaural amplification trial with word recognition tests like Multisyllabic Lexical Neighborhood test Lexical Neighborhood test score ≤ 30% for 2-17 years and limited benefit from binaural amplification trial for 12-24 months. [19]

2- Medical evaluation:

It is to verify if the child can withstand general anesthesia and surgical procedure. [20]

3- Vaccination: as children with SNHL are at gr-eater risk of having meningitis .[21]

4-Radiological evaluation:

a- MAGNETIC resonance imaging (MRI) to confirm presence of normal cochlear duct to implant the electrode, and confirm presence of a cochlear nerve to carry the signal to auditory cortex .[22]

b- High resolution computed tomography to detect cochlear congenital anomalies, number and pate-ncy of the cochlear turns, width of the internal auditory canal, the position of facial nerve and the vascular structure, and the anatomy of the middle ear and mastoid. [23]

5-Psychological evaluation:

Pervasive disorders and poor health quality of life are more common in patients with hearing loss, also for counselling toward appropriate expectation .[24]

IX-Subjective and objective measures used in programming:

Fitting the external sound processor is the critical point in rehabilitation with CI. Programming is based on combination of both psychophysical and objective measures. [25]

The main goal of fitting is to adjust the implant so it can effectively transform acoustic signals to electric signal for each stimulated electrode .[26]

Both behavioral and objective measures together can yield better evaluation outcome. [27]

1-Behavioral measures:

a- Conditioned play audiometry (CPA): Play audi-ometry is used to measure the threshold level in children with developmental age between 2 and 5 years old. [28]

b- Behavioral Observation Audiometry (BOA): It is largely subjective test as depends on the ability of the audiologist to detect response from the child's behavior. It is used in case of failure of conditioning of children. [28]

2-Objective physiologic measures:

Used for several purposes:

- Preoperative: prediction of nerve fibers survival, which side to implant and prediction of potential benefit from CI
- Intraoperative: confirm device integrity and meas-ure specific electrode output intraoperatively.
- Postoperative: confirm device integrity and meas-ure specific electrode output and to supplement various behavioral measures postoperatively .[29]

Objective measures include. [30]

a- Electrically compound action potential (ECAP).
b- Electrically evoked stapedial reflex (ESRT).
c- Electrically evoked auditory brainstem response (EABR).

X-Evaluation of outcome of CI:

It is the most important step after fitting of CI .[31]

Good performance with CI can be represented in more than one manner, reading, speech, word learn-ing skills and speech perception. [32,33].

Types of outcome measures:

a- Monitoring hearing related outcome with both subjective and objective measures. (34)

b- Tracking auditory related performance overtime .(34)

c-A test battery of outcome evaluation tools. (35)

1-Functional assessment:

- LikeQuestionnaires, diaries, and interviews. (35)
- It has advantage of that can be done while parents sitting and waiting their children to complete hearing tests. (31)

-Limitation of the functional assessment: questionaires are more appropriately administrated in the native language of the family and there may be challenges for caregivers who have literacy issues .(36)

2-Subjective measures:

a- Aided sound field threshold:
It measures threshold level and most comfortable level which can be used in mapping. Its limitations include the impact of room and circuit noise, and patient response to low sounds doesn't provide an indication of performance to moderate levels. (36)

b- Aided speech sound discrimination and early measures of speech recognition which require the use of age appropriate tests. (37)

c- Aided live voice sound detection and discrimination

d- Discrimination between various speech sound pattern (i.e.,"ahhh" vs, "ah ah ah". (36)

e- The word intelligibility by picture identification (WIPI) test: the test consists of four 25 item word lists with a vocabulary that is appropriate for preschool children. The child responds to each item by pointing to one of six pictures on a page, one being the test item .(38)
f-The Early Speech Perception test (ESPT): is a closed set measure of simple speech perception tasks using words and is intended for children who are 2 or more years. (39)

3-Objective measures:

Electric auditory brainstem response (EABR):

EABR testing may be performed for the following reasons:

-To verify adequate placement of the cochlear implant or auditory brainstem implant electrodes during surgery

-To estimate thresholds and comfortable levels in infants, young children or other patients who cannot be assessed using behavioral techniques

-To assist in mapping the cochlear implant or auditory brainstem implant device

-To assess interactions between electrode channels

-To determine the most appropriate rates of stimulation. (40)

b- Middle latency auditory evoked potential:
Wave pa of MLR isn't contaminated as it has relatively remote time frame. It can be elicited using lower current level with longer duration pulse. (41)

a- Cortical auditory evoked potential:
It can be used to assess hearing sensitivity, central auditory processing and neural encoding of speech sound; the p1 cortical evoked potential has been established as a biomarker for assessing the matura-tion of the central auditory system in children .(42)

Summary:

Evaluation of the outcome of cochlear implantation is very important issue since adequate hearing is linked to improved communication outcomes and school performance, development of speech and language, enhances speech perception in quiet and noise and even allows CI recipients to use the telephone. CI is a biomechanical device which is placed in the cochlea and provides electric stimulation of the auditory nerve directly. Sound is picked up by one or several microphones attached to the ear and transmitted to a speech processor, where the acoustic signal is digitized and encoded. These electrical impulses are sent to the array of electrodes inserted into the cochlea. The electrodes stimulate the auditory nerve fibers within the cochlea by inducing an electrical field through biphasic current pulses. Cochlear Implants can be applied in adults and children with bilateral, severe to profound sensorineural hearing loss, who have not benefited by the use of powerful hearing aids and have not improved their oral communication skills by specific speech therapy. A complete evaluation of candidate should

compromise a series of tests; the basic evaluation of the cochlear implant candidate includes medical, audiological, and radiological evaluation, as well as speech and language evaluation; furthermore patient/family counseling is fundamental to explain the potential benefits and to create realistic explanation. Acritical aspect of treating a child with a cochlear implant is the fitting of the external sound processor. Clinical fitting is based on combination of psychophysical and objective measures. The process of fitting of cochlear Implant includes an important step called outcome evaluation. Positive outcomes have been found in a variety of domains including, reading, speech, word learning skills and speech perception.

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