Impaired Vestibular Function After Cochlear Implantation in Children: Role of Static Posturography

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Abstract To identify vestibular dysfunction in children after cochlear implant surgery and to study the utility of static posturography in evaluating vestibular function in children. A prospective study was carried out on 25 children between 2 and 7 years of age with sensorineural hearing loss with no overt vestibular dysfunction. All children underwent static posturography using Synapsis Posturographic System (SPS) software (Version 3.0, REV C) using a static platform with foam. The centre of pressure (COP) shift was recorded as statokinesiogram on the software and the mean vestibular, visual and somesthetic scores were obtained. Cochlear implantation (CI) surgery was done with insertion of Med-El Pulsar standard cochlear implant with 12 twin electrodes. Children were evaluated again after 4 weeks of CI surgery (2 weeks after switch on) with static posturography on the same SPS software. The scores obtained were compared with pre op value and data analyzed statistically by paired t tests on SPSS 18 software. The mean age was 4.6 years with range 2–7 years. All the children in the study were able to complete the test with no difficulty and the mean time required for each child was

10.2 min. The mean pre op somesthetic score was 95.16 (SD 1.52) and post op score was 94.06 (SD 1.79). The mean pre op visual score was 86.64 (SD 2.24) and post op score was 82.55 (2.89). The mean pre op vestibular score was 84.11 (SD 2.20) and post op score was 73.66 (SD 4.25). Correlation and statistical analysis of the pre and post values of each score revealed statistically significant reduction in vestibular scores post CI. The vestibular system is at high risk of injury leading to vestibular dysfunction in children during CI. Our study found the static posturography as a simple, fast and efficient tool to screen children for vestibular dysfunction post CI. Identifying the dysfunction early can help in initiating early rehabilitation measures.

Keywords Static posturography · Vestibular dysfunction · Cochlear implant

Introduction

The auditory system is closely related to the vestibular system in terms of embryological development, innervation and vascular supply. Children with profound sensorineural hearing loss (SNHL) who undergo cochlear implantation (CI) have risk of surgically induced vestibular dysfunction due to instrumentation into the labyrinth. Although there are numerous reports of vestibular dysfunction in profoundly deaf adults receiving CI, there is paucity of data detailing vestibular dysfunction in children with profound SNHL receiving CI. This may be due to the lower reporting of symptoms in children as they are not able to express themselves or may be due to the difficulties in the vestibular evaluation in a child. The aim of our study was to identify vestibular dysfunction in children after CI

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surgery and to evaluate the utility of static posturography in evaluating vestibular function in children.

Materials and Methods

A prospective study was carried out at a ENT centre of a tertiary care referral government hospital in India. The study was approved by the institutional ethical committee. The study group included 25 children of the age group 2–7 years with congenital non-syndromic profound SNHL with no overt balance disorder. The children were candidates for CI and were evaluated by the institutional CI candidacy committee. Exclusion criteria included children who could not perform the tests due to physical limitations, children with history of ototoxic medication intake, head injury or central causes of giddiness and children showing abnormal inner ear anatomy on imaging. All children underwent detailed history, complete ENT and otoneurological examination, various audiological assessment tests and radiological evaluation with HRCT temporal bone and MRI brain.

The study group underwent Static Posturography using Synapsis Posturographic System (SPS) software (Version 3.0, REV C) using a static platform with foam to provide altered proprioception (Fig. 1). The static posturographic recordings were made in the vestibular lab after explaining the procedure to the child as well as the guardian. The tests were performed in the presence of the guardian of the child in four different conditions as described in Table 1 and demonstrated in Fig. 2a–d.

The software of the static platform recorded the centre of pressure (COP) shift as statokinesiogram. Each test condition was performed twice for 20 s and the average value was calculated by the software. On completion of the four test condition, the following scores were obtained: (1) Visual score, (2) Vestibular score and (3) Somesthetic score. These scores are the ratio (expressed as percentages) of COP shift in different conditions as described in Table 2. These scores indicated the contribution of each of these three modalities (visual, vestibular and somesthetic) in the maintenance of balance of an individual. The above scores were also obtained for Medio-lateral (ML) and Antero-posterior axis (AP) depending on the medial to lateral and anterior to posterior sway of the child during the tests. A Combined score of the mean combined value (AP + ML) was also recorded for each score.

All children underwent CI with insertion of Med-El Pulsar standard cochlear implant with 12 electrodes. The CI surgery was done by a senior neuro-otologist with a large experience in CI surgery. The surgical approach used was the postaural facial recess approach with cochleostomy performed anterior to the round window. The children after

Fig. 1 Static platform

CI surgery were again evaluated at 4 weeks (2 weeks after switch on) by static posturography. The scores obtained were compared with pre-op values and data analyzed by means of SPSS Ver 18 software. The results were statistically analysed by paired t tests for their statistical significance.

Results

Out of 25 children, 15 Children were males and 10 were females (M:F = 3:2). The mean age was 4.6 years with range 2–7 years. All 25 children showed profound SNHL with intact and mobile tympanic membrane. Imaging revealed normal internal acoustic meatus and vestibulo-cochlear apparatus bilaterally in all cases with two cases showing focal areas of demyelination on MR imaging. However, these two children after pediatric evaluation were found to be normal developmentally and were included in the study.

All the children in the study were able to complete the test with no difficulty. The mean time required for each child was 10.2 min. Figure 3 shows the recording of

Table 1 Various conditions studied by static platform and their inputs

Condition	Somaesthetic	Visual	Vestibular
Condition I: Eyes open, stable platform (no foam)	+	+	+
Condition II: Eyes closed, stable platform (no foam)	+	–	+
Condition III: Eyes open, unstable platform (with foam)	–	+	+
Condition IV: Eyes closed, unstable platform (with foam)	–	–	+

Fig. 2 (a, b, c, d) Static posturography

statokinesiogram showing shift in COP in a child with normal and abnormal balance.

Of the 25 children, there was change in the visual scores in 1 (4%) and somesthetic scores in 2 (8%) after CI which

was not found to be statistically significant. The vestibular scores changed in 9 children (36%) which was found to be statistically significant ($p < 0.5$).

Table 2 The scores obtained by the static platform

Visual score	Condition III
	Condition I
Vestibular score	Condition IV
	Condition I
Somesthetic score	Condition II
	Condition I

The somesthetic, visual and vestibular scores before and after CI are depicted in Figs. 4, 5 and 6. The mean pre op somesthetic score was 95.16 (SD 1.52) and post op score was 94.06 (SD 1.79). The mean pre op visual score was 86.64 (SD 2.24) and post op score was 82.55 (2.89). Vestibular The mean pre op vestibular score was 84.11 (SD 2.20) and post op score was 73.66 (SD 4.25). The preop visual, vestibular and somesthetic scores were found to be

Fig. 3 Statokinesiogram showing normal and abnormal COP shifts **Fig. 4** Scatter diagram: Somaesthetic score pre and post cochlear implantation

Fig. 5 Scatter diagram: Visual score pre and post cochlear implantation

Fig. 6 Scatter diagram: Vestibular score pre and post cochlear implantation

Table 3 Comparison between somesthetic, visual and vestibular scores pre and post CI

Pre and Post CI	Mean (preop)	Mean (postop)	Difference in mean	Significance (<i>p</i> value)
Somaesthetic score	95.16	94.06	1.1	0.812
Visual score	86.64	82.55	4.09	0.203
Vestibular score	84.11	73.66	10.45	0.043

Bold value indicates that the result is less than 0.05 and hence statistically significant

within the normative values as per the software. On correlating the pre and post operative scores, it was seen that there is a statistically significant reduction in vestibular scores post CI ($p < 0.5$) whereas there is no change in the somaesthetic and visual scores (Table 3).

Discussion

Cochlear implantation is a safe and effective treatment in patients with severe to profound SNHL. The introduction of the electrode array into the cochlea does place the

vestibular system at risk. The effects can be both to the semicircular canals due to the change in inner ear fluid pressure and also to the otolith organs due to their close proximity to the round window. The symptoms of dizziness after CI have been reported in the literature as an acute post-operative attack or delayed episodic type of giddiness [1, 2]. Almost all the studies have been performed in adults and have reported an incidence of symptoms of dizziness between 2 and 60% [1]. Contrary to these is a study by Migliaccio et al. [3] on adult patients which described no significant change in vestibulo-ocular reflex after CI.

Various authors have evaluated post CI vestibular dysfunction by subjective scores like Dizziness Handicap Inventory, Activity Balance Confidence questionnaires and objective tests like caloric irrigation (vestibuloocular reflex), vestibular-evoked myogenic potential (saccular function), rotatory chair and posturography. Most of these objective tests have indicated vestibular dysfunction in children after CI to be in the range of 10–70% [4, 5]. Tests using Caloric irrigation with ENG have shown a dysfunction in 0–60% [1, 2, 4, 6–9], rotatory chair in 20–38% [9, 10] and VEMP in the range of 13–62.5% after CI surgery [8, 11].

This potential vestibular damage in CI is hypothesised as due to the surgical insult during cochleostomy or insertion of electrodes, changes in the intracochlear fluid pressure causing mechanical alterations of the cupulae and cristae and due to galvanic current after switch on of CI causing stimulation of vestibular system [12]. Todt et al. [8] evaluated various surgical approaches of CI and found that round window approach to be the least traumatic with less vestibular dysfunction. Long term changes in inner ear after CI leading to endolymphatic hydrops and attacks of giddiness have also been reported [1]. A study on the post mortem histopathologic studies on the temporal bones of patients with CI has demonstrated fibrosis in the vestibule, collapse of the saccule, decrease in ganglion cells, and formation of hydrops in the inner ear supporting the above theories [13].

Posturography is the general term encompassing all the techniques used to quantify postural control in upright stance, in either static or dynamic conditions, by means of a force platform [14]. Static platform posturography involves stance or tandem stance on a fixed platform with eyes open or closed. It uses the Romberg test, and the outcome is quantified with respect to changes in COP sway amplitude, distance, or velocity as visual, vestibular and somesthetic scores. The literature has reported a varied level of sensitivity and specificity of static posturography [15–17]. A review of platform posturography by Di Fabio RP has described the sensitivity of static posturography as 61% (range 20–83%) in detecting peripheral vestibular disorders (PVD) which is higher than dynamic posturography (40%).

The sensitivity improves from 61 to 89% in combination with other vestibular tests. The specificity is high (95%) in ruling out PVD if the subject passes the test [18].

In our study vestibular dysfunction was seen in 36% of children after CI which is a significant number and is commensurate to various other published literature on this subject. In addition to the significant change in vestibular function we also found that static posturography is a simple, fast, non invasive, objective modality of testing especially in children. It is repeatable and can be better tolerated in small children as it did not require any ear irrigation, sedation and placement of electrodes which may be difficult to perform after surgery to ear.

The actual incidence of vestibular injury due to CI may be masked by central compensation of unilateral vestibular hypofunction (UVH) in unilateral recipients. However these findings of vestibular dysfunction detected by static posturography has clinical significance as the children having vestibular dysfunction have difficulty in expressing their symptoms as compared to adults. In view of the simplicity and repeatability of static posturography in identifying vestibular dysfunction, it is possible to identify children with decompensated vestibular function after CI. Hence the recipients and the guardians need to be counselled regarding the vestibular dysfunction and its compensation. As compared to unilateral CI, these results have far greater significance in simultaneous bilateral implantation or implantation in children with single functioning labyrinth where the loss of bilateral vestibular function post surgery may result in non-compensated vertigo causing significant handicap [19].

Conclusion

The vestibular system is at high risk of injury leading to vestibular dysfunction in children during CI. Our study found the static posturography as a simple, fast and efficient tool to screen children for vestibular dysfunction post CI. Identifying the dysfunction early can help in initiating early rehabilitation measures. The above results have significant impact on patients undergoing simultaneous bilateral CI.

Compliance with Ethical Standards

Conflict of interest No author has received any research grants and have any conflict of interests.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants/parents or guardians included in the study.

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