Changes in caloric responses after temporal bone surgery with posterior tympanotomy

Kazumasa Kondoh, Tadashi Kitahara *, Tetsuo Morihana, Koichi Yamamoto, Takeshi Kubo, Shin-ichi Okumura

Osaka University, Osaka Rosai Hospital, Japan

Received 22 March 2008; accepted 3 November 2008
Available online 25 December 2008

Abstract

Objective: To elucidate the role of facial recess bony plate in the thermal transmission route from external auditory canal to lateral semicircular canal during caloric stimulation test, we performed the test on patients before and after removal of the plate, i.e. posterior tympanotomy. In the present study, we adopted facial nerve decompression (FND) as posterior tympanotomy without surgery-induced inner ear damages and cochlear implantation (CI) as posterior tympanotomy with surgery-induced inner ear damages.

Methods: Between 1999 and 2003, we performed FND on 19 patients with unilateral facial nerve paresis due to Bell’s palsy (n = 7), Ramsay-Hunt syndrome (n = 7) or facial nerve trauma (n = 5) at Osaka Rosai Hospital. We also performed CI on 34 patients with bilateral deafness at Osaka University Hospital. To examine effects of FND or CI on caloric responses in vestibular periphery, caloric stimulation (30 °C cold water and 44 °C hot water) with ENG was performed twice, just before and 6 months after surgery in each subject. The caloric-induced nystagmus was recorded by using ENG under dark and open-eyes situation to calculate the maximum slow phase eye velocity.

Results: In cases of FND (n = 19), there were significant decreases between pre- and post-operative 30 °C responses (t-test: p = 0.049 < 0.05). There were no significant differences between pre- and post-operative 44 °C responses (t-test: p = 0.467 > 0.05). In cases of CI (n = 34), there were significant changes between pre and post-operative responses in both temperatures (t-test: p < 0.0001 in 30 °C; p = 0.011 < 0.05 in 44 °C).

Conclusion: The insertion of electrodes during CI did some damages to vestibular peripheral function and reduced both hot and cold caloric responses according to the results of CI. However, the procedure during posterior tympanotomy could also decrease caloric responses especially in cold stimulation according to the results of FND. Therefore, we should consider the effect of structural change in temporal bone on the thermal transmission in case of evaluation of vestibular peripheral function by using caloric stimulation test.

© 2008 Elsevier Ireland Ltd. All rights reserved.

Keywords: Caloric stimulation test; Facial nerve decompression; Cochlear implantation; Facial recess; Posterior tympanotomy; Endolymphatic convection theory

1. Introduction

Caloric stimulation test is one of the simplest and most popular examinations for inner ear function. According to Barany’s report of this examination in 1906 [1], one of the most powerful mechanisms of caloric-induced nystagmus has been supposed “endolymphatic convection theory”. In order to elucidate the role of facial recess bony plate in the thermal transmission route from external auditory canal to lateral semicircular canal during caloric stimulation test, we performed the test on patients before and after temporal bone surgery with removal of the plate, i.e. posterior tympanotomy. In the present study, we adopted facial nerve decompression (FND) as posterior tympanotomy without surgery-induced inner ear damages and cochlear implantation (CI) as posterior tympanotomy with surgery-induced inner ear damages.

* Corresponding author at: Department of Otolaryngology, Osaka University, School of Medicine, 2-2 Yamada-oka, Suita-city, Osaka 565-0871, Japan. Tel.: +81 6 6879 3951; fax: +81 6 6879 3959.
E-mail address: tkitahara@ent.med.osaka-u.ac.jp (T. Kitahara).
2. Materials and methods

We performed FND on 19 patients with unilateral facial nerve paresis due to Bell’s palsy (n = 7), Ramsay-Hunt syndrome (n = 7) or facial nerve trauma (n = 5) at Osaka Rosai Hospital between 1999 and 2003. There were 9 females and 10 males ranging in age from 25 years to 73 years, with a mean age of 49.9. Cases with acute vestibular peripheral dysfunction were excluded from FND group. We performed CI on 34 patients with bilateral deafness at Osaka University Hospital between 1999 and 2003. There were 17 females and 17 males ranging in age from 17 years to 75 years, with a mean age of 52.0. Cases with daily fluctuating vestibular function were excluded from CI group in accordance with their past history of vertiginous sensation like Meniere’s disease. There were no significant differences in patients’ background between FND and CI.

FND and CI were both performed under general anesthesia. The following parts of procedures in both surgeries were common: postauricular incision, simple total mastoidectomy and removal of the facial recess bony-bar from buttress to tympanic sinus. In different parts between these two surgeries, FND included procedures to expose facial nerve proximally from the horizontal portion of facial nerve to the genuculate ganglion during antrotomy and distally from the vertical portion of facial nerve to the vicinity of stylo-mastoid foramen during mastoidectomy [2]. CI included procedures to make a small hole of 1–2 mm in the scala tympani and insert an electrode there [3].

To examine effects of FND or CI on caloric responses in vestibular periphery, caloric stimulation test with ENG was performed twice, just before and 6 months after surgery in each subject. The head was inclined 30° from horizontal so as to make the lateral canal horizontal. 30°C cold water and 44°C hot water (20 cc respectively) were injected into the external auditory meatus for 10 s by turns. The caloric-induced nystagmus was recorded by using DC-ENG under dark and open-eyes situation to calculate the maximum slow phase eye velocity (max-SPEV). Electrodes were placed around the orbit to record horizontal and vertical eye movements, although interpretation could be confounded by muscle and blink artifacts and poor signal-to-noise ratio. Since an observation of nystagmus reaction could easily vary from one observer to the next, the tests were consistently performed by the same examiner.

We statistically analyzed all the data in Figs. 1 and 2 using t-test. ANOVA was performed only for statistical analysis between FND-induced changes in caloric responses and CI-induced ones.

3. Results

In cases of FND, there were significant differences between pre- (17.98 ± 6.57/s) and post-operative 30°C responses (16.42 ± 7.33/s) (t-test: p = 0.049 < 0.05) (Fig. 1A). There were no significant differences between pre- (16.47 ± 7.98/s) and post-operative 44°C responses (15.82 ± 8.67/s) (t-test: p = 0.467 > 0.05) (Fig. 1B). In cases of CI, there were significant differences between pre- (17.90 ± 6.69/s in 30°C; 20.22 ± 8.48/s in 44°C) and post-operative responses (12.31 ± 6.17/s in 30°C; 15.03 ± 8.74/s in 44°C) in both temperatures (t-test: p < 0.0001 in 30°C; p = 0.011 < 0.05 in 44°C) (Fig. 2A and B).

To compare FND- and CI-induced changes in max-SPEV during hot or cold caloric stimulation, we examined repeated measure ANOVA between results in these two groups. There were no significant differences in post-operative decreases of max-SPEV in hot or cold caloric stimulation between FND and CI (ANOVA: p = 0.230 > 0.05 in 30°C; ANOVA: p = 0.392 > 0.05 in 44°C) (data not shown).

Fig. 1. The maximum slow phase eye velocity (max-SPEV) in pre- and post-operation of facial nerve decompression (FND). (A) Shows max-SPEV at 30°C in pre- and post-operation of FND. There were significant differences between pre- (17.98 ± 6.57/s) and post-operative 30°C responses (16.42 ± 7.33/s) (t-test: p = 0.049 < 0.05). (B) Shows max-SPEV at 44°C in pre- and post-operation of FND. There were no significant differences between pre- (16.47 ± 7.98/s) and post-operative 44°C responses (15.82 ± 8.67/s) (t-test: p = 0.467 > 0.05).
As for the non-operated ear in both groups, FND and CI, there were no significant changes in caloric responses between before and after surgery (data not shown).

4. Discussion

In cases of FND, there were significant decreases between pre- and post-operative 30 °C responses. There were no significant differences between pre- and post-operative 44 °C responses. FND is a temporal bone surgery with posterior tympanotomy free from any surgery-induced damages to inner ear function. This suggests that posterior tympanotomy during FND affected the thermal transmission route from external auditory canal to lateral semicircular canal, resulting in significant reduction of caloric responses especially in cold stimulation. In cases of CI, there were significant changes between pre- and post-operative responses in both temperatures. Actually, CI is a temporal bone surgery with posterior tympanotomy including some inner ear damages due to insertion of electrodes. However, in the present study, there were no significant differences in post-operative decreases of max-SPEV in either hot or cold stimulation in comparison with FND and CI. Strictly speaking, this statistical analysis means that CI-induced decreases of max-SPEV in caloric stimulation could be due to no more than the structural change in temporal bone after CI. All these findings suggest that after temporal bone surgery with posterior tympanotomy, we should consider the effect of structural change in temporal bone on the thermal transmission during caloric stimulation in case of evaluation of vestibular peripheral function by using caloric stimulation test.

Facial recess bony plate is supposed a main structure for the thermal transmission route from external auditory canal to lateral semicircular canal. Zangemeister and Bock reported that patients with poorly pneumatized mastoid bone like chronic otitis media showed better transfer of caloric stimulation and greater caloric-induced nystagmus than those with well pneumatized one [4]. Schmaltz proposed that the bony connection between posterior–inferior wall of external canal and lateral canal composed of the main route of heat transfer [5]. On the other hand, mastoid-aeration is also supposed an essential factor for the thermal transmission route from external auditory canal to lateral semicircular canal. Harrington demonstrated in experimental studies using cadaveric temporal bones that there was no significant difference in the temperature change of lateral semicircular canal during caloric stimulation even after posterior tympanotomy and that the bony connection between posterior wall of ear canal and horizontal semicircular canal was not so important in the transfer of caloric stimulation [6]. Moreover, O’Neill described that the temperature change of the lateral semicircular canal during caloric stimulation was not affected even after the bony ridge removal between external meatus and inner ear in isolated human cadaveric temporal bones and that the middle ear space besides the bony ridge was much more important for the route of caloric stimulation [7]. In the present study, FND was a temporal bone surgery with mastoid-aeration as well as removal of facial nerve bony plate and actually caused the post-operative decreases in max-SPEV. Taken together, it is suggested that facial recess bony plate could make a much more important role in the thermal transmission route from external auditory canal to lateral semicircular canal than mastoid-aeration.

In cases of FND, there were significant differences between pre- and post-operative 30 °C responses, although there were no significant differences between pre- and post-operative 44 °C responses. The reasons remain unclear why the discrepancy could be observed between FND-induced changes in caloric responses to hot and cold temperatures. One possible explanation is as follows: posterior tympanotomy could take the main action site of caloric stimulation in different location in inner ear. In the post-operative
condition after posterior tympanotomy, the thermal change in tympanic cavity during caloric stimulation in spine could be much more predominant than that in mastoid cavity through facial recess. Warm aeration in tympanic cavity after hot stimulation could be easily lifted and transferred to the ampulla site of lateral semicircular canal, though cold aeration after cold stimulation could be easily sunk and hard to be transferred there. Another possible explanation is that there could be additional theories other than Barany’s endolymphatic convection for caloric-induced nystagmus [1]. For example, there have recently been a couple of reports concerned with thermo-receptors in inner ear endo-organs [8–10]. These receptors, so-called transient receptor potential superfamily V (TRPV), are actually heat-sensitive in vestibular periphery and possibly responsive to the thermal change during hot stimulation [11]. If the thermal sensitivity of TRPVs would be much greater than endolymphatic convection flow, vestibular hair cells could be depolarized firstly by these receptors’ activation during hot stimulation in the post-operative condition after posterior tympanotomy. Interestingly these receptors are not responsive to cold stimulation and therefore temporal bone surgery with posterior tympanotomy such as FND could affect caloric-induced nystagmus much more during cold stimulation than during hot one. Further studies are needed to clarify the mechanisms of caloric-induced nystagmus other than Barany’s endolymphatic convection [1].

References