

## INVITED REVIEW

### Taste Disorder After Middle Ear Surgery

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Because patient demand for informed consent regarding surgical complications has been increasing over the past decade, otosurgeons have been required to explain potential complications such as taste disorder after surgery. In this article, a series of our studies and related literature were reviewed and the following information was proven to be useful in daily practice.

(1) Taste disorder occurs more frequently with preservation of the chorda tympani nerve (CTN) than with section of CTN. (2) With preservation of CTN, the recovery rate of CTN function is higher in younger patients than in middle-aged or older patients. (3) Taste disorder easily occurs and persists in patients with non-inflammatory disease such as otosclerosis. (4) With unilateral section of CTN, about 50% of patients complain of taste disorder, however taste disorder will cease within one year in most cases. (5) Recovery of threshold of electrogustometry is not related to recovery of symptoms, and it is delayed in most cases. (6) Even with bilateral section of CTN, patients do not complain of difficulty in tasting food within two years. (7) Elderly patients complain of taste disorder less frequently because taste naturally deteriorates with aging. (8) Because CTN has the ability to regenerate, it is desirable to preserve CTN during surgery or to anastomose the nerve ends if CTN is unavoidably cut. (9) Trigeminal sensations such as tongue numbness, tingling, and metallic taste may also develop after surgery, however the mechanism remains unclear.

The chorda tympani nerve (CTN) controls taste in the anterior two-thirds of the tongue on each side; it runs close to the annulus of the tympanic membrane, crossing the tympanic cavity between the incus and malleus. The CTN is initially encountered at this location when elevating the annulus and it is frequently damaged by traction, stretching and cutting during surgical procedures<sup>[1]</sup>. Because many surgeons consider hearing improvement to be the most important surgical result, taste disorder has rarely received attention during the last five decades. However, patients have recently tended to require otosurgeons to explain the potential for surgical complications before surgery. Based on mainly our clinical and experimental studies, we herein review changes in CTN function after middle ear surgery and propose procedures to handle CTN during surgery in order to minimize postoperative taste disorder.

#### *Points in which CTN is Frequently Touched*

There are three points at which CTN is commonly encountered during middle ear surgery (Figure 1). The most frequently touched point is the portion running just behind the annulus in the posterior-superior quadrant. Typical findings are seen during stapes surgery. When the tympanomeatal flap is elevated and the bony annulus is removed by drilling or chisel to see the incus-stapes joint, CTN is damaged by touching, traction, or stretching. The second most frequently touched point is the portion anterior to the malleus neck. When calcification is removed with a fine pick or the anterior tympanic scutum is cut using a chisel, injury to the CTN may occur without being apparent. The third most frequently touched point is the bifurcation from the descending portion of the facial nerve. As this portion runs through the bony canal, CTN is sometimes injured by drilling the opening of the facial recess during canal wall up procedure or cochlear implant surgery.

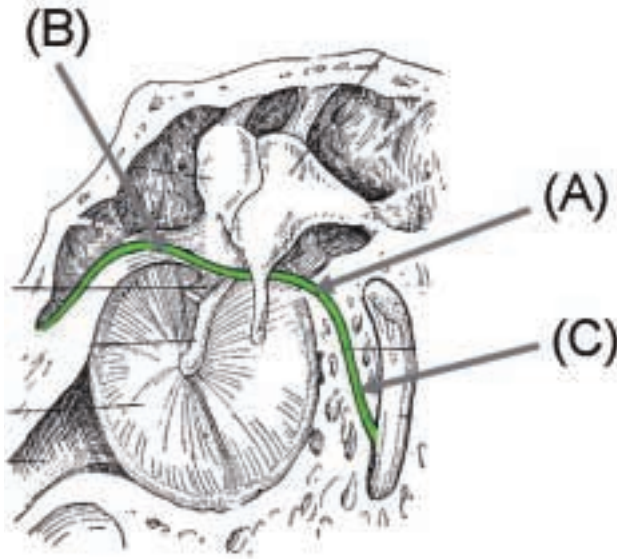
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**Figure 1.** Chorda tympani nerve illustrated with a view of the middle ear cavity. A: chorda tympani nerve behind the annulus of the posterior-superior quadrant; B: chorda tympani nerve in front of the malleus neck; C: chorda tympani nerve after bifurcation from the descending portion of the facial nerve.

#### How to evaluate taste function

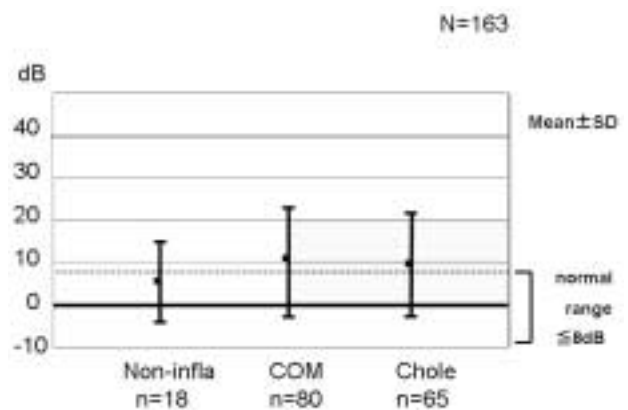
First, in order to evaluate patients' symptoms, questionnaires about taste disorder and tongue numbness were performed 2 weeks and 6 months postoperatively after obtaining patient consent. Second, in order to measure CTN function, electrogustometry (EGM) was performed according to the method described by Tomita et al<sup>[2]</sup>. The stimulation range of EGM threshold was -8 to 34 dB. The normal range was less than or equal to 8 dB. Cases that were not measured by EGM were statistically analyzed as 36 dB. The point measured with EGM was the ridge 2 cm behind the tip of the tongue.

In our previous studies, patients older than 60 years were excluded because their taste function is expected to have naturally deteriorated with age<sup>[3]</sup>.

#### Taste function before middle ear surgery

In our series examined between 1997 and 1999<sup>[4]</sup>, EGM threshold before surgery was  $4.2 \pm 9.4$  dB in the non-inflammatory group such as otosclerosis,  $10.6 \pm 13.5$  dB in the chronic otitis media (COM) group, and  $10.3 \pm 12.6$  dB in the cholesteatoma group (Figure 2). None of the patients complained of taste

disturbance, except one patient with facial palsy. Yaginuma et al.<sup>[5]</sup> reported that the EGM threshold was  $-1.0 \pm 6.2$  dB in the non-inflammatory group,  $-1.5 \pm 6.2$  dB in the COM group, and  $7.4 \pm 13.7$  dB in the pars flaccida cholesteatoma group, and  $9.6 \pm 18.2$  dB in the pars tensa cholesteatoma group. These studies suggested that the EGM threshold is higher in the COM and cholesteatoma groups than in the non-inflammatory group, but most of the patients did not complain of taste disorder before surgery.



**Figure 2.** EGM threshold before surgery is within the normal range in cases of non-inflammatory diseases, while it is a little higher than the normal range in cases of COM and cholesteatoma.

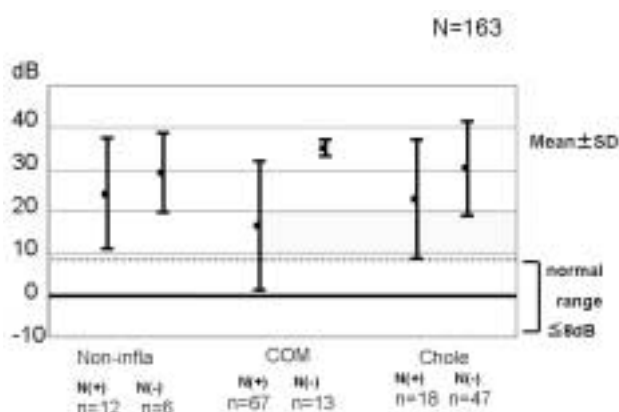
Because the CTN lacks any bony cover within the middle ear cavity, it is completely exposed to the effects of chronic infection. Histopathological study showed thickening of the perineural and epineural connective tissue, vacuolar degeneration of Schwann cells, proliferation of fibroblasts, and disorganization of the axons<sup>[6]</sup>. Ultrastructural study showed a decrease in the number of unmyelinated fibers, decrease in thickness of myelin sheaths, increase in collagen fibers, degeneration of myelinated fibers, and occasional presence of inflammatory cells and edema<sup>[7]</sup>. These findings suggest that CTN may gradually develop loss of function under persistent inflammation and that patients were much less likely to notice taste disturbance.

#### Taste function after preservation of CTN

##### (a) Symptoms

EGM threshold is elevated after surgery compared

with that before surgery regardless of preservation or section of CTN (Figure 3). This provides evidence that EGM represents the function of CTN.



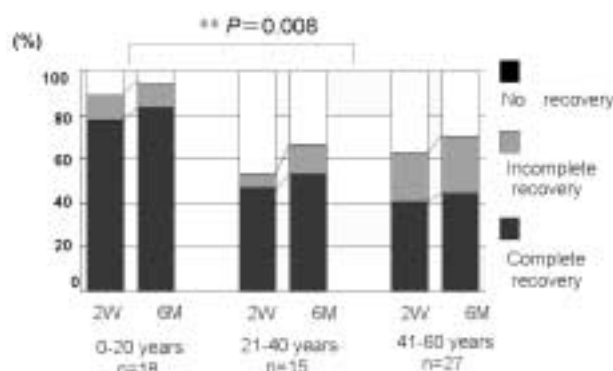
**Figure 3.** EGM threshold was elevated after surgery regardless of preservation (N+) or section (N-) of CTN.

Based on clinical experience, otologists know that patients less frequently complain of taste disorder when CTN is cut than when CTN is preserved. Our previous first report documented this phenomenon<sup>[4]</sup>. Patients complained of taste disturbance in 8/37 (22%) cases and tongue numbness in 6/37 (16%) cases after section of CTN, while 37/67 (55%) and 28/67 (42%) had these respective complaints after preservation of CTN. These percentages were significantly different. Other studies later confirmed our results<sup>[8,34]</sup>. It is possible that injury of the CTN by traction or stretching produces abnormal stimulation that was transferred to the peripheral organ, but this has not been established. Furthermore, since most of the symptoms had ceased within 6 months after surgery, taste disturbance and numbness in the tongue were not considered serious problems.

#### (b) Recovery rate in relation to age

To investigate the effect of age on recovery of CTN function after preservation of CTN, we selected patients with a normal EGM threshold before surgery and divided them into three age groups; 0-20 year old group, 21-40 year old group, and 41-60 year old group. Six months after surgery, the rate of complete recovery was 83% in patients aged 0-20 years, 53% in those aged 21-40 years, and 44% in those aged 41-60 years

(Figure 4). The youngest group showed a significantly higher recovery rate of EGM threshold than the middle-age or old-age group ( $P=0.008$  for all). Especially, children under 10 years old showed remarkable recovery of CTN function after surgery. These findings suggest that younger patients have a higher ability to regenerate CTN function, as is generally observed with other nerves.

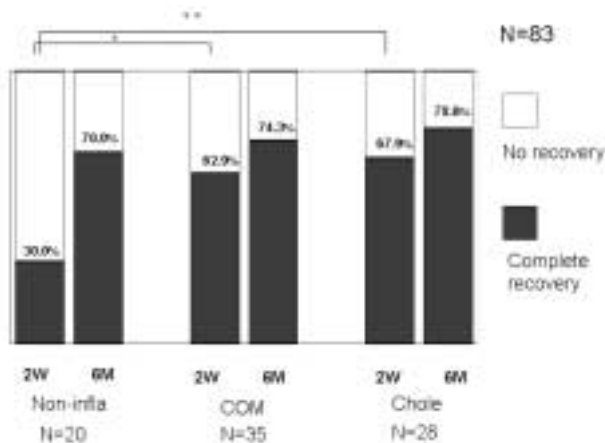


**Figure 4.** Rate of recovery of EGM threshold by age group 2 weeks and 6 months after surgery. The youngest group had a significantly higher rate of recovery than the other two age groups ( $P=0.008$ ). No recovery indicates that the threshold level did not improve or deteriorate; incomplete recovery, threshold level improved but did not reach the normal level; and complete recovery, the threshold level improved to the normal range (reprinted with permission from reference 4).

#### (c) Recovery rate in relation to type of diseases

Since early 1960, postoperative taste dysfunction has been examined in stapes surgery because CTN is not damaged by inflammation<sup>[9,10]</sup>. However, the recovery rate of CTN function in stapes surgery has not been compared with that in surgery for infectious diseases. In our study<sup>[11]</sup>, symptoms were present 2 weeks after surgery in 13/20 (65%) non-inflammatory disease patients, in 13/35 (37.1%) COM patients, and in 20/28 (71.4%) cholesteatoma patients, and those 6 months after surgery were present in 5/20 (25%), 2/35 (5.7%), and 2/28 (7.1%), respectively. The non-inflammatory group showed a higher rate of symptoms than the COM group or the cholesteatoma group. Our EGM study also showed that the non-inflammatory group had a significantly lower recovery rate than the COM group or the cholesteatoma group (Figure 5)<sup>[11]</sup>. These

findings and those of other studies<sup>[8,12,13,34]</sup> suggest the CTN is more sensitive to manipulation during stapes surgery than during other ear surgeries. Fortunately, symptoms abated within two years after surgery in most cases<sup>[14,15]</sup>.



**Figure 5.** Rate of recovery of EGM threshold in 3 groups at 2 weeks and 6 months after surgery. At 2 weeks, the group with non-inflammatory (NI) disease had a significantly lower rate of recovery than the group with chronic otitis media (COM; \* $p=0.015$ ) or the group with cholesteatoma (\*\* $p=0.008$ ). At 6 months, there were no significant differences among the 3 groups. "No recovery" indicates that threshold level did not improve or deteriorate, while "complete recovery" indicates that the threshold level improved to the normal range (reprinted with permission from reference 11).

#### (d) Bilateral cases

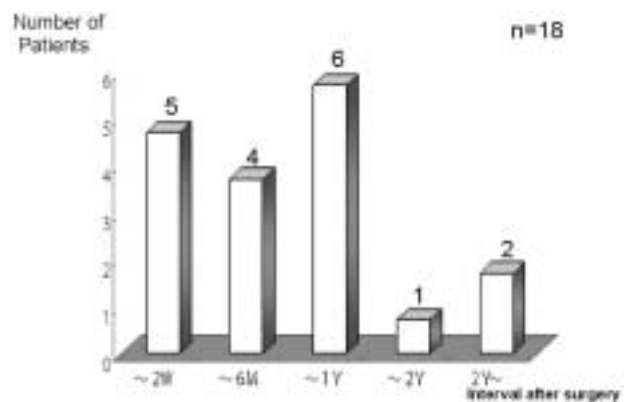
The lives of Japanese women remain rather conservative and most of them cook for family members daily. Although the incidence of otosclerosis is low in Japan, most of the patients are women. Taste disorder after stapes surgery seriously influences a woman's daily life. Therefore, we proposed that in bilateral otosclerosis, surgery on the second side should be delayed until taste function on the first side has recovered to the normal level<sup>[11]</sup>. Another report recommended taste testing at least in patients who have undergone surgery on the contralateral ear<sup>[14]</sup>.

#### Taste function after section of CTN

As indicated previously, patients complain of taste disorder less frequently with section of CTN than with preservation of CTN<sup>[4,8]</sup>.

#### (a) Unilateral section of CTN

Our study reported that, in unilateral section of CTN, 19/32 (59.4%) complained of taste disorder and 11/32 (34.4%) complained of tongue numbness and that most symptoms (16/18) disappeared within 1 year (Figure 6), although the EGM threshold did not recover<sup>[16]</sup>. This means that recovery of symptoms is not necessarily related to recovery of EGM. The discrepancy of recovery between symptoms and the EGM threshold is explained as follows. Subjective taste is expressed as a whole-mouth taste sensation<sup>[17]</sup>. It is possible that, in some cases, activity of CTN on the unoperated side is enhanced and compensates for taste dysfunction on the operated side, and that, in other cases, inhibition of the glossopharyngeal nerve function by the CTN is released after injury of CTN and activity of glossopharyngeal nerve is enhanced on the unoperated side<sup>[18,19]</sup>.



**Figure 6.** Interval until recovery of taste symptoms after unilateral section of CTN (n=18). (reprinted with permission from reference 16).

We also conducted questionnaire survey about cooking<sup>[16]</sup>. Patients who responded to questionnaire indicating "yes" for cooking everyday were all women. Generally, most Japanese housewives still cook everyday for their family members. Therefore, we were concerned about the effect of unilateral section of CTN on seasoning the dishes while cooking. Surprisingly, 12/17 patients (70.6%) did not have difficulty in seasoning dishes just after surgery, and only one patient (5.9%) who was engaged in cooking at a local restaurant, had a persistent complaint for more than two years. These findings encouraged otologists when there is no option but to cut CTN on one side during surgery.

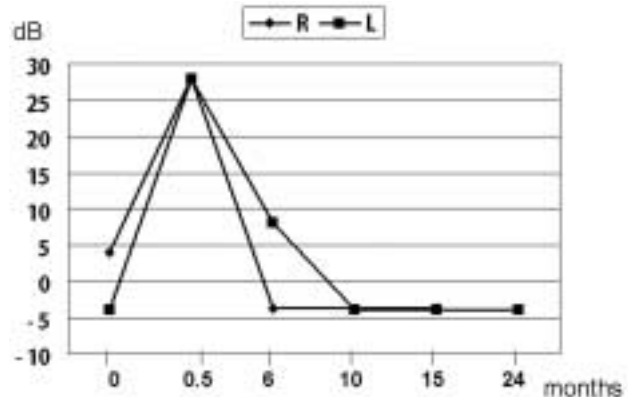
### (b) Bilateral section of CTN

Although one-third of cholesteatoma cases are bilateral<sup>[20]</sup>, few reports have examined taste function after bilateral section of CTN. The reason could be that, in most of the cases, each ear undergoes surgery at a different time or in a different hospital and, therefore, long-term follow-up is needed to evaluate bilateral taste function.

In our small series (n=3)<sup>[16]</sup>, two patients with bilateral cholesteatoma and adhesive otitis media did not complain of taste disturbance or tongue numbness two years after surgery. EGM did not show any response (>34 dB) during the period. The patients reported that they got used to tasting food on the deep side of the tongue with time. In the last patient with bilateral chronic otitis media, CTN was accidentally cut due to severe granulation tissue around the ossicles, and the nerve ends were reconnected together with fibrin glue. The patient continued to have taste disorder on the first operated side for 8 months. The threshold of EGM was elevated extremely 2 weeks after surgery, but had recovered to the normal level 10 months after surgery (Figure 7). These findings suggest that the patients had no problem with taste 2 years after surgery even though CTN was unavoidably cut on both sides.

### (c) Nerve regeneration after section of CTN

As shown in Figure 7, Saito's group reported several interesting studies. They identified a regenerated chorda tympani nerve behind the ear drum at the second stage of surgery after an end-to-end anastomosis was performed at the first stage of surgery (Figure 8)<sup>[21]</sup>.



**Figure 7.** The recovery rate of EGM threshold after bilateral section of CTN. CTN was accidentally cut, and the two nerve ends were reconnected with fibrin glue in a patient of bilateral chronic otitis media (reprinted with permission from reference 16).

Samples harvested during surgery showed myelinated nerve fibers although the number of axons was low compared with that in normal subjects<sup>[22]</sup>. Functionally, 22/52 (42.3%) patients showed complete or incomplete recovery on EGM before the second surgery<sup>[23]</sup>. On long-term follow-up, the recovery rate on EGM was 5/5 (100%) in patients receiving end-to-end anastomosis, 10/30 (33%) in those with a nerve gap defect of 1-3 mm, 11/23 (48%) in those with a 4-6 mm gap defect, and 21/55 (38%) in those with a gap defect greater than 7 mm<sup>[17]</sup>. These findings suggest CTN can regenerate if nerve ends are reconnected or placed as closely as possible after section of CTN.

Where do nerve growth factors and neurotrophic factors come from during regeneration? An animal model of CTN injury showed that expressions of growth-



**Figure 8.** (a) Endo-to-end anastomosis was performed between the proximal and distal cut ends. Arrow: point of anastomosis; arrowheads: chorda tympani nerve. (b) In case of a nerve gap defect, the proximal and distal cut ends (arrows) were approximated in the original position and fixed with fibrin glue on the temporal fascia used to reconstruct the eardrum by the underlay method. Arrows: proximal and distal cut ends; arrowheads: chorda tympani nerve. (c) Identification of the regenerated nerve at the second stage operation. The regenerated nerve (arrowheads) existed in the submucosal connective tissue layer of the reconstructed eardrum (reprinted with courtesy from the original pictures given by Dr. Takehisa Saito and with permission from reference 21).

associated protein (GAP)-mRNA<sup>[24]</sup> and brain-derived neurotrophic factors (BDNF)<sup>[15]</sup> were increased in geniculate ganglion cells, suggesting CTN axonal regeneration. It is suggested that geniculate ganglion cells play a key role in regenerating CTN.

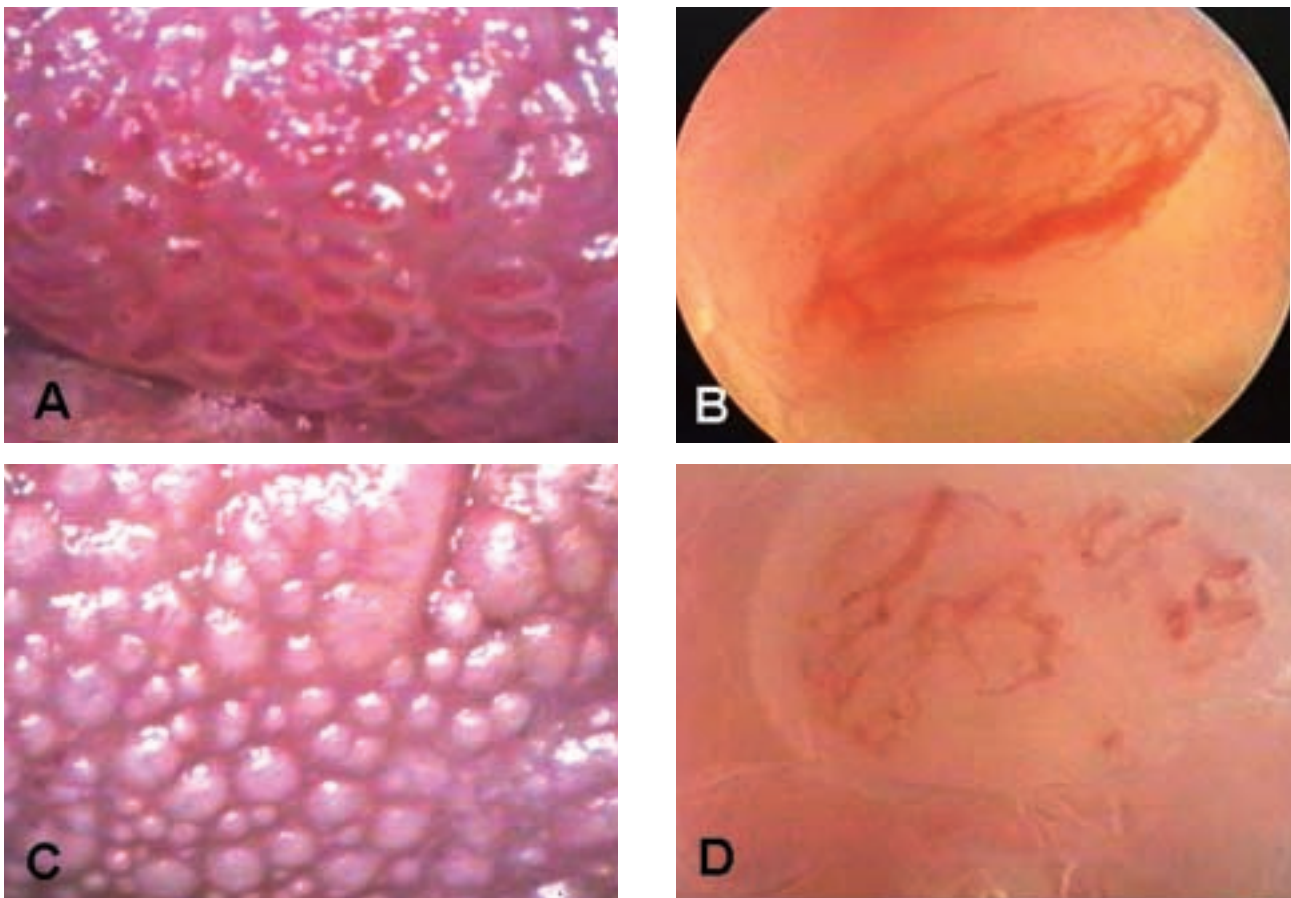
**(d) Morphological change of tongue papillae after section of CTN**

In animal models with section of CTN, the number of fungiform papillae decreased, and fungiform papillae become atrophic together with impaired taste buds<sup>[24,25,26]</sup>. Such section of CTN is sometimes unavoidable during middle ear surgery. By microscopy and contact endoscopy, we qualitatively showed that fungiform papillae became flat and irregular, and had few vessels a long time after section of CTN (Figure 9)<sup>[27]</sup>.

Hummel's group quantitatively showed morphological evidence that the number and density of fungiform papillae was significantly lower on the operated side than on the unoperated side<sup>[28]</sup>. These findings suggest that CTN is necessary to maintain the structure and function of tongue papillae.

**Taste function in elderly patients**

It is generally considered that taste function naturally deteriorate with age<sup>[3,28]</sup>. When patients with unilateral middle ear diseases undergo surgery, taste function on the side of the healthy ear was also measured by EGM. We analyzed the EGM threshold on the healthy side, and reported that EGM threshold in patients over 70 ( $19.6 \pm 3.9$  dB, mean  $\pm$  SD) was significantly higher than that in those aged 0-20 years ( $0 \pm 7.1$  dB), in those



**Figure 9.** The ridge of the frontal tongue in a 28-year-old male who had undergone right tympanoplasty 20 years previously. (A) The normal left side of fungiform papillae observed by microscopy. Many papillae had a smooth oval shape and abundant vessels. (B) Normal left side observed by contact endoscopy. Many straight vessels were running parallel. Erythrocyte flow was visible on a motion picture. (C) Postoperative right side observed by microscopy. Fungiform papillae were flat and irregular, and had few vessels in each papilla. (D) Postoperative right side observed by contact endoscopy. Vessels were atrophic, irregular and tapering (reprinted with permission from reference 27).

aged 21-40 years ( $3.3 \pm 9.5$  dB), in those aged 41-60 years ( $8.7 \pm 12.5$  dB) or in those aged 61-70 years ( $9.0 \pm 10.0$  dB)<sup>[29]</sup>. This value is almost the same as that in patients over 60 with cholesteatoma ( $21.7 \pm 14.6$  dB) and a little higher than that in patients over 60 with COM ( $13.1 \pm 14.2$  dB).

These findings suggest that taste function of CTN deteriorates on the diseased side as much as on the normal side in elderly patients. Therefore, in most cases, we do not have to pay more attention to the CTN when performing surgery in elderly patients compared with that during surgery on young and middle-aged patients.

#### ***Change in trigeminal sensation after CTN injury***

It is well known that damage to the CTN often leads to temporary sensations on the tongue surface such as numbness, tingling, and metallic taste. In our experience, tongue numbness was observed in 28/67 (42%) patients with preservation of CTN, and in 6/37 (16%) patients with section of CTN<sup>[4]</sup>. The reason why trigeminal sensation appeared has not been clarified, however recent studies may throw a light on this phenomenon.

Perez et al. reported that light touch, static two-point discrimination, and moving two-point discrimination on the tongue were significantly diminished after surgery<sup>[30]</sup>. Just et al. reported that the threshold for capsaicin was elevated on the operated side after surgery and correlated with the EGM threshold<sup>[31]</sup>. Both studies indicate decrease in trigeminal sensitivity which causes postoperative clinical symptoms together with decrease in gustatory sensitivity. A possible explanation for this phenomenon might be that the CTN conveys trigeminal sensation from the tongue but in a small amount compared with the existing trigeminal pathway. Central interactions may also be involved. There is evidence of somatosensory projections to gustatory nuclei<sup>[32]</sup>, but little information is available regarding the affect on the trigeminal system after gustatory denervation.

#### ***Taste disorder after cochlear implantation***

Over the past two decades, cochlear implantation has been performed worldwide to restore hearing in patients with profound hearing loss. Data on taste dis-

order after middle ear surgery have accumulated, however few data are available on the frequency and degree of taste loss in patients after cochlear implantation.

Surgical procedure for cochlear implantation is usually performed with a traditional approach with mastoidectomy and posterior tympanotomy. Mueller et al. reported that results of taste strip testing were not significantly changed after surgery compared with those before surgery and only 1/24 (4.2%) patients complained of subjective taste loss, and concluded that cochlear implantation is a relatively safe procedure regarding taste function<sup>[33]</sup>. However, Lloyd et al. reported that 43/141 (43%) patients experienced taste disorder and in 18/141 (19%) patients, taste dysfunction had not resolved. It was concluded that these taste outcomes were comparable to those of patients undergoing stapes surgery<sup>[34]</sup>. Although the two studies presented opposite conclusions, they agreed that careful attention should be paid in cases that had already received surgery on the contralateral side and cases undergoing bilateral cochlear implantation.

Recently, the suprameatal approach has been developed as an alternative approach for cochlear implantation<sup>[35]</sup>. Migirov et al. compared two approaches regarding postoperative taste disorder and reported that the suprameatal approach caused injury to CTN less frequently than the traditional approach<sup>[36]</sup>. However, further study is needed to clarify advantages of the suprametal approach.

#### **Conclusions**

A series of our studies and related literature were reviewed. Although taste disorder frequently occurs after middle ear surgery regardless of preservation or section of CTN, postoperative taste disorder will generally abate within one year in most cases. Postoperative taste disorder is more prevalent in cases of non-inflammatory diseases such as otosclerosis and bilateral cases while it is less frequent in unilateral cases and elderly patients. Because CTN has the ability to regenerate, it is desirable to preserve CTN during surgery or put nerve ends together if CTN is unavoidably cut. Trigeminal sensations such as tongue numb-

ness, tingling, and metallic taste may also occur after surgery, however their mechanisms remain unclear.

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