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Effects of the chorda tympani damage on submandibular glands: scintigraphic changes

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Abstract

The aim of this study is to compare the scintigraphic results of a denervated submandibular gland with the contralateral normal side in patients with unilateral chorda tympani damage. Sixteen patients (11 women and five men with a mean age of 27) with unilateral proven chorda tympani damage during their previous ear surgery were included in the study. The perfusion ratio (PR), concentration ratio (CR) and stimulated excretion ratio (SER) were calculated scintigraphically and the results from the salivary glands on opposite sides were compared.

For submandibular glands, the perfusion ratio (PR), concentration ratio (CR) and stimulated excretion ratio (SER) were found to be 0.65 ± 0.21, 0.70 ± 0.21, 0.79 ± 0.37, respectively. All ratios resulted from statistically decreased radioactivity accumulation on the affected side ($p<0.05$).

Chorda tympani damage negatively affects the function of the ipsilateral submandibular glands despite the absence of atrophy. Dynamic salivary gland scintigraphy is a practical and valuable method of disclosing the decreased capacity of perfusion, concentration and secretion function in unilateral neurological deprivation.

Key words: Chord Tympani Nerve; Wound and Injuries; Submandibular Gland; Radionuclide Imaging

Introduction

The nerve supply to the submandibular glands is via the facial nerve, specifically the chorda tympani transmitting afferent sensory and efferent secretory impulses.[1] The chorda tympani is vulnerable during pathological conditions of the middle ear and is in danger of being sectioned during otological surgery. The negative effects chorda tympani damage on the submandibular glands have been studied largely demonstrating both functional and anatomical changes both in animal models and in human studies.[2,3] Submandibular gland scintigraphy has been used in peripheral facial nerve paralysis to predict prognosis and has been found as a reliable indicator in the early symptomatic period.[4] Thus, it is worth investigating the scintigraphic changes in submandibular glands after chorda tympani damage.

Dynamic scintigraphy relies upon the acquisition of images throughout the period of the scan reflecting perfusion, concentration, activation and secretion of salivary glands. The uptake and secretion of ^{99m}Tc-pertechnetate by the salivary glands correlates with salivary flow rates.[5] But, despite almost 40 years of investigation of normal quantitative results of scintigraphic patterns, the high degree of variability of indices impairs the capability of salivary gland scintigraphy in the establishment of the normal reference limits.[6] Whereas, the benefit of using salivary gland scintigraphy in unilateral disease is to obtain a comparison between anatomical, physiological and pathological information.

Our recent study was of the biometric changes in the submandibular gland after unilateral chorda tympani damage using B-mode ultrasonography.[7] A late effect was the significant increase in the size of non-denervated submandibular glands of the patients undergoing chorda tympani section on the contralateral side, when compared with the submandibular glands of a healthy control group. Atrophy in the parasympathetically denervated gland was not ascertained due to the section of the chorda tympani. These results have compelled us to start a new investigation using dynamic scintigraphy to evaluate the functional changes in these denervated glands.

The aim of this study was to compare the scintigraphic results of denervated submandibular glands with the contralateral normal side in the patients with unilateral chorda tympani damage. The ultrasonographic findings from the submandibular glands, as well as the scintigraphic data from the parotid glands, will also be considered in the discussion.

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Materials and methods

Patients

Sixteen patients with unilaterally proven chorda tympani damage during their previous ear surgery were recruited. Patients were included in the study if they had a healthy contralateral ear. These patients were clinically and biochemically euthyroid and had no recent history of any disease of either the salivary glands or the thyroid. None of them had complained of mouth dryness nor was taking any prescribed medication that interfered with salivation. They had no rapid ^{99m}Tc-pertechnetate uptake nor concentration of tracer in the thyroid gland. None of the women was pregnant.

The study group consisted of 11 women and five men with a mean age of 27 (12–45 years). At the affected side, the chorda tympani was damaged either iatrogenically or acquired as a sequelae of middle-ear surgery such as canal wall down tympanoplasty (11 patients) or radical mastoidectomy (five patients). The pathology of all the patients was extensive middle-ear and mastoid cholesteatoma.

The mean follow-up time after the surgery was 18 months (one to 91 months). All patients, on their examination day, had provided informed consent for study approved by our institutional review board. They have approved submandibular B-mode ultrasonography and dynamic ^{99m}Tc-pertechnetate salivary glands scintigraphy.

Ultrasonography

The submandibular glands were scanned at an angle that enabled maximum possible visualization of the glandular tissue. The software of the ultrasonographic devices used in this study (HDI 5000 and 3500 Diagnostic Ultrasound System; ATL; Bothell, WA, USA) included a feature to calculate the volume in millilitres (mL) based on the measured dimensions (the anterior-posterior length, the frontal, lateral-medial width, and the paramandibular depth in millimetres).

Scintigraphy

Dynamic ^{99m}Tc-pertechnetate salivary glands scintigraphy was carried out after at least three hours of fasting. Patients were laid in the supine position and the head was fixed slightly in an extended position during the imaging. In brief, 370 MBq ^{99m}Tc-pertechnetate was injected intravenously to study the kinetics of the function of the parotid and submandibular glands. Scanning was performed using Vertex Ultra 60 (Adac Laboratories, Milpitas, CA, USA) gamma camera equipped with a low energy, high resolution, parallel-hole colimator, with energy centered on 140 keV and with a 20 per cent window. The images were digitally recorded in a 64×64 matrix frame with $\times 2.19$ zoom. Salivary gland images were acquired sequentially one frame every 60 seconds for 40 minutes. Salivary secretion was stimulated with 4 ml of pure lemon juice 25 minutes after injection.

Regions of interest (ROIs) were selected manually in the submandibular and parotid glands. The background ROIs were set on the orbital region. The mean count per pixel for each salivary gland with background correction was calculated for every frame. Then, the time-activity curves of the salivary glands were generated. As ^{99m}Tc-pertechnetate scintigraphy patterns are variable even in normal populations,[6] each patient's normal side served as a control; accordingly, the ratio of the perfusion (PR), the ratio of the concentration (CR) and the ratio of the stimulated excretion (SER) of the affected side to normal side were evaluated as functional parameters for further data analysis.

The perfusion ratio (PR) was found comparing the first images. The numbers were directly related to the perfusion of the glands. The formula was the mean count with background correction in the affected gland/mean count with background correction in the normal gland.

The concentration ratio (CR) reflected the mean count at the 10th minute in the affected salivary gland/mean count at the 10th minute in the normal gland.

The stimulated excretion ratio (SER) was seen after the lemon juice stimulation. It was calculated by a comparison of the results of the salivary glands on opposite sides. The formula was [(mean counts at the 25th minute in the ROIs) – (mean counts at the 35th minute in the ROIs)]/(mean counts at the 25th minute in the ROIs).

Statistics

All numerical data were presented as mean ± SD. The normal distribution of the groups was analysed by the Kolmogorov-Smirnov test; the equality of variances in compared groups was analysed by the Levene test. Submandibular gland volumes were measured by ultrasonography; mean counts at first and 10th minutes, and the mean count of parotid and submandibular glands following stimulation by lemon juice were compared statistically between affected and unaffected sides with the two tailed, unpaired student *t*-test with equal variance using the SPSS 6.0® statistical software package. $p>0.05$ was considered statistically significant.

Results and analysis

Quantitative glandular scintigraphic parameters found between the affected side and the unaffected side are shown in Table I. In the submandibular glands, all ratios were statistically reduced on the affected side ($p<0.05$). The radioactivity in the parotid glands on both sides was the same ($p<0.05$).

The ultrasonographically measured mean volume of the affected side's submandibular gland was 5.58 ± 1.88 mL, whereas the mean volume of the unaffected submandibular gland was 8.51 ± 3.02 mL. The unaffected side was found to be significantly greater in volume than the affected side ($p<0.01$). Although the affected side's volume was in the range of the volume of the healthy control group's submandibular gland from our recent study.[7]

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TABLE I
QUANTITATIVE GLANDULAR SCINTIGRAPHIC PARAMETERS FOUND BETWEEN THE AFFECTED SIDE AND THE UNAFFECTED SIDE

(n = 16) (results as mean ± 1 SD)	Perfusion ratio (PR)	Concentration ratio (CR)	Stimulated excretion ratio (SER)
submandibular gland	0.65 ± 0.21	0.70 ± 0.21	0.79 ± 0.37
parotid gland	0.97 ± 0.45	0.92 ± 0.22	0.98 ± 0.55

The representative case was a 40-year-old woman with a history of left radical mastoidectomy 14 months ago because of extensive cholesteatoma. The left chorda tympani had been sectioned during the surgery. Salivary gland scintigraphic images taken every two minutes were presented in Figure 1 demonstrating poor accumulation in the left submandibular gland. The quantitative indices of submandibular glands of this patient (PR, CR, and SER) resulted in 0.32, 0.41 and, 0.80, respectively indicating decreased stimulatory secretion.

- **This paper compares the scintigraphic changes in submandibular glands denervated by division of the chorda tympani and compares these findings to the contralateral normal side**
- **The paper found that division of the nerve impairs the function of the gland in the absence of frank atrophy**
- **The authors conclude that scintigraphy is a good way of assessing function in neurological damage**

Discussion

The integrity of the parasympathetic division of the facial nerve is crucial for submandibular gland function. In any condition affecting the chorda tympani, salivary flow from the cannulated submandibular gland can be measured,[2] but it requires a special armamentarium and training. The test is also uncomfortable for patients. The salivary flow test is sometimes inaccurate. Because of the oedema of the ducts, repeat tests cannot be performed immediately. In contrast, dynamic submandibular gland scintigraphy is easy to perform with minimal discomfort for the patient.[4] It is accepted as a minimally invasive method, since the whole dose of radioactivity for the four major salivary glands approximates the dose of three consecutive skull radiograms.[5]

In this study, ultrasonographic findings of the submandibular gland were in accordance with our previous study.[7] While the affected glands showed normal volume; contralateral, non-denervated submandibular glands were found to be hypertrophied. This hypertrophying effect had been seen as a late sequela of the chorda tympani damage especially in patients with more than 12 months of follow-up. The study group of this research consisted of 16 patients with a range of post-operative follow-up time one to 91 months. The study group consisted of only three patients with less than 12 months of follow-up. This probably could not interfere with the late hypertrophying effect on the contralateral submandibular gland. Moreover, the scintigraphic investigation has been used to demonstrate the effect of parasympathetic denervation of submandibular gland within the 14 days of facial nerve paralysis.[4] Thus, it was not logical to categorize the patients to an early or late group for scintigraphic results in this study.

The scintigraphic parameters that we used in this study, are well-accepted and commonly used parameters demonstrating the function of the submandibular gland.[8,9] The main application of this test is in the diagnosis of Sjögren's syndrome.[8,10] The ability of the gland to take up radioactivity reveals a normal functioning parenchyma. The mean PR for our study was 0.65 indicating that the parenchymal function of the denervated submandibular glands was affected. The maximal count of the gland shows its concentrating ability. The concentration ratio (CR = 0.70) was also found to be decreased in our study. Finally, if a gland fails to respond to stimulation, this indicates a gross neurological impairment as in our study (SER = 0.79), or ductal obstruction.[5]

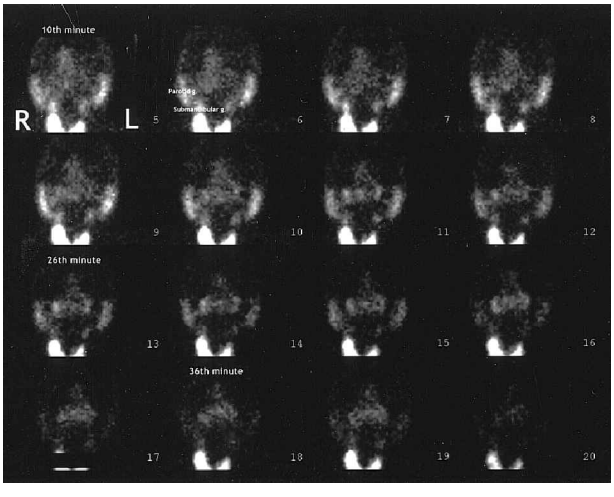

FIG. 1
Dynamic salivary gland scintigraphy images of a patient with chorda tympani damage on the left side. The fifth frame represents 10th minute of concentration of salivary glands. The 13th frame (26th minute) is the image taken just after stimulation with lemon juice. The 18th frame (36th minute) is just after the measurement of SER. In these frames, left submandibular gland hypofunction is obvious compared to the right one.

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To predict the bad prognosis of facial paralysis, Taki *et al*. have used <0.8 criteria for CR and SER. Interestingly, despite the absence of explanation of choosing this criteria in their study, our results have fallen in that limit showing an unrecoverable neurological condition. Their study has demonstrated the comparable value of submandibular gland scintigraphy with electroneurography in the prognosis of peripheral facial paralysis in the early period. They have found that SER was more reliable, featuring an excellent positive predictive value and a good negative predictive value. If both CR and SER were <0.8 within 14 days after the onset of the paralysis, none of the patients showed complete recovery suggesting that these criteria were reliable. Our results support their conclusion showing all these parameters to be <0.8 on submandibular glands. As the scintigraphic parameters were approximately symmetrical in the parotid glands the accuracy and reliability of the results obtained on submandibular glands in chorda tympani damage was confirmed.

In our comparison of the scintigraphic data from opposite sides it was shown that while there was no difference between the parotid glands, affected submandibular glands showed significant functional loss. The most valuable role of salivary gland scintigraphy is in comparing a diseased side to the contralateral normal functioning side. It is accepted that, at any point of time, there is a good correlation between glands on opposite sides.[11] But the application of salivary scintigraphy to normal subjects discloses a high degree of interindividual variability in the frequency and magnitude of salivary secretion.[6] Therefore, unilateral chorda tympani damage could reflect a good indication for dynamic submandibular gland scintigraphy.

Because of the compensation for the decreased function of the denervated submandibular gland by the contralateral partner, the side effects of corda tympani damage are commonly underestimated. But the important functions of saliva should not be ignored. Malpani *et al*.,[12] in their letter to the editor, discussed newly investigated functions of saliva. Besides the well-known function of maintenance of oral hygiene, bolus formation and secretion of digestive enzymes, a recent report showed evidence of an oesophagoprotective, neuroendocrine, neuroimmunomodulator role of the saliva. The compensated volume of contralateral gland saliva may be sufficient to maintain the digestive function, but it is not yet known whether this volume is sufficient for these newly suggested roles of the saliva.

Conclusion

Chorda tympani damage negatively affects the function of the ipsilateral submandibular gland despite the absence of atrophy. Dynamic salivary gland scintigraphy is a practical and valuable method of disclosing the decreased capacity of perfusion, concentration and secretory function in unilateral neurological deprivation. The effect of unilateral hypofunction of the submandibular gland on the all-important roles of saliva needs to be clarified with further studies.

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