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ORIGINAL RESEARCH

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Ultrasound shear wave elastography for patients with sialolithiasis undergoing interventional sialendoscopy

Chia-Fan Chang MD, MHA[1,2] | Hsin-Kai Wang MD[3,4]

[1]Department of Otolaryngology-Head and Neck Surgery, Taipei Veterans General Hospital, Taipei, Taiwan

[2]Faculty of Medicine, School of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan

[3]Department of Radiology, Taipei Veterans General Hospital, Taipei, Taiwan

[4]Department of Medical Imaging and Radiological Technology, Yuanpei University of Medical Technology, Hsinchu, Taiwan

Correspondence
Hsin-Kai Wang, Department of Radiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan.
Email: hkwang@vghtpe.gov.tw

Abstract

Objective: Ultrasound shear wave elastography is an objective tool to evaluate the stiffness of human tissues. Patients with sialolithiasis could be treated by interventional sialendoscopy with a high success rate. Sialolithiasis could be extracted, and the diseased gland could be preserved and evaluated after treatment. Whether ultrasound shear wave elastography could be used for objective outcome measurement and short-term follow-up of the parenchyma of gland in patients with sialolithiasis remains unclear.

Methods: This retrospective self-controlled study was conducted. Patients with sialolithiasis treated by interventional sialendoscopy and followed by high-resolution ultrasound shear wave elastography were selected between January and September 2017.

Results: Seventeen patients with sialolithiasis (mean age: 39.63 ± 12.49 years), including 10 women and 7 men, were enrolled. Fifteen patients had sialolithiasis in the submandibular gland and two in the parotid gland. The preoperative value of shear wave velocity was significantly higher in the diseased gland than in the contralateral normal gland ($p < .001$; 95% confidence interval [CI], 0.3915–0.6046). After successful treatment by interventional sialendoscopy surgery, the shear wave velocity of the diseased gland decreased significantly ($p = 0.001$; 95% CI, −0.38792 to −0.20474). However, there was a significant difference between the diseased and contralateral normal glands ($p = 0.001$; 95% CI, 0.0423–0.2895) after 1.55 months of surgery.

Conclusion: Ultrasound shear wave elastography could be an adjuvant tool to distinguish sialolithiasis-affected diseased glands from contralateral normal glands and assess the short-term treatment outcome objectively. The changing trend of shear wave velocity could help monitor the healing process of the parenchyma in the diseased gland after treatment.

Level of Evidence: 4

KEYWORDS
interventional sialendoscopy, shear wave elastography, sialolithiasis, ultrasound

1 | INTRODUCTION

Sialolithiasis is the most common cause of chronic obstructive sialadenitis in major salivary glands.[1] The estimated annual symptomatic incidence is 1 per 10,000–30,000 individuals. It costs a heavy finance burden on the National Health Service due to annual hospital admission.[2,3] Patients with sialolithiasis may develop periprandial gland swelling, pain, tenderness, change in saliva production, or other symptoms that impair their quality of life.[1,4,5] The submandibular gland is the most common involved gland (~75.2%–79.2%), followed by the parotid gland (~20.8%–24.8%). The sublingual gland is rarely affected. Sialolithiasis involves one gland in most patients and two in only 1.9% of patients.[6,7] Sialolithiasis may obstruct duct secretion and cause recurrent inflammation and infection of the gland. As the disease progresses, the acinar cells may become atrophic, and the parenchyma of the gland may become fibrotic.[8–10] Therefore, the increased hardness of the diseased gland can be palpated on physical examination, which can be compared with the normal side. With advancement in medical technology, sialolithiasis treatment has changed, and sialendoscopy becomes a first-line treatment. Sialendoscopy is a minimal invasive surgery with diagnostic and interventional purposes and allows direct visualization of the ductal system of major salivary glands, evaluation of the possible cause of gland disease, and intervention of intraductal pathology. It has been proven to be an effective and safe treatment with high success rate in patients with sialolithiasis. It not only prevents gland ablation surgery but also substantially decreases the necessity of gland excision surgery.[11–15]

Ultrasound shear wave elastography is an ultrasound-based point-of-care technique for objectively assessing tissue stiffness and can be called "palpation imaging."[16] Increased shear wave speeds have been correlated with increased stiffness of the tissue in the measured organ. It has been used to help differentiate between the diseased and normal tissues in the liver, breast, thyroid, and prostate glands.[17–20] For the major salivary gland, high-resolution ultrasound is a useful and effective assessment tool due to the superficial location without invasion or radiation exposure.[21] In patients with primary Sjogren syndrome, the ultrasound characteristics in major salivary glands include more hypoechogeneity and inhomogeneity of the parenchyma with more unclear borders, hypoechoic areas, and hyperechogenic reflections than those of non-Sjogren syndrome.[22] Combined with shear wave elastography, the mean shear wave velocities of the parotid and submandibular glands are significantly higher in patients with primary Sjogren syndrome than in healthy volunteers.[23–25] Moreover, high-resolution ultrasound is also a valuable diagnostic tool in patients with chronic sialadenitis. Combined with shear wave elastography, the mean shear wave velocities of diseased glands are significantly higher in patients with chronic sialadenitis, including sialolithiasis, stenosis, or unknown causes, than in healthy controls.[26,27] Therefore, ultrasound shear wave elastography can be a valid adjuvant means to high-resolution ultrasound for the clinical diagnosis of patients with primary Sjogren syndrome and chronic sialadenitis.

After interventional sialendoscopy surgery, the diseased gland can be preserved, and the function of the gland can gradually recover.[28] We can evaluate the treatment outcome after removal of sialolithiasis using either subjective or objective methods. Patient-reported outcome is one of the commonly used subjective evaluation methods directly generated from patients' feeling.[29,30] Several salivary gland-related questionnaires were developed and used.[4,31,32] Conversely, objective assessment was also frequently used, including imaging studies, sialometry, and sialoscintigraphy.[28,33,34] It is unclear whether high-resolution ultrasound with shear wave elastography could become an objective tool to assess the treatment outcome of patients with sialolithiasis in a short term. Therefore, we performed high-resolution ultrasound with shear wave elastography in patients with sialolithiasis before and after interventional sialendoscopy surgery and compared the changes in shear wave velocity between the diseased and contralateral normal glands during the postoperative follow-up.

2 | MATERIALS AND METHODS

2.1 | Study design and population

This retrospective self-controlled study was conducted at the Department of Otorhinolaryngology, Head and Neck Surgery, and Department of Radiology, Taipei Veterans General Hospital, and approved by the Institutional Review Board of Taipei Veterans General Hospital. Between January and September 2017, patients diagnosed with sialolithiasis and treated at our hospital were included in the study. All patients underwent routine ultrasound examinations with shear wave elastography before and after treatment. The treatment included interventional sialendoscopy surgery or interventional sialendoscopy surgery combined with transoral incision. All surgeries were performed by Dr. CF Chang with 10 years of experience in sialendoscopy surgery. Patients who could not undergo postoperative follow-up or refused postoperative ultrasound examination were excluded from the study.

2.2 | Ultrasound imaging technique

High-resolution ultrasound studies were applied on Siemens ACUSON S2000 (Siemens Medical Systems, Erlangen, Germany) using a linear 4–9 MHz transducer. The examination consisted of a conventional B-mode scan followed by color-coded duplex ultrasound. Acoustic radiation force impulse elastography was then applied to measure the shear wave velocity of the gland, expressed in m/s. The examination included 10–15 single measurements of the diseased and contralateral normal glands at a depth of 1.0–1.5 cm at the center of the submandibular or parotid glands apart from sialolithiasis, adjacent bone, or blood vessels (Figure 1). All ultrasound examinations were performed by Dr. HK Wang with 15 years of experience in general ultrasound, including 8 years of experience in shear wave elastography.

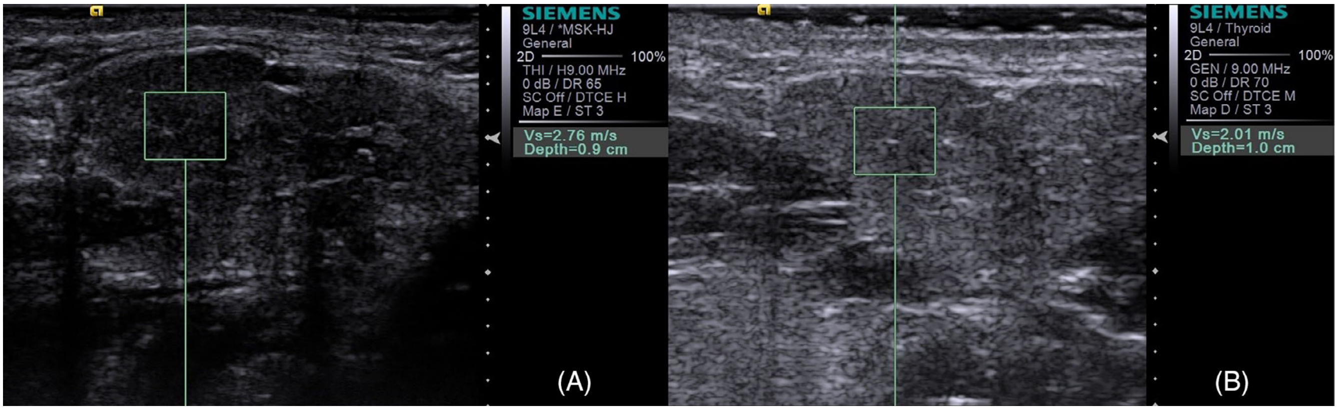

FIGURE 1 (A) Preoperative ultrasound shear wave elastography. (B) Postoperative ultrasound shear wave elastography

TABLE 1 Patients' characteristics ($n = 17$)

Variables	Mean ± SD, range/n (%)
Age (years)	39.63 ± 14.38
Average number of stone	1.24 ± 0.56
Average stone size (mm)	6.22 ± 2.83
Gender	
Female	10 (58.82%)
Male	7 (41.18%)
Side of stone	
Right	11 (64.71%)
Left	6 (35.29%)
Gland of involvement	
Parotid gland	2 (11.76%)
Submandibular gland	15 (88.24%)
Location of stone	
Distal	6 (35.29%)
Middle	4 (23.53%)
Hilum/Proximal	7 (41.18%)
Type of surgery	
Interventional sialendoscopy	10 (58.82%)
Combined with transoral incision	7 (41.18%)

2.3 | Statistical analysis

Data analysis was performed using the IBM Statistical Product and Service Solutions 20 package (SPSS Inc., Chicago, Illinois). Continuous variables were presented as mean ± standard deviation. Each measurement of shear wave velocity was counted as a single parameter. The generalized estimating equation was used for repeated measures analysis of shear wave velocity to evaluate the correlation of change in the bilateral major salivary glands before and after treatment, whereas the 95% confidence interval (CI) was calculated to estimate the difference between two continuous variables. The independent *t*-test was used to compare the average shear wave velocities of the bilateral major salivary glands to determine if there was a significant difference. In all analyses, a p-value < .05 indicated statistical significance.

3 | RESULTS

A total of 17 patients with sialolithiasis (10 women and 7 men) were enrolled in this study. Table 1 shows the characteristics. The mean age was 39.63 ± 12.49 years (range, 16.39–62.22). Fifteen patients had sialolithiasis in the submandibular gland, and two had sialolithiasis in the parotid gland. Sialolithiasis was located at the right side in 11 patients and at the left side in 6 patients. No patient had more than one gland involvement at the time of diagnosis. The most common location of sialolithiasis was the hilum/proximal duct, followed by the distal and middle ducts. Regarding the number of stones, 1 patient had 3 stones, 2 patients had 2 stones, and 14 patients had 1 stone. The mean size of the stone was 1.24 ± 0.56 mm (range, 0.21–1.08). Ten patients underwent interventional sialendoscopy surgery, and seven underwent interventional sialendoscopy surgery combined with transoral incision. Sixteen patients were successfully treated, and sialolithiasis was completely removed. Only one patient had a residual stone fragment due to adhesion to the ductal wall. However, this patient had no symptom or sign during follow-up. After 1 month of interventional sialendoscopy surgery, postoperative ductal stenosis developed in one patient. No other complication was found. The average time interval between surgery and postoperative ultrasound examination was 1.55 ± 0.61 months.

A total of 810 measurements of shear wave velocity were recorded preoperatively, 402 for the diseased gland and 408 for the contralateral normal gland. After treatment, there were 899 measurements of shear wave velocity, 454 for the diseased gland and 445 for the contralateral normal gland. Preoperative shear wave velocity was significantly different (p < 0.001; 95% CI, 0.3915–0.6046) between the diseased and contralateral normal glands. Table 2 shows that the diseased gland was much harder, exhibiting higher shear wave velocity than the contralateral normal gland. After interventional

TABLE 2 Generalized estimating equations for comparison of shear wave elastography between the diseased side and the contralateral side.

Parameter	Coefficients	SE	*p*-value	95% Confidence interval (m/s) Lower bound	Upper bound
Intercept	2.300342	0.038274	0.000	2.225274	2.375410
Preoperation (diseased vs. contralateral side)	0.498089	0.054329	0.000	0.391532	0.604647
Opposite (preoperation vs. postoperation)	0.035860	0.052990	0.499	−0.068072	0.139793
Different of slope change from pre to post between two groups (in average 1.55 month)	−0.201759	0.074907	0.007	−0.348679	−0.054838

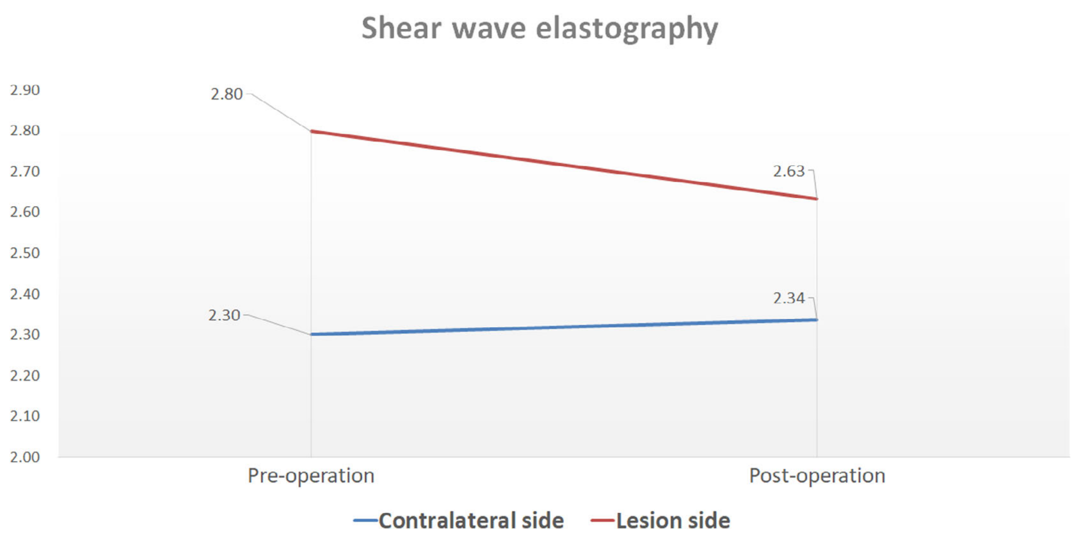

FIGURE 2 Changes in shear wave elastography before and after interventional sialendoscopy

sialendoscopy surgery, the difference in slope change from preoperative to postoperative status between two sides of the gland was statistically significant ($p = .007$; 95% CI, −0.348679 to −0.054838) (Figure 2). The shear wave velocity of the diseased gland significantly decreased ($p = 0.001$; 95% CI, −0.38792 to −0.20474). However, there was a significant difference between the diseased and contralateral normal glands ($p = 0.001$; 95% CI, 0.0423–0.2895) after 1.55 months of surgery. Conversely, there was no significant difference in shear wave velocity in the contralateral normal gland between the preoperative and postoperative stages ($p = 0.499$; 95% CI, −0.068072 to 0.139793).

4 | DISCUSSION

In this study, the stiffness of the major salivary glands in patients with chronic sialadenitis caused by sialolithiasis was evaluated by ultrasound shear wave elastography before and after interventional sialendoscopy surgery. The change in shear wave velocity was significant in the diseased gland than in the contralateral normal gland before and after surgery ($p = 0.007$). In chronic sialadenitis with sialolithiasis, the parenchyma of the diseased gland could become inflamed, fibrotic, or atrophic, which was found in the histopathology of the excised gland with sialolithiasis.[8,10] Zengel et al.[27] used ultrasound shear wave elastography to evaluate 30 healthy volunteers and 15 patients with sialolithiasis in the submandibular gland. There was a significant difference in the average value between the diseased and contralateral glands, similar to our findings. Our study showed that the shear wave velocity of the diseased gland was significantly higher than that of the contralateral normal gland preoperatively ($p < 0.001$). However, the change in the parenchyma in most diseased glands was minimal and could be reversible.[8–10] Su et al.[28] assessed the function of the salivary gland of 17 patients with sialolithiasis or ductal stenosis by sialometry and scintigraphy. All patients were free of symptoms after interventional sialendoscopy surgery and underwent functional assessment at a median of 7 months postoperatively (range, 4–24 months). The function of the diseased gland significantly improved, and there was no difference between the diseased and contralateral normal glands postoperatively. Therefore, after removal of sialolithiasis without excision of the gland, the preserved parenchyma of the diseased gland seemed to be less fibrotic and edematous and could be assessed by shear wave elastography. The postoperative shear wave velocity of the diseased gland significantly decreased ($p = 0.001$) in our study. It may imply that the diseased gland became softer after removal of sialolithiasis with progressive recovery of salivary gland function.

Shear wave elastography could be applied into routine ultrasound examination protocol for patients with chronic sialadenitis of major salivary glands.[27,35] Reichel et al.[35] used ultrasound shear wave elastography to assess 25 patients with sialolithiasis of the submandibular gland and 7 patients with sialolithiasis of the parotid gland. The shear wave velocity was significantly higher in the diseased glands than in the contralateral normal glands. All patients underwent minimally invasive treatment, including endoscopy-based surgery, extracorporeal shock-wave lithotripsy, and transoral duct splitting surgery. After successful treatment, the average values in the diseased glands were not significantly different from those of the contralateral normal glands. The authors did not indicate the time of follow-up in their study. When compared with our study, all of our patients underwent interventional sialendoscopy surgery and received postoperative ultrasound at an average time of 1.55 months. The postoperative shear wave velocities in diseased glands significantly decreased. However, the values were still significantly higher in the diseased glands than in the contralateral normal glands ($p = 0.001$). One possible explanation may lie in the fact that the average postoperative follow-up time of ultrasound examination was short and the parenchyma of diseased glands may be still under recovery. Another study by Zengel et al.[36] included 25 patients with chronic recurrent parotitis and employed shear wave elastography for follow-up. All patients underwent interventional sialendoscopy surgery with prednisolone installation and become free of symptoms after surgery. Their study found that the shear wave velocity in diseased glands was no longer significantly different from contralateral normal glands after more than 2 months postoperatively. Therefore, it may take up more than 2 months for the diseased gland to fully recover after successful treatment. Although the time of postoperative assessment was relatively short in our study, the changing trend in ultrasound shear wave velocities could also help monitor the healing process of the parenchyma of the diseased gland. One patient developed recurrent swelling of the submandibular gland after 1 month of interventional sialendoscopy surgery. Elevated shear wave velocity was noted during follow-up and postoperative ductal stenosis at the previous stone site was found by revision interventional sialendoscopy surgery. Accordingly, shear wave elastography allowed measurement and monitoring of the changes of parenchymal stiffness of the salivary gland in patients with sialolithiasis.

This study had several limitations. First, only 17 patients were recruited. Although 810 measurements of shear wave velocity before treatment and 899 measurements after treatment were recorded, the patient number was inadequate for further subgroup analysis by stone location, size, or numbers. A larger sample size should be used in future studies. Second, the time interval of the follow-up ultrasound examination was relatively short. Most patients were free of symptoms after successful treatment and received postoperative ultrasound examination once. Although there was a significant difference of shear wave velocities between the diseased and contralateral normal glands after treatment, the differences in shear wave velocity preoperatively and postoperatively provided us with a valuable tool for assessment of treatment effect, with the long-term outcome. Third, all ultrasound examinations were performed by a single operator. The procedure of ultrasound is technically dependent, and the size and location of the region of interest may be influenced by the technical skills of the operator. Nevertheless, ultrasound shear wave elastography has already been proven as a reliable tool with high intraobserver and interobserver reproducibility.[37]

5 | CONCLUSION

Our findings indicate that high-resolution ultrasound examination integrated with shear wave elastography could be an objective and reliable tool to differentiate diseased glands from normal glands and assess the treatment outcome in patients with sialolithiasis in a short-term follow-up. The changing trend of shear wave velocity may enable us to monitor the healing process of parenchyma in the diseased gland after treatment. Further management should be considered if the postoperative shear wave velocity rebound in the diseased gland.

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CONFLICT OF INTEREST

The authors declare no funding, financial relationships, or conflicts of interest related to the subject matter or materials discussed in this article.

ORCID

Chia-Fan Chang https://orcid.org/0000-0002-8980-6865

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