

Original Article

Diagnostic value of high-frequency ultrasound for submandibular gland sialolithiasis

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Abstract: The purpose of the study was to evaluate the diagnostic value of combined use of linear-array and intracavity high-frequency transducers in submandibular gland sialolithiasis. This retrospective study involved 77 cases with surgically confirmed submandibular gland sialolithiasis. All patients underwent high-frequency ultrasound with linear-array and intracavity transducers before surgery. Submandibular gland size, shape, echogenicity, blood supply, duct dilation, and other sonographic characteristics were carefully analyzed. Using linear-array high-frequency transducer, among the 77 cases with submandibular gland sialolithiasis, 63 cases were correctly diagnosed before operation, 13 cases had missed diagnoses and 1 case was wrongly diagnosed, resulting in an accurate diagnosis rate of 81.8% (63/77). However, using linear-array together with intracavity transducer, 72 cases were correctly diagnosed before operation, 4 cases had missed diagnoses and 1 case was wrongly diagnosed, resulting in an accurate diagnosis rate of 93.5% (72/77). According to location, submandibular gland sialolithiasis was divided into four types: type I, intra-gland stones only; type II, hilum or gland-duct junction stones, with or without intra-gland stones; type III, extra-gland stones (stones in the main duct), with or without intra-gland stones; and type IV, intraductal stones at mouth floor close to the ductal opening. Among 17 cases of type III sialolithiasis, 9 were detected by linear transducer and another 7 were detected by additional use of intracavitary transducer under the chin. Two cases of type IV sialolithiasis were detected by putting intracavity transducer under the chin, whereas they were not detected using linear transducer. In conclusion, combined use of linear-array and intracavity high-frequency transducers enables scanning from multiple directions, which leads to improved visualization and high accuracy in detecting submandibular gland sialolithiasis.

Keywords: High frequency ultrasound, linear-array transducer, intracavity transducer, submandibular gland, sialolithiasis

Introduction

Submandibular gland sialolithiasis is a relatively common form of sialolithiasis, accounting for 80%-90% of all the cases; it is a major cause of acute or chronic submandibular gland inflammation [1, 2]. Primary clinical manifestations of submandibular gland sialolithiasis include submandibular pain and swelling. Previously, the diagnosis of submandibular gland sialolithiasis was mainly achieved by palpation, X-ray inspection. However, X-ray examination has difficulty in visualizing soft stones, thus limiting its diagnostic accuracy. Cone beam computed tomog-

raphy (CBCT) had higher sensitivity than ultrasound (US) (79% vs 70%) in diagnosis of sialolithiasis; nevertheless, it is radioactive and costly and not suitable for all populations [3]. US examination has become the first-line imaging modality for diagnosing submandibular gland sialolithiasis in clinical practice due to its ease of performance, real-time scanning, no radiation, non-invasiveness, and cost-effectiveness [3-7]. However, conventional US using linear transducer has difficulty in displaying the entire course of the submandibular duct because of the limited contact between the linear transducer and skin, leading to an increased chance

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that a stone within the duct could be missed. To further improve the detection rate of submandibular gland sialolithiasis, US in combination with X-ray examination is generally used. This increases the sensitivity to 80-96% in visualizing soft stones [8, 9], but the radiation associated with X-ray examination cannot be avoided. The intracavity transducer, although designed primarily for gynecology & obstetrics or prostate studies, has better contact between the transducer and skin compared to the linear transducer. Therefore, the utilization of the intracavity transducer might provide better visualization of the submandibular duct, leading to an improved diagnostic accuracy for submandibular gland sialolithiasis.

In this retrospective study, the US features of 77 cases of surgically confirmed submandibular gland sialolithiasis over a 9 year period were analyzed. All cases underwent preoperative high frequency US examination with a combination of linear transducer and intracavity transducer. The aim of the study was to evaluate the diagnostic value of the combined use of linear-array and intracavity transducers for submandibular gland sialolithiasis.

Methods and materials

Patients

The study included 77 patients with submandibular gland sialolithiasis that were confirmed by surgery between October 2004 and August 2013. There were 51 men and 26 women, ranging in age from 12 to 75 years old, with a mean age of 44 ± 12 years. All the cases with sialolithiasis were unilateral and all the patients underwent unilateral submandibular gland excision. Forty-five cases were on the right side and 32 cases were on the left side.

Methods

A Philips IU22 color Doppler ultrasound imaging unit (Philips Ultrasound, Bothell, WA, USA) with an intracavity transducer (frequency range, 5-17 MHz) and an Esaote DU-6 color Doppler ultrasound imaging unit (Esaote, Genoa, Italy) with a linear array transducer (frequency range, 7.5-10 MHz) were used. In order to fully expose the submandibular area, patients were scanned in a supine position, with a pillow located under the shoulder when necessary. The submandib-

ular glands were scanned thoroughly to observe the gland size, morphology, internal echogenicity, and duct diameter. Color Doppler flow imaging was performed to evaluate the vascularity in the gland and was used to make a distinction between blood vessels and submandibular gland duct dilation.

The findings in the suspected submandibular gland were referenced with the contralateral submandibular gland, and the whole course of the submandibular gland duct was traced on the oblique coronal plane parallel to the mandibular body. Once duct dilation was found, its course was tracked until the stone obstruction location was detected. When the stone was located in the main duct rather than intraglandular, an intracavity transducer was applied. A sterile membrane was placed over the intracavity transducer, which was placed under the chin or directly placed under the tongue near the lingual frenulum.

Statistical analysis

Statistical analysis was performed using SPSS software (version 18.0, Chicago, IL, USA). Continuous variables were expressed as mean \pm standard deviation (SD) and range. The numbers of four types of submandibular gland sialolithiasis on ultrasound characteristics were counted using descriptive statistics. Differences in accuracy were compared using the χ^2 test. A two-tailed $P < 0.05$ was defined as statistically significant difference.

Results

Using linear-array high-frequency transducer, among the 77 cases with submandibular gland sialolithiasis, 63 cases were correctly diagnosed before surgery, 13 cases had missed diagnoses and 1 case was wrongly diagnosed, resulting in an accurate diagnosis rate of 81.8% (63/77). However, using linear-array in combination with intracavity transducer, 72 cases were correctly diagnosed before surgery, 4 cases had missed diagnoses and 1 case was wrongly diagnosed, resulting in a statistically significant increased accurate diagnosis rate of 93.5% (72/77) ($P = 0.048$) (**Table 1**).

The submandibular gland sialolithiasis were divided into four types according to lesion location:

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Table 1. The accuracy of two different methods

Methods	Correctly diagnosed	Missed diagnosed	Wrongly diagnosed	Accuracy
Linear-array high-frequency transducer	63	13	1	81.8% (63/77)
Together with intracavity transducer	72	4	1	93.5%* (72/77)

Note: *P=0.048, compared with accuracy of linear-array high frequency transducer (93.5% vs 81.8%).

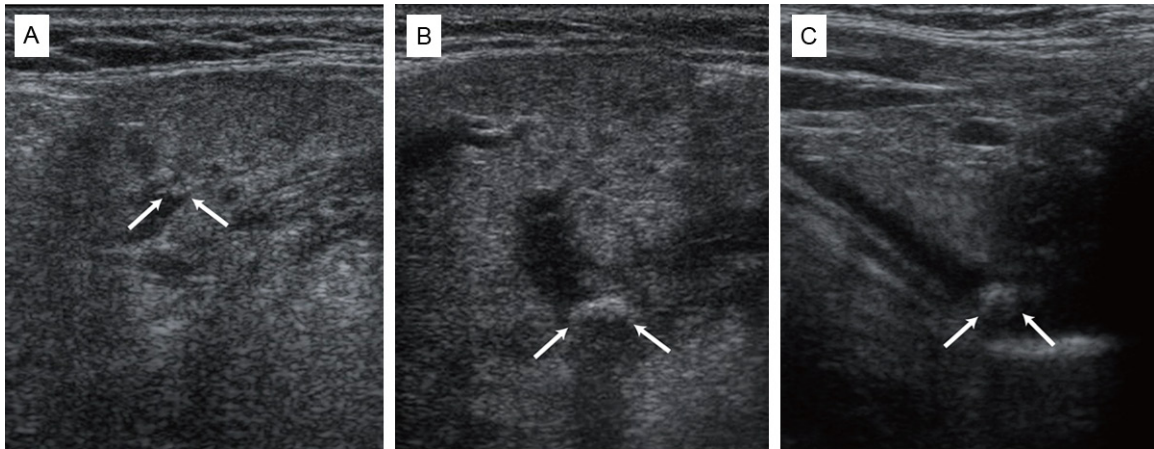


Figure 1. Intra-gland stone (Type I), gland hilum stone (Type II) and extra-gland stone (Type III) of submandibular gland sialolithiasis. A: Intra-gland stones and intra-glandular duct dilation (arrows); B: Gland hilum stone is shown in the gland-duct junction (arrows); C: Extra-gland stone is present in the main duct (arrows).

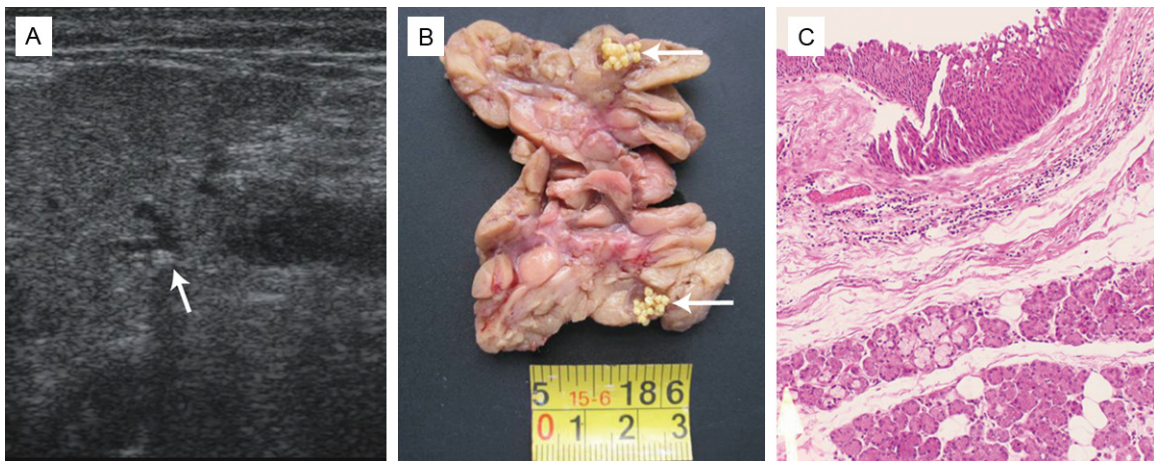


Figure 2. Gland hilum stones of submandibular gland sialolithiasis (Type II). A: Gland hilum stone and intra-glandular duct dilation (arrow); B: A bunch of stones in the gland-duct junction (arrows); C: The lesion is confirmed to be submandibular gland sialolithiasis with duct dilation pathologically (H&E staining, magnification, 10×10).

1) Type I, intra-gland stones only (n=46): All the lesions appeared hyperechoic, among which 38 cases showed posterior acoustic shadowing and 8 cases did not. Fifteen cases had single stone and 31 cases had multiple stones. Twenty-eight cases showed tree-like duct dilation and 18 cases showed thin strip-like duct dilation (**Figure 1A**).

2) Type II, gland hilum (gland-duct junction) stones, with or without intra-gland stones (n=12): All were hyperechoic with acoustic shadowing on US, of which 11 cases had single stone and 1 case had multiple stones. In the 11 cases with single stone at the gland hilum, 4 cases were accompanied by intraglandular stones. Ten cases showed tree-like dilation of

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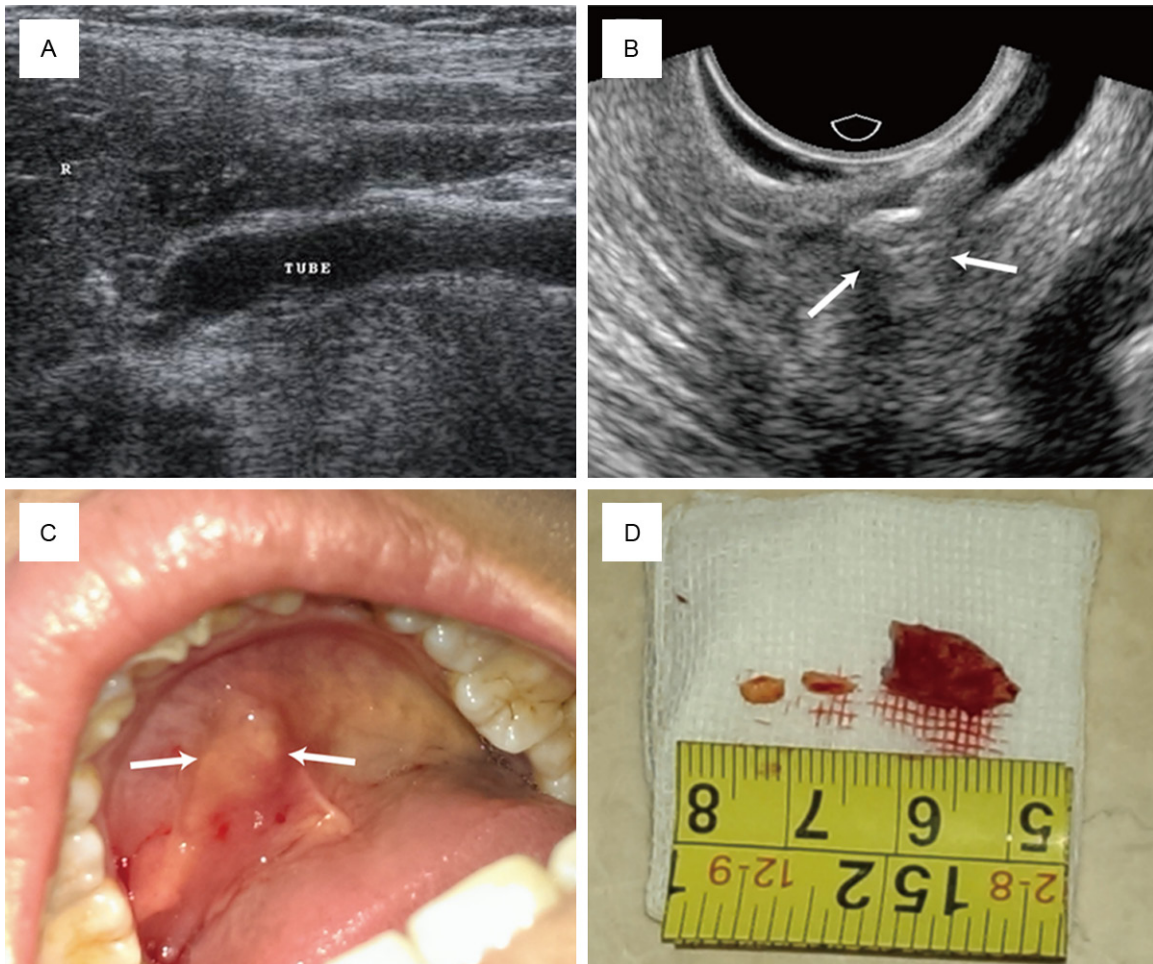


Figure 3. Intraductal stones of submandibular gland sialolithiasis (Type IV). A: Stones are not detected by the linear transducer; B: Stones are detected by putting the intracavity transducer under the chin (arrows); C: Stones are at the mouth floor close to ductal opening (arrows); D: Stones are taken out by surgery.

the duct and 2 cases showed cystic duct dilation (**Figures 1B and 2**).

3) Type III, extra-gland stones (stones in the main duct), with or without intra-gland stones (n=17): All the lesions were hyperechoic, among which 10 cases showed posterior acoustic shadowing and 7 cases did not. Fifteen cases had single stone and 2 cases had multiple stones (multiple segmental duct obstructions), including 11 cases accompanied by intraglandular stones. The duct showed tree-like dilation in 10 cases, thin strip-like dilation in 5 cases, and cystic dilation in 2 cases. Among 17 cases of type III stones, 10 were detected by linear transducer and additional 7 were detected by intracavity transducer under the chin. All the type III stones were located in the middle-lower of the main duct (from gland hilum to the mouth floor close to ductal opening) (**Figure 1C**).

4) Type IV, intraductal stones at the mouth floor close to ductal opening (n=2): Both cases were detected by putting the intracavity transducer under the chin. Neither was detected by the linear transducer (**Figure 3**).

The ultrasound features of the submandibular glands for the 77 cases were shown in **Table 2**. Among the 77 cases with submandibular gland sialolithiasis, 17 cases had simple submandibular gland duct calculi, 30 cases had coexisting chronic submandibular gland inflammation, and 31 cases had acute episode of chronic inflammation.

There were four false-negative cases in this series. Among these cases, three appeared to have submandibular gland enlargement and uneven echo on US, which were speculated to be submandibular gland inflammation without

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Table 2. Ultrasound findings of the submandibular glands in the 77 cases

Characteristics	Type I	Type II	Type III	Type IV
Number of cases	46	12	17	2
Submandibular morphology				
Swelling	34	10	12	2
Normal	12	2	5	0
Increased volume				
Obvious	29	8	7	2
Mild	5	2	5	0
None	12	2	5	0
Uneven echogenicity				
Decreased	27	8	10	2
Increased	19	4	7	0
Blood supply				
Rich	25	10	12	2
Dotted	21	2	5	0

Note-Types of submandibular gland sialolithiasis: Type I, intra-gland stones only; Type II, gland hilum stones (gland-duct junction), with or without intra-gland stones; Type III, extra-gland stones (stones in the main duct), with or without intra-gland stones; Type IV, intraductal stones at the mouth floor close to ductal opening.

any signs of duct dilation and stones. Surgical results showed that two cases had muddy intraglandular duct stones and one case had small loose stones in the main duct. Another case was negative on US and surgical result revealed muddy intraglandular duct stones. On the other hand, there was one false-positive case in the study. US images indicated glandular duct dilation with muddy stones and bilateral main duct dilation was found. Surgery confirmed duct dilation due to stricture caused by a long-term chronic inflammatory adhesion; there were inflammatory sediments in the glandular duct.

Discussion

The submandibular gland is located within the submandibular triangle. After leaving the gland, the salivary duct runs irregularly, opening lateral to the lingual frenulum in the anterior floor of the mouth. The total length of the salivary duct is approximately 6-7 cm and its diameter is about 2 mm. Submandibular duct is slender and long, with a predilection as the site of calculi and inflammation [10]. Typical US features for submandibular gland stones consist of round or oval hyperechoic structures with posterior acoustic shadowing. Proximal ductal dilation can be seen if the stone causes complete

obstruction. Small stones often result in a faint posterior shadowing [8, 9, 11, 12].

Because the submandibular duct is thin, curved, and superficially located, it is difficult to visualize its entire course via US with a conventional high-frequency linear transducer. This is due to the limited contact between the transducer and the skin. In the current study, we applied a 5-17 MHz high-frequency intracavity transducer, which is smaller in size and has a more curved surface compared to the linear transducer, to clearly visualize the entire course of the submandibular duct. With the help of this transducer, all the obstruction sites were clearly visualized without signal loss. When combined with glandular information such as size, morphology, internal echogenicity, blood supply, and duct dilation, the degree of obstruction and infection in the submandibular gland can be comprehensively evaluated.

Submandibular duct dilation in combination with inflammatory change of the gland on US always suggests ductal obstruction. As such, the duct should be tracked along its entire course from the gland hilum to determine the nature and location of the obstruction. The diagnosis of submandibular sialolithiasis can be achieved when there is a hyperechoic object with posterior acoustic shadowing. When an extraglandular stone is far from the gland hilum (especially if near the ductal papilla), the conspicuity of the US will be diminished due to gas interference in the mouth floor or the mandibular tissue blockage. In such a case, we used an intracavity transducer under the chin at a location near the lingual frenulum to avoid the mandibular bone interference. If needed, the intracavity transducer can also be placed inside the mouth after the transducer is completely cleaned and disinfected, which further improved the diagnostic accuracy for stones located near the papilla. Our accurate diagnosis rate was 93.5%, consistent with previously reported accuracy of about 90% [13].

Several factors may have contributed to the 4 false-negative results in our study. In three cases, the intraglandular duct muddy stones were isoechoic and spread in the slightly dilated ducts, making it difficult to be differentiated

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from inflammatory changes of the gland or the duct within normal glands. In the fourth case, small loose stones in the main duct were found. Obstruction was incomplete and thus ductal dilation was not significant. Terraz [4] reported that stone size is an important factor that can influence diagnostic accuracy. Stones <3 mm often do not have strong echo and obvious posterior acoustic shadowing; the duct may not be dilated, thus resulting in false-negative results. In addition, the loose stones appeared isoechoic, which also contributed to the misdiagnosis.

Several useful tips to minimize false negative results are as follows: 1) If there is intraglandular duct dilation, the stones may be present either in the glandular duct or the main duct. If it is located in the main duct, the main duct is usually dilated. 2) The diagnosis of sialolithiasis should be considered if there is a history of alternate submandibular swelling and degradation. 3) A patient who is suspected to have salivary obstruction can be given stimulating food in order to make ductal dilation more obvious. Koischwit [9] has injected agents to facilitate salivary secretion and duct dilation and improved display of intraductal stones is available. Other authors reported that vitamin C administration prior to US examination can promote duct dilation and thereby improve the detection rate of duct stones [14, 15]. 4) Missed diagnoses may occur when there are intraductal stones in parenchyma which fails to cause dilation [9, 12].

There was one false-positive case in this study. Although the patient had bilateral main duct dilation, it was caused by the stricture of the main duct due to previous surgery. The debris in the duct mimicked intraductal stones. Therefore, it is necessary to exclude duct obstruction caused by duct wall fibrosis or scarring [4, 12], as well as echogenic gas in the duct [11]. In addition, some authors used finger compression from oral cavity towards the transducer, which can also improve the display of stones within the main duct [11, 12]. Patel et al [12] found that the diagnostic sensitivity and specificity of US alone were 91% and 80%, which were improved to 96.9% and 90% using routine US plus finger compression from oral cavity.

Currently, there are several diagnostic imaging methods for submandibular gland sialolithiasis,

including US, X-ray, CT, MRI, iodinated sialography and salivary endoscopy. Of them, X-ray and CT are associated with radiation exposure. They also have difficulties in visualizing soft stones, thus up to 20% of stones are invisible by these modalities [8, 16], which affects the accuracy of these imaging modalities [17, 18]. Although iodinated sialography is considered as the clinical gold standard, it is invasive and highly dependent on the operator experience. Additionally, the intra- or post-operative pain and possible allergic reactions cannot be neglected. Furthermore, it is contraindicated for submandibular gland inflammation since contrast is apt to increase the extent of inflammation [3, 4, 19, 20]. MRI, as a non-invasive method, has a sensitivity and specificity of 80-100% and 90-100% [19, 21, 22]; however, it is not suitable for daily practice due to its high cost. Salivary endoscopy is highly accurate for diagnosis of sialolithiasis and treatment by endoscopic removal of stones is available; nevertheless, it is invasive and expensive, acute submandibular gland inflammation/large stones (>10 mm)/intra-gland stones were unsuitable for this examination [23, 24].

In summary, high-frequency US examination is convenient and noninvasive; it can determine the location the submandibular gland duct calculi intuitively and accurately if combined with the use of intracavity transducer, which is of great value in choosing appropriate treatment method and is an important modality in postoperative follow-up.

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Disclosure of conflict of interest

None.

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