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Comparative Analysis of Ultrasound and Surgical Findings in Anatomical Variations of de Quervain's Disease

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Background: This study compares ultrasound and surgical findings of anatomical variations in de Quervain's disease.
Methods: Seventy-four wrists from patients with unilateral de Quervain's disease were examined through ultrasonography and surgery. Presence of intracompartment septum, abductor pollicis longus (APL) slips, and selective stenosis were verified by both methods. Two orthopedic surgeons assessed ultrasound findings for intra- and interobserver reliability.
Results: Amongst 74 participants (43 women and 31 men), 60.8% had a complete septum, 31.1% had an incomplete septum, and 8.1% had no septum; 70.3% had multi-slip APL and 66.2% had extensor pollicis brevis stenosis. Surgical and ultrasonographic findings displayed a high level of sensitivity and specificity. Intraobserver reliability was high, and interobserver reliability was substantial.
Conclusions: The study confirms ultrasonography's reliability in identifying anatomical variations in de Quervain's disease, with high sensitivity, specificity, and substantial intra- and interobserver reliability, emphasizing its usefulness in preoperative assessment and planning.
Keywords: *De Quervain disease, Ultrasonography anatomical variations, Septum, Multi-slip, Selective stenosis*

De Quervain's tenosynovitis is a condition that involves inflammation and narrowing of the first extensor compartment of the wrist, which houses the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) tendons.[1,2] This condition is often caused by repetitive friction on these tendons, leading to swelling and thickening of the extensor retinaculum, the tissue covering the compartment, which restricts tendon movement and causes pain.[3] Various theories have been proposed to explain its cause, including trauma, increased frictional forces, repetitive microtrauma, and anatomical variations.[4,5)]

Anatomical variations in the first extensor compartment are common in de Quervain's disease. These variations include separate fibro-osseous ducts for the APL and EPB,[6] individual synovial membranes, and multiple tendons.[7,8] Stenosis may occur in 1 or both subcompartments, affecting either the APL or EPB,[9-13] a condition we refer to as selective stenosis, which has been implied but not formally defined in previous literature. Such anatomical differences can considerably influence the disease course and treatment outcomes. For instance, the independent compartment of the EPB makes it challenging to insert steroids properly due to its narrow and deep location; this limits the effectiveness of conservative treatments.[4,14-16] Subcompartmentalization within the first extensor compartment can also lead to poor surgical outcomes if all subcompartments cannot be adequately decompressed.[5,15,17]

Previous studies have focused on anatomical and surgical findings related to the septum, multi-slip, and

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selective stenosis.[5,7,15,17-20] Ultrasound has been used to identify anatomical variations in de Quervain's disease,[9,10,21-26] and several studies have tested its validity in this context.[9,21,25] However, to the best of our knowledge, the reliability of ultrasonography for anatomic variants of de Quervain's disease has not yet been investigated, except for 1 study of the thickness of the extensor retinaculum.[25] Furthermore, ultrasonography has not been used to assess selective stenosis in the subcompartments.

The primary aim of this study was to evaluate the validity and interobserver reliability of ultrasonographic assessments of anatomical variations in patients with de Quervain's disease by comparing ultrasonographic findings with surgical observations. We also aimed to assess the presence of selective stenosis in the subcompartments using both ultrasonographic and surgical findings.

METHODS

The Institutional Review Board of Hanyang University Hospital approved the study (No. HYUH-2023-08-008). Written informed consent was obtained from all the patients who were involved in this study.

Participant Selection and Data Collection

This study included 74 consecutive patients diagnosed with unilateral de Quervain's disease between October 2020 and May 2022. The patient group comprised 34 women and 40 men, all of whom showed resistance to steroid injections, splints, and nonsteroidal anti-inflammatory drugs. Patients received an average of 1.7 steroid injections, ranging from 1 to 4 injections, performed without ultrasonography. Regardless of the injection, a wrist splint was applied, typically for about 1 month. The effectiveness of the treatment was then monitored over an average period of 3 months to assess the response to the injections. The diagnosis was made by an orthopedic surgeon with 12 years of experience (CHL) based on the presence of pain and tenderness in the first extensor compartment and positive Finkelstein test results. Each participant underwent both ultrasonography and surgical treatment. Data were collected retrospectively from patient records. Patients with bilateral de Quervain's disease or other wrist conditions were excluded. All patients initially received conservative treatment, including steroid injections; however, due to persistent pain, surgery was eventually performed on all patients.

Ultrasonographic Examination

The surgeon who performed the surgical procedure also directly conducted the ultrasound examination for each patient. A standardized protocol was followed during each ultrasonographic examination to ensure consistency. We stored 3 images for each patient: 2 axial views and 1 longitudinal view of the first extensor compartment. The axial images were captured at the proximal and distal levels relative to the radial styloid to encompass the ends of the compartment. The longitudinal image was obtained along the APL and EPB tendons. In complex cases where anatomical variations were difficult to assess, we recorded videos during the ultrasonographic examinations to facilitate accurate classification. All images and videos were saved in digital imaging and communications in medicine (DICOM) format to ensure consistent quality and compatibility for analysis. Examinations were conducted using ultrasonography (Nemio 30 equipped with a high-frequency 14.0-MHz linear transducer). The patients were positioned with their arms and thumbs in a neutral position and the radial styloid facing upward. Ultrasonic gel was applied to the radial styloid area before transverse scanning of the first extensor compartment.

Surgical Procedures and Evaluation

During the surgical intervention, the senior surgeon directly evaluated and recorded the anatomical variations observed in the first extensor compartment. To ensure consistency in diagnosis, ultrasonography, and surgical intervention, all procedures were conducted by the same practitioner. A small oblique skin incision was made, and the extensor retinaculum was carefully dissected and incised. The released tendons were evaluated, and the EPB tendon was identified. In patients where the EPB tendon was not found, the intracompartmental septum was explored and resected. The presence of an intracompartmental septum, APL multi-slip, and selective stenosis was assessed. Patients were allowed to resume daily activities without a splint on the same day of surgery.

Independent Evaluation of Ultrasonographic Images

Validity was assessed by comparing the ultrasonographic findings with the surgical findings, which served as the reference standard. For each anatomical variation, the assessments from 2 observers (SHB and KYK) were averaged to obtain mean values. These mean values were then compared to the surgical findings to calculate sensitivity and specificity.

Reliability was defined as the consistency of the measurement. To assess the reliability of the ultrasound findings, 2 independent orthopedic surgeons (SHB and KYK), who were blinded to the surgical results, performed a separate evaluation of the ultrasound images. Each surgeon conducted 2 rounds of image analysis to verify the consistency and accuracy of the anatomical variations identified. A consensus on the identification of anatomical variations was reached through a comparative analysis of these images and surgical results obtained during a period outside of the study timeframe. This training focused on familiarizing them with the identification of key anatomical structures and variations, as well as differentiating common findings.

The images were displayed on identical 24-inch computer monitors, with each examiner in an identical setting. Inter- and intra-observer reliabilities were determined by 2 orthopedic surgeons (SHB and KYK), each with 3 and 4 years of experience in ultrasonography, respectively. These 2 observers separately evaluated the presence of septum, APL multi-slip, and selective stenosis while being blinded to patient data and the evaluations of the other observers. Reliability sessions were conducted twice with a 1-month interval. Orders for measurements were assigned randomly, and all data were collected by a research assistant (YSL) who otherwise did not participate in the reliability sessions. To measure intra- and interobserver reliability, kappa statistics were calculated.

Anatomical Variations in de Quervain Disease

Septum

The presence or absence of a septum within the compartment was evaluated in 3 groups: no septum, incomplete septum, and complete septum. The APL and EPB tendons are usually in the same compartment, but some have separate subcompartments for the APL and EPB tendons within the first extensor compartment. Hiranuma[27] defined subcompartmentalization as follows: the presence of vertical or oblique linear septum-like structures extending from the extensor retina between the APL and EPL, or the presence of a completely separate hypoechoic circular rim around the EPB and APL.

Regarding subcompartmentalization of the first extensor compartment, 3 anatomical variations can be found by ultrasonography with the recent development of high-resolution ultrasonography: complete subcompartmentalization, distal incomplete subcompartmentalization, and no subcompartmentalization.[9] In recent studies, ultrasonography has also been performed in patients with de Quervain's disease with subcompartmentalization of the first extensor compartment[9,10,26] (Fig. 1).

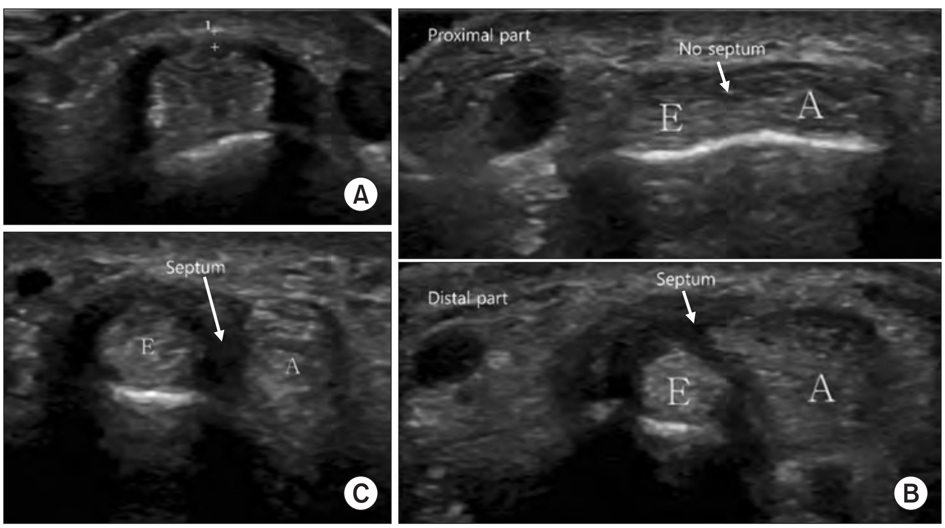

Fig. 1. The sonographic images visually represent the varying degrees of subcompartmentalization within the first extensor compartment of the wrist, specifically focusing on the presence or absence of a septum. E: extensor pollicis brevis, A: abductor pollicis longus. (A) The "no septum" section shows the extensor pollicis brevis and abductor pollicis longus tendons appearing as 1, with no visible septum, indicating no subcompartmentalization. (B) Ultrasonographic images of an incomplete septum. The proximal part (upper image) shows no septum (arrow) between the abductor pollicis longus and extensor pollicis brevis tendons, while the distal part (lower image) displays a septum (arrow) partially dividing the first extensor compartment. (C) Ultrasonographic image of a complete septum. An arrow indicates the septum fully separating the abductor pollicis longus and abductor pollicis longus tendons into distinct subcompartments throughout the entire length of the first extensor compartment.

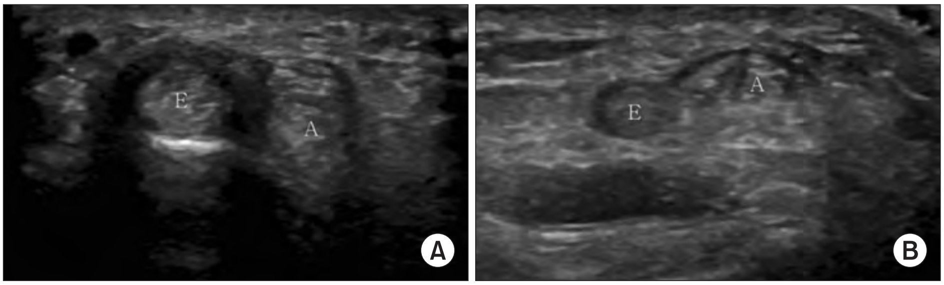

Fig. 2. Ultrasonographic images of the first extensor compartment of the wrist, specifically focusing on the number of abductor pollicis longus (APL) tendons present. E: extensor pollicis brevis, A: abductor pollicis longus. (A) The "single APL" section of the image shows a single APL tendon in the first extensor compartment. This represents a less-common anatomical variation. (B) The "multi APL" section shows multiple APL tendons within the first extensor compartment. This is the most common anatomical pattern, present in 57% of wrists, typically consisting of 2 APLs and 1 extensor pollicis brevis in the compartment. However, the exact number of APL tendon slips can vary and may be difficult to identify using ultrasound due to incomplete division, crowding, or anisotropic effects.

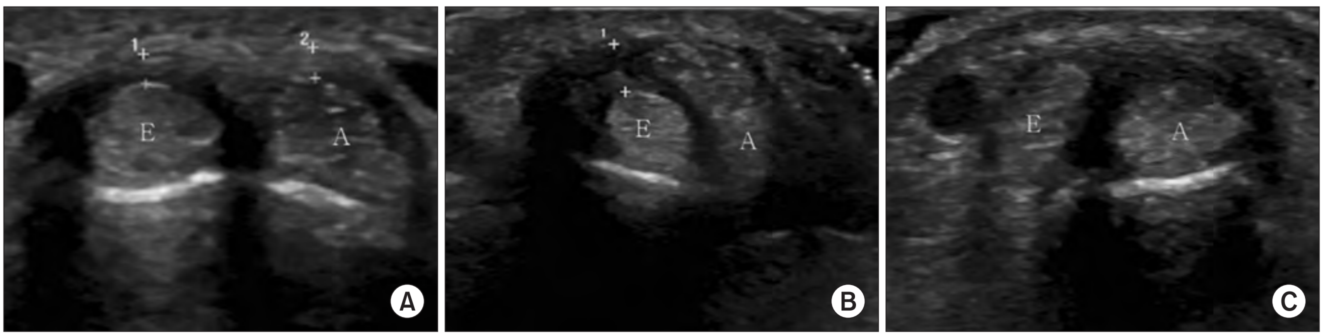

Fig. 3. The sonographic images provide a detailed representation of the first extensor compartment of the wrist, specifically focusing on instances of selective and non-selective stenosis in either or both subdivisions of the first dorsal compartment. E: extensor pollicis brevis, A: abductor pollicis longus. (A) The "non-selective stenosis" section of the image shows instances where stenosis is not selectively affecting either the abductor pollicis longus or extensor pollicis brevis, but rather is present in both tendons. (B) The "extensor pollicis brevis stenosis" section of the image shows selective stenosis predominantly affecting the extensor pollicis brevis alone. The thickness between the '+' signs represents extensor pollicis brevis hypertrophy. (C) The "abductor pollicis longus (APL) stenosis" section of the image shows selective stenosis in the APL alone, which was observed in very few patients in this study.

APL multi-slip

The ultrasound and surgical findings confirmed the presence of multiple slips in the APL (Fig. 2). According to a cadaveric study by Jackson et al.,[28] the most common anatomic pattern (present in 57% of wrists) consists of 2 APLs and 1 EPB in the compartment.[4] However, the number of tendons on the APL side can vary.[5,17,18] As it is difficult to accurately assess the number of APLs with multiple slips, we divided them into 2 groups: those with 1 slip and those with 2 or more slips.

Selective stenosis

Selective stenosis was assessed by measuring the thickness of the extensor retinaculum over the APL and EPB tendons using ultrasonography. An extensor retinaculum thickness greater than 0.45 mm was considered indicative of stenosis, while a thickness of 0.45 mm or less was considered normal.[25] These measurements were used to determine the presence of selective stenosis in the APL and EPB tendons for each patient (Fig. 3).

Statistical Analysis

The data were analyzed using SPSS version 23.0 (IBM Corp.). To evaluate the validity of ultrasonographic versus surgical findings, sensitivity and specificity analyses were conducted. Sensitivity was the ratio of true positives, the instances in which ultrasound correctly identified anatomical variations confirmed by surgery. Conversely, specificity was the ratio of true negatives, where ultrasound accurately noted the absence of variations, which was also confirmed surgically. To measure intra- and interobserver reliability, kappa statistics were calculated. We established

Table 1. Summary of Methodological Approach

Section	Description
Participant selection	74 Patients with unilateral de Quervain's disease; excluded if bilateral or other wrist conditions; all resistant to conservative treatments; data collected retrospectively
Ultrasonographic examination	Performed by the senior surgeon; documented anatomical variations through saved images and videos; used high-frequency transducer; patients positioned with arms and thumbs neutral.
Surgical procedure	Same senior surgeon to ensure consistency; small oblique skin incision; evaluated extensor pollicis brevis and anatomical variations; allowed immediate return to daily activities postoperatively
Independent evaluation	Two orthopedic surgeons blinded to surgical results; evaluated ultrasound images for anatomical variations; evaluations conducted twice with a 1-month interval
Anatomical variation	Evaluated the presence of septum and APL multi-slip and selective stenosis assessed using ultrasound with established criteria
Statistical analysis	Used SPSS 23.0; sensitivity and specificity analyses for ultrasound vs. surgical findings; kappa statistics for inter-/intra-observer reliability; $p < 0.05$ considered significant.

APL: abductor pollicis longus.

a *p*-value of 0.05 as the threshold for statistical significance to mitigate the likelihood that our findings could be attributed to random chance. This comprehensive statistical approach was foundational to ensuring the validity and reliability of our study outcomes (Table 1).

RESULTS

The demographic data of the patients are as follows: the average age was 40.6 years, ranging from 20 to 54 years, with 43 women and 31 men. The right to left ratio was 41:33 (Table 2). Surgical findings revealed that 6 patients (8.1%) had no septum, 23 (31.1%) had an incomplete septum, and 45 (60.8%) had a complete septum. Regarding the APL, 22 (29.7%) had a single slip and 52 (70.3%) had a multi-slip. Selective stenosis was non-selective in 23 patients (31.1%), present in the EPB in 49 patients (66.2%), and present in the APL in 2 patients (2.7%) (Table 3).

The sensitivity and specificity of the surgical and ultrasonographic findings were analyzed. The sensitivity and specificity in the absence of a septum were 100 and 99.2, respectively. The sensitivity and specificity for an incomplete septum was 85.8 and 96.7, respectively. For a complete septum, the sensitivity was 98.3 and the specificity was 90.4. The sensitivities and specificities for a single slip and multi-slip in the APL were 74.9 and 96.1, respectively, and 96.1 and 74.9, respectively. For non-selective stenosis, the sensitivity was 86.9 and the specificity was 95.1. The sensitivity and specificity for stenosis in the EPB was 94.8 and 88, respectively. For stenosis in the APL, both the sensitivity and specificity were 100 (Table 4).

Table 2. Demographic Data

Variable	Value
Age (yr), median (range)	40.6 (20–54)
Sex (female : male)	43 : 31
Right : left	41 : 33

Table 3. Surgical Findings

Variable		No. (%)
Septum	No septum	6 (8.1)
	Incomplete	23 (31.1)
	Complete	45 (60.8)
APL	Single slip	22 (29.7)
	Multi-slip	52 (70.3)
Selective stenosis	Non-selective	23 (31.1)
	EPB	49 (66.2)
	APL	2 (2.7)

APL: abductor pollicis longus, EPB: extensor pollicis brevis.

Table 4. Sensitivity and Specificity of the Surgical Findings and Ultrasonographic Findings (Mean Values)

	Sensitivity (%)	Specificity (%)
No septum	100	99.2
Incomplete	85.8	96.7
Complete	98.3	90.4
Single slip	74.9	96.1
Multi-slip	96.1	74.9
Non-selective	86.9	95.1
EPB	94.8	88.0
APL	100	100

EPB: extensor pollicis brevis, APL: abductor pollicis longus.

The results of this study demonstrated a high level of intraobserver reliability between the first and second sessions for the 2 raters across 3 anatomic variations: septum type, APL (single/multi-slip), and selective stenosis. For rater No. 1, the kappa statistics for septum type, APL (single/multi-slip), and selective stenosis were 0.842, 0.705, and 0.729, respectively. This indicates an almost perfect reliability for septum type and substantial reliability for APL (single/multi-slip) and selective stenosis.

Similarly, for rater No. 2, the kappa statistics for septum type, APL (single/multi-slip), and selective stenosis were 0.895, 0.796, and 0.868, respectively. This indicates an almost perfect reliability for septum type and selective stenosis and substantial reliability for APL (single/multi-slip) (Table 5). Interobserver reliability was also assessed across 2 sessions for the same anatomic variations. In the first session, the kappa statistics for septum type, APL (single/multi-slip), and selective stenosis were 0.864, 0.667, and 0.703, respectively. This indicates an almost perfect reliability for septum type and substantial reliability for APL (single/multi-slip) and selective stenosis. In the second session, the kappa statistics for septum type, APL (single/multi-slip), and selective stenosis were 0.822, 0.688, and 0.767, respectively. This indicates an almost perfect reliability for septum type and substantial reliability for APL (single/multi-slip) and selective stenosis (Table 6).

DISCUSSION

This study investigated the validity and reliability of ultrasonography in detecting anatomical variations in de Quervain's disease in comparison to surgical findings. The results showed high agreement between ultrasonography and surgical findings, indicating the reliability of ultrasonography. Anatomical variations, including septum presence, multi-slip APL, and selective stenosis, were consistently identified, demonstrating high intra- and interobserver reliability.

Anatomical variations within the first extensor compartment, such as the presence of a septum, can separate the APL and EPB tendons into distinct subcompartments. In a study by Motoura et al.,[29] these variations were classified into types, with the normal configuration observed in 63.4% of cases, complete septation in 23.2%, incomplete septation in 8.9%, and absence of the EPB tendon in 4.5%. The presence of a septum is a known risk factor for de Quervain's disease, complicating conservative treatments[4,14-16] and potentially leading to challenges during decompression surgery due to the risk of overlooking small, isolated compartments.[5,15,17]

Our study used preoperative ultrasonography to identify these subcompartments, showing high sensitivity and specificity compared to surgical findings. This accurate preoperative detection is crucial for tailoring surgical interventions. Additionally, this study is the first to evaluate both intra- and interobserver reliability of ultrasonography in identifying these variations, further confirming its value as a reliable diagnostic tool in clinical settings.

Previous studies have reported anatomical variations in the APL,[5,17,18,28] with cadaveric studies indicating that the most common pattern includes 2 APLs and 1 EPB within the compartment, present in 57% of wrists.[28] However, the number of APL tendons can vary, and as this number increases, accurately determining the exact count using ultrasound becomes more challenging.[9] This difficulty can lead to mistakes during surgery, such as mistaking APL and EPB for a single structure, potentially resulting in incomplete decompression if the EPB is released without addressing all APL tendons. Therefore, confirming the number of APLs preoperatively with ultrasound is crucial. In this study, we used preoperative ultrasound to

Table 5. Intraobserver Reliability between the First and Second Sessions

Rater	Anatomic variation	Kappa statistics	Reliability
No. 1	Septum type	0.842	Almost perfect
	APL (single/multi-slip)	0.705	Substantial
	Selective stenosis	0.729	Substantial
No. 2	Septum type	0.895	Almost perfect
	APL (single/multi-slip)	0.796	Substantial
	Selective stenosis	0.868	Almost perfect

APL: abductor pollicis longus.

Table 6. Interobserver Reliability

Session	Anatomic variation	Kappa statistics	Reliability
First	Septum type	0.864	Almost perfect
	APL (single/multi-slip)	0.667	Substantial
	Selective stenosis	0.703	Substantial
Second	Septum type	0.822	Almost perfect
	APL (single/multi-slip)	0.688	Substantial
	Selective stenosis	0.767	Substantial

APL: abductor pollicis longus.

assess whether the APLs were multi-slipped, and while the agreement was substantial (as indicated by the kappa coefficients), the reliability was lower compared to identifying subcompartments or selective stenosis, partly due to the anisotropic effect of ultrasound.

Selective stenosis was assessed by measuring the thickness of the extensor retinaculum over the APL and EPB tendons using ultrasonography. An extensor retinaculum thickness greater than 0.45 mm was considered indicative of stenosis, while a thickness of 0.45 mm or less was considered normal.[25] These measurements were used to determine the presence of selective stenosis in the APL and EPB tendons for each patient (Fig. 3). This study is significant as it provides a theoretical contribution by being the first to confirm selective stenosis using ultrasound, a methodology not previously documented. This highlights the effectiveness of ultrasonography as a dependable diagnostic tool for detecting specific narrowing, especially in the EPB. This research addresses concerns about the subjectivity of ultrasonography by validating established measurement standards and demonstrating high sensitivity and specificity. In addition, this study contributes to our knowledge of anatomical differences in the first extensor compartment, including the presence of septum and variability in the APL tendon. It highlights the importance of precise diagnostic tools in the diagnosis of de Quervain's disease.

Practically speaking, ultrasonography can potentially improve surgical outcomes by accurately identifying selective stenosis and septal variations before surgery. Surgeons can customize their approach using precise anatomical information, which helps minimize the chance of incomplete decompression and enhances patient outcomes. It seems that including regular ultrasonographic assessment in the preoperative workflow could become a common practice for managing de Quervain's disease.

Despite the valuable insights provided by this study regarding the ultrasonographic assessment of anatomical variations in de Quervain's disease, several limitations should be acknowledged. First, this study was retrospective, focusing on surgery patients with preoperative ultrasonography and lacking a control group without de Quervain's disease. This limits our ability to fully compare anatomical variations between patients and the general population, potentially introducing bias. Second, the ultrasonography was performed by a single examiner, and the findings were subsequently assessed by multiple evaluators who reviewed the stored ultrasound images. Although this method guarantees uniformity in image acquisition, it does have a drawback. The interpretation of the first examiner could potentially impact the stored images. If independent examiners had conducted the initial ultrasonography, it could have minimized potential biases related to image selection and interpretation, resulting in a more precise depiction of the modality's capabilities. This could have provided a more impartial and potentially dependable evaluation of the anatomical variations. Third, the surgeon was aware of ultrasound findings during surgery, which could influence their judgments and introduce bias.

Finally, this study primarily focused on assessing anatomical variations and their agreement between surgical and ultrasonographic evaluations. Further investigation of the clinical implications and outcomes associated with these variations would provide a more comprehensive understanding of their significance in the management and prognosis of de Quervain's disease.

This study confirms the efficacy of ultrasonography in identifying important anatomical variations in de Quervain's disease, showing strong agreement with surgical observations. This emphasizes the significance of ultrasound in preoperative planning, specifically for precise surgical decompression. It does so by accurately identifying variations such as the presence of a septum, multi-slip APL, and selective stenosis.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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