Ultrasonographic Assessment of Testicular Viability Using Heterogeneity Levels in Torsed Testicles

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Purpose: Gross testicular heterogeneity on ultrasound has been associated with testis loss following testicular torsion in children. We aimed to quantify the extent of temporal heterogeneity associated with testis loss in testicular torsion cases using a noninvasive technique to determine a HI (heterogeneity index) on ultrasound images.

Materials and Methods: We retrospectively studied the records of patients who presented with acute scrotal pain to the Pediatric Emergency Department over a 6-year period. Ultrasound images of the affected testis and the unaffected contralateral testis were examined using a proprietary program to determine the extent of heterogeneity of each image. The difference between the HI of the torsed testis and that of the contralateral normal testis was termed ΔHI. Receiver operating characteristics curve analysis was performed to determine the ΔHI threshold for nonviability.

Results: Among 529 patients who presented with acute scrotal pain 147 had testicular torsion based on surgical findings. Of these 147 patients 110 (74.8%) were found to have a viable testis while 37 (25.2%) had a nonviable testis. Using the ΔHI cutoff of 0.394 or greater for nonviability, sensitivity and specificity were 100% and 94.5%, respectively. Positive and negative predictive values were 86% and 100%, respectively.

Conclusions: Our results demonstrate that a quantifiable temporal gradation of heterogeneity exists and the heterogeneity index can be used as an objective parameter to determine the viability of a torsed testicle. By developing the technology to measure the heterogeneity index in real time, we could potentially identify which patients with testicular torsion have a nonviable testicle and, thus, would not require immediate surgical exploration.

Key Words: testis; spermatic cord torsion; pain; ultrasonography, Doppler; tissue survival

Abbreviations and Acronyms

HI = heterogeneity index

ROC = receiver operating characteristic

ROI = region of interest

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Testicular torsion is a surgical emergency that requires timely operative intervention. The yearly incidence is 3.8 cases of surgically confirmed testicular torsion per 100,000 males younger than 18 years.[1] Prompt diagnosis is vital as delays in management result in higher rates of testicular loss.[2] Unfortunately, many patients present to the emergency room several hours or even days after the onset of scrotal

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pain, severely decreasing the likelihood of testicular salvage.[3]

Doppler ultrasound has made routine exploration an excessive management approach because it provides assessment of testicular perfusion without significant cost or delay in diagnosis.[4] The sensitivity and specificity of Doppler ultrasound for detecting testicular torsion ranges from 69% to 100% and 77% to 100%, respectively.[5–7] However, Doppler ultrasound is limited in reliably determining the viability of a torsed testicle.

When comparing 2 patients with testicular torsion who present to the emergency room with a full stomach, including 1 patient with a viable testicle and the other with a nonviable testicle, the risk of general anesthesia would be justified only in the first patient. Currently, to our knowledge we do not have a reliable preoperative predictor of testicular viability. Thus, many patients with nonviable testicles are being exposed to arguably unnecessary anesthetic risk partly to avoid medicolegal disputes. One promising modality is the evaluation of testicular echogenicity on scrotal ultrasound.

The pathophysiology of testicular torsion leads to loss of parenchymal viability, which appears as changes in the echotexture of the testis on ultrasound. Previous studies have shown that an increase in heterogeneity of the torsed testicle is associated with a higher likelihood of nonviability.[8,9] However, these changes in echotexture have only been grossly detected on grayscale ultrasound and subjectively interpreted to try to determine the viability of the torsed testis.

To quantify the extent of heterogeneity of each testis, we applied a unique, noninvasive technique to determine the HI of ultrasound images. This novel technology has been used in other applications, such as determining whether a thyroid nodule is malignant or benign and measuring the healing process of bone and cartilage.[10–12] Our aim was to develop an objective parameter that quantifies the testicular echotexture of ultrasound images to differentiate nonviable from viable testes in patients who present with testicular torsion.

MATERIALS AND METHODS

We performed a retrospective study of patients with a chief complaint of acute scrotal pain who were evaluated by the urology team in the Pediatric Emergency Department between January 2009 and December 2014. The study was approved by the institutional review board. The electronic health record was reviewed for information, including age, laterality and duration of pain from onset to diagnosis and final diagnosis based on ultrasound and operative findings. Intraoperative findings were reviewed from the operative note. We excluded from study patients who had bilateral testicular torsion, lacked a contralateral testicle, did not have a scrotal ultrasound performed or had incomplete medical records. We included all patients who underwent a scrotal ultrasound, which was performed using a 7.5 MHz LOGIQ™ E9 linear transducer with color and spectral flow Doppler to evaluate the affected testis and the normal contralateral testis.

Representative ultrasound images of the affected testis and its unaffected contralateral testis were then examined retrospectively using a proprietary program to determine the HI of each ultrasound image. Three of us (PS, CH and RP) collectively agreed on 1 representative ultrasound image of each testicle per patient, consistently using the sagittal view of each testis that captured the greatest surface area of the seminiferous tubules for analysis. We selected the best quality image to be analyzed by our software.

In brief, the software uses a dithering technique based on the Floyd-Steinberg algorithm in which the pixels of an ultrasound image are transformed into a binary map. An algorithm was applied to this binary map to determine HI values. The average HI for a single testis was obtained by performing the dithering method on 5 ROIs from 1 ultrasound image of each testicle (the same testis). To confirm the validity of the method from the standpoint of texture analysis of affected vs contralateral testes, the ROI was divided into a number of subROIs, each containing 100 pixels (fig. 1). For each subROI the number of white pixels were counted and then stored as percentages. An average of the 5 highest and the 5 lowest peaks were used to obtain a HI value for the image (fig. 2).

The difference in HI between the torsed and the contralateral nontorsed testis in each patient was determined and this value was termed ΔHI. We used the contralateral testis in the same patient as the control to minimize the variability of ultrasound image quality.

Patients with confirmed testicular torsion were divided into 2 groups, including viable and nonviable testes, respectively. A decision matrix was then determined to classify the ΔHI. All testes in the viable group were considered the actual (true) negative value while those in the nonviable group were considered the actual (true) positive value.

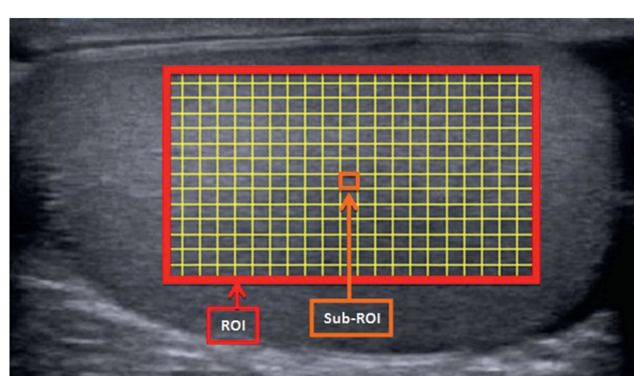

Figure 1. Description of Floyd-Steinberg algorithm used to determine percent HI with ROI divided into subROIs containing 100 pixels each.