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Ultrasonic Evaluation of Heterogeneity Levels in Normal and Torsed Testes

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Abstract -Testis torsion in pediatric patients is a surgical emergency that requires immediate operative intervention. Heterogeneity, which has been associated with testis loss, is only grossly detected on grayscale ultrasound. To quantify the extent of heterogeneity associated with torsion, we employed a unique, noninvasive technique to determine Dynamic Range (DR) in ultrasound images, and then compared DR in ultrasound of torsed testes with untorsed testes. We performed a retrospective review over a 2-year period of pediatric patients with a chief complaint of testicular pain. Patients who demonstrated an absence of blood flow on testis ultrasound and who underwent scrotal exploration for testis torsion were included in the study population. Representative ultrasound images of the affected testis and its normal contralateral testis were examined. The program 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 DR values. Univariate *t*-test analysis was performed, comparing DR values in testes with confirmed torsion to those of testes with normal blood flow. Among the 25 patients eligible for inclusion in this study, 18 underwent orchiopexy for a viable torsed testis, while 7 patients underwent orchiectomy for a nonviable testis. The mean DR on scrotal ultrasound was significantly greater in torsed testes compared to normal contralateral testes (3.89 vs. 2.75, p=.004). Additionally, using a cut-off point of 3.2 for DR, a 68% correlation was reached for predicting testis torsion on scrotal exploration. Our results demonstrate that measuring DR of the testis as a reflection of heterogeneity correlates with testis torsion. A cutoff DR of 3.2 accurately predicted torsion in 68% of testes. These results argue that DR may be a potential non-invasive indicator of testis torsion in real-time.

Keywords**:** Testicular Torsion, Ultrasound, Dynamic Range, Heterogeneity

1. Introduction

Testicular torsion in pediatric patients is a surgical emergency that requires immediate operative intervention. The yearly incidence is 3.8 cases of surgically confirmed testicular torsion per 100,000 males younger than 18 years old (Zhao et al., 2011). Prompt diagnosis is vital since delays in diagnosis and management result in higher rates of testicular loss (Dunne and O'Loughlin, 2000). However, prior to surgical exploration, other diagnoses must be considered when assessing a patient with an acute scrotum. The three most common etiologies of the acute scrotum in the pediatric population are torsion of the testicular appendage (46%), epididymitis (35%), and testicular torsion (16%) (Lewis et al., 1995). Testicular torsion is managed surgically while other causes of the acute scrotum are managed with supportive care, underscoring the importance of obtaining an accurate diagnosis.

Historically, the decision to take a patient to the operating room for surgical exploration is triggered by high clinical suspicion from the history and physical examination. Though, routine surgical exploration of the acute scrotum has been reported to have a negative rate for torsion of up to 50%, subjecting a large portion for patients to unnecessary surgery (Dubinsky et al., 1998). With the development of Doppler ultrasound and its growing availability, the evaluation of the acute scrotum has

increasingly included the use of ultrasound. It provides detailed imaging of scrotal anatomy and assessment of perfusion without significant cost or delay in diagnosis (Gunther et al., 2006). The sensitivity and specificity of detection of testicular torsion via Doppler ultrasound ranges from 69 to 100% and 77% to 100%, respectively (Lam et al., 2005; Nussbaum et al., 2002; Paltiel et al., 1998).

Testicular heterogeneity has been associated with testis loss, but is only grossly detected on gray-scale ultrasound. Prior studies have been able to use echotexture to determine viability of testes that have been torsed (Middleton et al., 1997; Kaye et al., 2008). However in those studies, whether or not a testis was "homogeneous" or "heterogeneous" was determined subjectively by a radiologist. Our aim is to develop an objective parameter that measures testicular echotexture to aid in the diagnosis of testicular torsion. To quantify the extent of heterogeneity associated with torsion, we employed a unique, noninvasive technique to determine the Dynamic Range (DR) in ultrasound images, and then compared DR in ultrasound of torsed testes with non-torsed testes.

2. Methods

We performed a retrospective review over a 2-year period of pediatric patients who presented to the Emergency Department with testicular pain. Patients who demonstrated an absence of blood flow on testis ultrasound and who underwent scrotal exploration for testis torsion were included in the study. In all patients, a 7.5 MHz linear transducer was used with a Logiq E9 ultrasound unit with color and spectral flow Doppler to evaluate both the affected testis and the normal contralateral testis. Representative ultrasound images of the affected testis and its normal contralateral testis were examined using a proprietary program to determine the DR of each ultrasound image, with investigators blinded to the status of each testis. 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 (Figure 1). An algorithm was applied to this binary map to determine DR values. Univariate *t*-test analysis was performed, comparing DR values in testes with confirmed torsion to those of testes with normal blood flow.

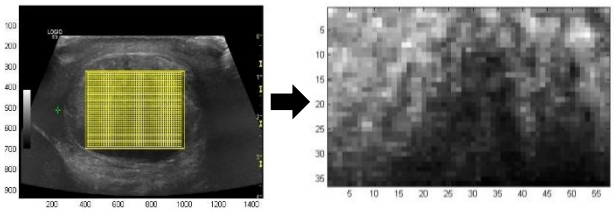

Fig. 1. Converting ultrasound image to binary map

3. Results

We were able to retrospectively gather data on 25 boys ages four years to eighteen years (mean age = 13.6 years) who underwent emergent scrotal exploration. We only included patients who had testicular torsion confirmed intraoperatively. Of the 25 patients, 18 underwent orchiopexy (mean age 14.2 years) for a viable torsed testis as well as contralateral orchiopexy of the unaffected testis, while 7 patients underwent orchiectomy (mean age 12.3 years) for a nonviable testis with contralateral orchiopexy. In all cases, the ultrasound evaluation revealed decreased or absent flow to the affected testis and normal flow to the contralateral testis. Fifty representative ultrasound images (25 torsed and 25 normal) were obtained and analyzed using the aforementioned software by a blinded investigator. The mean Dynamic Range on scrotal ultrasound was significantly greater in torsed testes compared to normal contralateral testes (3.89 vs. 2.75, p=.004) (Table 1). Additionally, using a cut-off point of 3.2 for DR, we found that the positive predictive value of DR >3.2 was 71% and negative predictive value was 65%.

4. Discussion

The diagnosis of testicular torsion has evolved over the years. Classic teaching has encouraged clinicians to utilize the history and physical examination to make the decision whether to take the patient to the operating room for surgical exploration. Most cases of acute scrotum, however, are not caused by testicular torsion can be managed conservatively (Gunther et al., 2006; Boettcher et al., 2012). Misdiagnosis of testicular torsion is the third most common cause of malpractice lawsuits in teenage boys

(Selbst et al., 2005). The goal of the urologist is to accurately diagnose and promptly treat those children with true testicular torsion while at the same time minimizing the rate of unnecessary surgical exploration. Clinical scoring systems have been developed to help systematically evaluate a patient with an acute scrotum. A retrospective study by Srinvasan et. al. (2011) was able to identify three out of 22 clinical factors that were predictive of testicular torsion (Srinvasan et. al., 2011). Barbosa et al. performed a prospective single institution study of 338 boys in which they developed a clinical scoring system that had 100% PPV and 100% NPV based on selected cutoffs (Barbosa et al., 2013). A similar study found that the use of Doppler ultrasound resulted in a significant reduction in negative explorations (Boettcher et al., 2013). However, doppler ultrasound, although with reports of high specificity, still has room for improvement. Decreased testicular perfusion is not entirely specific to testicular torsion, as it can also be seen in some patients with large hydroceles, scrotal abscesses, hematomas, or scrotal hernias (Perron, 2006). On the other hand, patients with clinically significant intermittent testicular torsion may present with intact testicular flow on Doppler ultrasonography but may eventually require surgical exploration (Munden et al., 2013). Evidently, torsion cannot be made based on one clinical factor but by the aggregate of multiple pieces of clinical information. The addition of testicular echogenicity to existing clinical information can potentially be an important factor in the evaluation of testicular torsion.

Table. 1. Comparison of dynamic range on ultrasound between testes with testicular torsion and normal testis and correlation with scrotal exploration

	Dynamic Range			**Correlation with Scrotal Exploration**			
	Normal Testis	**Torsed Testis**		**TRUE**	**FALSE**	**Total**	**Predictive value**
Mean	2.75	3.89	**Positive**	15	6	21	PPV=.71
Standard Deviation	0.71	1.74	**Negative**	10	19	29	NPV=.65
p-value	0.004						

Prior studies have looked into echogenicity and its role in diagnosing testicular torsion. Middleton et al. (1997) and a larger study by Kaye et al. (2008) found that heterogeneity of a testicle on ultrasound accurately predicted non-viability of a testicle upon surgical exploration (Middleton et al., 1997; Kaye et al., 2008). The aim of these studies was to determine which patients required emergent surgical exploration (those with viable testes) vs. those who may have opted for elective surgery (those with nonviable testes). This is the ultimate goal of our research, however, we first wanted to prove that we could reliably discern patients with torsion vs. those without torsion. Furthermore, the prior studies did not use any objective measurements of echogenicity, but instead labeled certain testes as “heterogeneous” or “homogeneous.”

To our knowledge, this is the first study objectively measuring Dynamic Range (DR) on ultrasound to evaluate echotexture in testicular torsion. We found a statistically significant difference in the mean DR of echotexture between torsed testes compared to normal testes (3.89 vs 2.75, p=.004). In plain terms, the testicles that were torsed were significantly more heterogeneous than the normal contralateral testes. Also when using a cutoff DR of 3.2, we found a positive predictive value of 71% and negative predictive value of 65%. The predictive values may not be as valuable owing to our small sample size. One study showed that Doppler ultrasonography can have PPV and NPV of 100% and 97.5%, respectively (Lam et al., 2005). Further studies utilizing our technique with a larger sample size may be more promising.

This study has several limitations, mostly owing to its retrospective nature and small sample size. Although the goal in using the DR software was to limit subjectivity and maximize objectivity of assessment of echotexture, there was still an element of sampling bias since the representative ultrasound images were selected by a clinician. A more standardized way of capturing these images needs to be

developed in order to limit the subjectivity of determining which images show "heterogeneous" testicles. Furthermore, assessment of the timing and onset of pain would have been helpful in correlating the duration of pain with the degree of heterogeneity. This was difficult to ascertain from a retrospective chart review since the time of onset of pain was often reportedly vague (i.e. "last night" or "a few days ago"). In a prospective study, this variable could be more accurately assessed.

5. Conclusion

Our results demonstrate that measuring DR of the testis as a reflection of heterogeneity significantly correlates with the diagnosis of testis torsion. These results argue that DR may be a potential non-invasive indicator of testis torsion in real-time. DR may be used in addition to already available clinical information to better guide the management of the acute scrotum. Future studies are needed to determine whether the DR of patients with nonviable testes differs from that of patients with torsed but viable testes.

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