Received:
23 December 2015

Revised:
24 May 2016

Accepted:
7 June 2016

<http://dx.doi.org/10.1259/bjr.20151077>

Cite this article as:

Xiao H, Gao Y, Li Y, Tang Y, Zhu L, Xu J, et al. Ultrasound assessment of perinatal testicular torsion. *Br J Radiol* 2016; **89**: 20151077.

FULL PAPER

Ultrasound assessment of perinatal testicular torsion

^{1,2,3,4}HUAN XIAO, MD, ^{1,2,3,4}YANG GAO, MD, ^{2,3,4,5}YINGLIANG LI, MD, ^{1,2,3,4}YI TANG, MD, ^{1,2,3,4}LIRONG ZHU, BD, ^{1,2,3,4}JUAN XU, BD, ^{1,2,3,4}FANGTING MOU, BD and ^{1,2,3,4}YINGLE HUANG, BD

¹Department of Ultrasound, Children's Hospital of Chongqing Medical University, Chongqing, China

²Ministry of Education Key Laboratory of Child Development and Disorders, Chongqing, China

³Key Laboratory of Pediatrics in Chongqing, Chongqing, China

⁴Chongqing International Science and Technology Cooperation Center for Child Development and Disorders, Chongqing, China

⁵Department of Pediatric Surgery, Children's Hospital of Chongqing Medical University, Chongqing, China

Address correspondence to: Yingliang Li, MD

E-mail: liyingsiang3170@sina.com

Huan Xiao and Yang Gao contributed equally to this study.

Objective: The goal of this study was to elucidate the different sonographic features of prenatal and postnatal testicular torsion (TT) using high-frequency colour Doppler ultrasound (HCDU) in an effort to increase diagnostic accuracy.

Methods: 29 patients (average age, 7.5 days) with perinatal TT were divided into patients with postnatal (acute) TT vs patients with prenatal (chronic) TT and their clinical characteristics, imaging features on HCDU and surgical pathology results were retrospectively analyzed.

Results: Significant differences were observed between prenatal and postnatal TT cases with regard to testicular size ($p = 0.01$) and echogenicity ($p = 0.007$). All 17 prenatal cases had non-homogeneous testicular parenchymal echo patterns compared with only 9 (64.3%) postnatal TT cases. Five postnatal TT cases presented with homogeneous echo patterns compared with none of the prenatal TT cases. Testicular blood supply was absent

in 25 (80.7%) of 31 testes on colour Doppler flow imaging, with the majority occurring in the prenatal TT cases [*i.e.* 16 (94.1%) cases]. 1 affected testis out of a total 17 testes from 16 patients with prenatal TT was salvaged, with a salvage rate of 1/17 or 0.06%. 7 affected testes out of a total 16 testes from 13 patients with postnatal neonatal TT were salvaged, with a salvage rate of 7/16 or 43.8%.

Conclusion: In neonates with acute scrotal symptoms, the possibility of perinatal TT should be considered and HCDU examination should be performed in a timely manner. HCDU examination could aid in testicular salvage by prompting quick surgical intervention.

Advances in knowledge: This study underlined the clinical contribution of HCDU in evaluating postnatal (acute) vs prenatal (chronic) TT. The sonographic features of postnatal TT with salvageable testes were compared with prenatal torsion and the relative salvage rates in both cases were discussed.

INTRODUCTION

The differential of acute neonatal scrotal disease includes testicular torsion (TT), testicular appendage torsion, epididymal torsion, epididymal appendage torsion, orchitis, epididymitis, scrotal abscess, periorchitis, incarcerated hernia and scrotal haematoma.¹ Perinatal TT is a special condition of acute scrotal disease, and the treatment time directly influences the survival of the testes. In addition, the clinical symptoms of perinatal TT are difficult to detect and are easily misdiagnosed. Therefore, early identification plays a critical role in treatment efficacy.

Ultrasound examination of testicular teratoma shows disordered echoes in the affected scrotum, and calcified lesions with intense echoes may be observed.² The characteristics of testicular idiopathic perineuritis and sheath

empyema on ultrasound are significantly different from those of neonatal testicular torsion (NTT). The former shows spotty echoes or cord-like echoes in the echo-free region and a normal morphology, echoes and blood flow of bilateral testes compared with NTT. High-frequency colour Doppler ultrasound (HCDU) is helpful for differentiating between them.

Testicular appendage torsion, epididymis torsion and epididymis appendage torsion, at the early stage, are easy to misdiagnose as TT. Immediate HCDU is needed to examine the morphology and blood flow within the testes. The heterogeneous echoes and increase in the blood flow of the swollen epididymis may exclude the possibility of TT. The clinical manifestations of embedded hernia are also similar to those of NTT, but an embedded hernia has

a normal testicular structure on ultrasound examination, which is helpful in differentiating it from NTT.

The application of HCDU in cases of acute scrotal disease is widely preformed. HCDU can not only greatly reduce the likelihood (75%)³ and false-positive rate (55%)⁴ of surgical exploration, but it also has a high sensitivity (69–90%)⁵ and specificity 98–100%⁶ for TT. Therefore, its application in perinatal acute testicular disease is clinically appropriate. In addition, perinatal TT can be subdivided into prenatal and postnatal torsion, each with its own distinct ultrasonographic features. In acute postnatal TT, the affected testis has a normal, slightly enlarged or significantly enlarged size, a relatively normal, irregular or blurred border, a homogeneous/heterogeneous echo pattern within the parenchyma and no liquefaction or calcification. The presence of calcification suggests old necrosis of the testis, as seen in prenatal torsion, where colour Doppler flow imaging (CDFI) shows no blood flow signals.

The goal of this study was to elucidate the different sonographic features of perinatal TT, using HCDU, in an effort to increase the accuracy of perinatal TT diagnosis.

METHODS AND MATERIALS

Subjects

The ethics review board of our institution approved this study, which conformed to the World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects, as revised in 2008. Informed consent was obtained from each parent or guardian prior to allowing participation of their offspring in our study.

From January 1994 to February 2014, the data from 29 patients with confirmed perinatal TT [average age, 7.5 days (range, 1–30 days)] treated at our hospital were retrospectively reviewed.

High-frequency colour Doppler ultrasound

High-frequency ultrasound probes used in the study included the Aloka α 10 (Hitachi Aloka Medical, Ome, Tokyo, Japan), Philips iU22 (Philips Healthcare Solutions, Bothell, WA), Sequoia 512 (Acuson, Mountain View, CA) and GE VIVID7 (GE Vingmed, Horten, Norway) with a frequency range of 7.5–14 MHz. These high-grade machines have mature detection techniques during colour Doppler examination. During the ultrasound examination, multisectional scanning was performed on the scrotum and bilateral groin regions.

The location, size, morphology and echogenicity of both the testes and surrounding tissues were evaluated. The colour-sampling frame was adjusted to precisely contain the testis. The pulse repetition frequency and wall filter wave were set to a low level to prevent false positives caused by improper instrument adjustment. The sonographer was careful to avoid compressing the testes with the probe (and thereby compressing the testicular blood vessels), which would artificially reduce the blood supply to the testes.

Over the 20 years this study was conducted, a total of 5 physicians performed ultrasonography; however, only 1 physician

(who had 20 years' experience in paediatric ultrasonography) conducted most of the ultrasound examinations (about 21 cases).

Treatment methods

Because of the large range of times from diagnosis to surgery, different treatment periods, different physicians performing the diagnosis and treatment and the varying willingness on the part of the parents to consent to treatment, the surgical treatments differed among the patients.

Four surgical methods were used including resection of the ipsilateral testis, resection of the ipsilateral testis plus fixation of the contralateral testis, preservation of the ipsilateral testis and preservation of the ipsilateral testis plus fixation of the contralateral testis.

Follow-up

As most of the parents of the patients did not attend a post-operative follow-up visit, the post-operative ultrasound follow-up data on the patients in this study were limited. Only 12 patients with perinatal TT had post-operative follow-up data.

RESULTS

Patient demographics (including age, body weight at birth and birth history) and clinical findings in the 29 patients with perinatal TT are shown in Table 1. Their average age was 7.5 days (age range, 1–30 days) and their average body weight was 3.6 kg (range, 2.5–4.25 kg). A total of 25 (86.2%) cases of perinatal TT were unilateral, with 15 (51.7%) cases on the right side and 10 (34.5%) cases on the left side. 4 (12.8%) cases were bilateral testicular torsion (BTT) (Table 1).

All patients with perinatal TT were full-term infants. There were 11 cases of natural birth (1 case was a breech birth at home), 14 cases were caesarean-section deliveries and 3 cases had an unknown birth history as they were not born in our hospital. One patient experienced suffocation at birth. All mothers were healthy except for one mother with gestational diabetes. There were 16 prenatal torsion cases and 13 postnatal torsion cases (Table 1). There were no significant differences between prenatal and postnatal TT with regard to the affected side, birth history, suffocation or mother's condition during pregnancy (all $p > 0.05$).

Sonographic findings

Diagnostic ultrasound was performed in 27 of 29 patients comprising 31 testes. The sonographic presentations of the 27 patients with perinatal TT are summarized in Table 2. Regarding testicular morphology, there were 10 (32.3%) cases of irregular testicular morphology, 3 (10.0%) cases showing fuzzy testicular display and 18 (58.1%) cases showing regular testicular morphology. There was no significant difference between prenatal and postnatal TT cases with regard to testicular morphology ($p = 0.10$).

Significant differences were observed between prenatal and postnatal TT cases with regard to testicular size ($p = 0.01$) and echogenicity ($p = 0.007$). All 17 prenatal cases had a non-

Table 1. Clinical data of 29 patients with perinatal testicular torsion divided into prenatal torsion and postnatal torsion

Clinical data	Total (<i>n</i> = 29)	Prenatal torsion (<i>n</i> = 16)	Postnatal torsion (<i>n</i> = 13)	<i>p</i> -value
Age (days)	7.5 (1, 30)	9.43 (1, 30)	5.15 (1, 21)	0.25
Body weight at birth (kg)	3.6 (2.5, 4.25)	3.6 (3.1, 4.25)	3.6 (2.5, 4)	0.86
Affected side				
Right	15 (51.7)	9 (56.3)	6 (46.2)	0.43
Left	10 (34.5)	6 (37.5)	4 (30.8)	
Both	4 (12.8)	1 (6.2)	3 (23.1)	
Birth history				
Natural birth	11 (37.9)	4 (25)	7 (53.8)	0.22
breech birth	1 (3.4)	0 (0)	1 (7.7)	
Caesarean section	14 (48.3)	11 (68.8)	3 (23.1)	
Unknown birth history	3 (10.3)	1 (6.2)	2 (15.4)	0.26
Suffocation	1 (3.4)	0 (0)	1 (7.7)	
Mother's condition during pregnancy				
Gestational diabetes	1 (3.4)	1 (6.2)	0 (0)	0.26

Age and body weight are summarized as mean (range: minimum, maximum) and *n* (%) for other variables by antenatal and postnatal torsion. Differences between prenatal and postnatal torsion were compared using Mann-Whitney *U*-test for age and body weight and Fisher's exact test for other variables. A *p*-value <0.05 was considered statistically significant.

homogeneous testicular parenchymal echo pattern compared with only 9 (64.3%) postnatal TT cases. 5 (35.7%) postnatal TT cases presented with a homogeneous echo pattern compared with none of the prenatal TT cases. Testicular hydrocele was about equally noted in both prenatal and postnatal TT cases.

In addition, most prenatal TT cases were either swollen [*i.e.* 10 (58.8%) cases] or smaller [*i.e.* 6 (35.3%) cases] compared with postnatal cases, which were usually either swollen [*i.e.* 6 (42.9%) cases] or of equal size [*i.e.* 7 (50%) cases].

Testicular blood supply was absent in 25 (80.7%) of 31 testes on CDFI, with the majority occurring in the prenatal TT cases [*i.e.* 16 (94.1%) cases]. Five cases had a small amount of blood flow, with the majority (4/5 cases) presenting in the postnatal TT cases. One postnatal TT case had faintly visible blood flow within the testis.

Ipsilateral TT/necrosis was directly suggested in 21 (67.7%) cases and almost equally distributed between prenatal and postnatal TT cases. Ipsilateral TT/necrosis was indirectly suggested in 8 (25.8%) cases, also equally distributed between prenatal and postnatal TT cases. The other 2 (6.4%) cases were suggestive of possible testicular teratoma and occurred only in prenatal TT cases.

HCDU examination findings from 27 patients with perinatal TT are summarized in Figure 1.

Treatment

2 patients with perinatal TT had no surgery owing to complete testicular necrosis and 27 patients with perinatal TT in this study received surgical treatment. Intraoperative observation showed

that 17 of 27 cases had different degrees of TT (360–1080°). 19 cases underwent resection of the necrotic testis only. Pathology showed that the ipsilateral testis in 27 patients with perinatal TT was necrosed and bleeding, and 1 case had haemosiderosis and obvious necrotic calcification.

Eight testes from three cases of BTT and three cases of perinatal TT were saved, with a salvage rate of 8/33 or 24.2%. 1 affected testis out of a total 17 testes from 16 patients with prenatal TT was salvaged, with a salvage rate of 1/17 or 0.06%. 7 affected testes out of a total 16 testes from 13 patients with postnatal NTT were salvaged, with a salvage rate of 7/16 or 43.8%.

Post-surgical follow-up

HCDU follow-up was conducted in 12 patients with perinatal TT after surgery. Among them, follow-up in three patients who underwent resection of the ipsilateral testes revealed an absent ipsilateral testis, while the contralateral testes had no obvious abnormalities. Follow-up in one patient who underwent fixation of the left testis (because the right testis was necrotic) is shown in Figure 2.

1-month follow-up of the eight testes from three cases of BTT and three cases of perinatal TT showed recovery of testicular blood supply, and the morphology and structure of the testes had not obviously changed. However, for one patient with BTT and one patient with perinatal TT, no regular testis was observed nor did the affiliated testis have a blood supply.

DISCUSSION

Based on 20 years of experience with perinatal TT at our hospital involving 29 patients, significant differences were observed between prenatal and postnatal TT cases with regard to testicular

Table 2. Sonographic presentation in the 31 testes of 27^a patients with perinatal testicular torsion (TT) divided into prenatal and postnatal torsion

Clinical data	Total (<i>n</i> = 31) ^{<i>b</i>}	Prenatal torsion (<i>n</i> = 17)	Postnatal torsion (<i>n</i> = 14)	<i>p</i> -value
Testicular morphology				
Irregular morphology	10 (32.3)	8 (47.0)	2 (14.3)	0.10
Fuzzy display	3 (10.0)	2 (11.8)	1 (7.2)	
Regular morphology	18 (58.1)	7 (41.2)	11 (78.6)	
Testicular size				
Swollen	16 (51.6)	10 (58.8)	6 (42.9)	0.01
Testes of equal size	8 (25.8)	1 (5.9)	7 (50)	
Smaller	7 (22.6)	6 (35.3)	1 (7.2)	
Sonographic testicular echoes				
Homogeneous	5 (16.1)	0 (0)	5 (35.7)	0.007
Non-homogeneous	26 (83.9)	17 (100)	9 (64.3)	
Non-homogeneous enhancement	11	6	5	
Medium to low	1	0	1	
“Circular” or “eggshell-like” hyperechoic	10	9	1	
“Radial shape” hypoechoic	1	1	0	
Small anechoic areas	3	2	1	
Blood supply				
No blood supply	25 (80.7)	16 (94.1)	9 (64.3)	0.11
Small amount of blood supply	5 (16.1)	1 (5.9)	4 (28.6)	
Faintly visible blood flow	1 (3.2)	0 (0)	1 (7.1)	
Testicular hydrocele	23 (74.2)	13 (76.4)	10 (71.4)	0.72
Ultrasound diagnosis				
TT and necrosis directly suggested	21 (67.7)	10 (58.8)	11 (78.6)	0.77
TT/necrosis indirectly suggested	8 (25.8)	5 (29.4)	3 (21.4)	
Testicular teratoma suggested	2 (6.4)	2 (11.8)	0 (0)	

Data are summarized as *n* (%) by prenatal and postnatal torsion and compared using Pearson's χ^2 or Fisher's exact test.

^a2 out of 29 patients did not receive ultrasound examinations. It was confirmed later that both cases were postnatal TTs and the testes were surgically removed.

^bBecause 4 out of 27 patients had bilateral testicular torsions, the total count was 31 testes examined by ultrasound in 27 patients.

size ($p = 0.01$) and echogenicity ($p = 0.007$). All 17 prenatal cases had a non-homogeneous testicular parenchymal echo pattern compared with only 9 (64.3%) postnatal TT cases. Five postnatal TT cases presented with a homogeneous echo pattern compared with none of the prenatal TT cases. Testicular blood supply was absent in 25 (80.7%) of 31 testes on CDFI, with the majority occurring in the prenatal TT cases [*i.e.* 16 (94.1%) cases]. 1 affected testis out of a total 17 testes from 16 patients with prenatal TT was salvaged, with a salvage rate of 1/17 or 0.06%. 7 affected testes out of a total 16 testes from 13 patients with postnatal NTT were salvaged, with a salvage rate of 7/16 or 43.8%.

TT in the neonate is a separate clinical entity from TT in children. TT in children is commonly seen as a “bell clapper-like”

deformity of the testis, with loss of adhesion between the visceral fascia and the testis and epididymis, *i.e.* an intravaginal torsion.⁷ In TT within the sheath, HCDU can easily identify the “whirlpool sign” above or posterior to the testis owing to TT. However, the whirlpool sign in TT outside of the sheath is difficult to identify using high-frequency colour Doppler ultrasonography, as perinatal TT is an extravaginal torsion. In our clinical practice, we carefully examined the affected scrotum, and spermatic cord torsion (including the whirlpool sign) was not observed outside of the sheath on ultrasonography.

Perinatal TT can be divided into prenatal and postnatal TT. The aetiology of postnatal TT is unclear. Potential causes include increased body weight at birth or dystocia (breech birth).^{8–11}

Figure 1. High-frequency colour Doppler ultrasound examination findings from 27 patients with perinatal testicular torsion: (a) testicular swelling, non-homogeneous enhancement of echoes, peripheral circular “string of bead-like” hyperechoic region and peripheral hydrocele; (b) right testicular swelling, non-homogeneous enhancement of echo and bilateral inherent testicular hydrocele; (c) fuzzy testicular structure—no blood flow is observed on colour Doppler flow imaging (CDFI); (d) non-homogeneous testicular echo—small anechoic areas and a peripheral “eggshell-like” calcification focus are observed, no blood flow within the testes is observed on CDFI and the peripheral blood flow is increased; (e) right epididymal and testicular swelling, non-homogeneous enhancement of echoes and peripheral testicular hydrocele; (f) non-homogeneous testicular echoes and radial hypoechoic areas are observed. LT = left testis, RT = right testis.

The only case of postnatal BTT in our study was caused by a breech birth. That case was an example of the early phase of postnatal TT with an abnormal testicular axial position but

normal-sized testicles with a homogeneous parenchymal echo pattern and inherent hydrocele, in contrast to the sonographic findings in early NTT proposed by Traubici et al.¹² Therefore,

Figure 2. Pre-operative and post-operative follow-up sonographic images of testicular torsion: (a) pre-operative sonogram showing testicular swelling, non-homogeneous parenchymal echoes, circular “string of bead-like” hyperechoic areas and anechoic areas observed around the testis. (b) Post-operative Day 3: a small testicular detection value, more obvious calcification than before and a few anechoic areas are observed around the testis. (c) Post-operative Day 8: the testicular detection value is slightly smaller than it was previously, even more obvious calcification and no anechoic areas around the testis. LT = left testis.

based on our experience, at the early stage of postnatal TT, the testes may be of normal size with homogeneous echoes. For postnatal TT cases with this type of sonographic presentation, timely surgical repositioning may achieve testicular salvage. 7 affected testes out of a total 16 testes from 13 patients with postnatal NTT were salvaged, with a salvage rate of 7/16 or 43.8%. With prolonged TT time, the testes will diminish, peripheral echogenicity will be more evident and hydrocele will decrease or disappear. These latter characteristics are consistent with prior reports.¹² Signs such as a diminished testis, non-homogeneous parenchymal echogenicity and calcific foci suggest a testis that is already twisted and necrotic.

Approximately 72–81% cases of TT occur before birth.^{8,13,14} Prenatal TT can present as a painless, palpable, hard mass with pigmentation of the scrotal skin immediately after birth. The size and hardness of the mass differ according to the extent of torsion time.¹⁵ A total of 16 (55.2%) out of 29 cases in our study were prenatal, significantly lower than the 72–81% incidence reported in the literature.^{5,14} This discrepancy may be related to the fact that some of our prenatal TT cases were missed or misdiagnosed as postnatal TT. Postnatal TT, in contrast, presents 1 month after birth with scrotal redness, swelling and tenderness combined with vomiting and abdominal distension.

Among the 29 patients with perinatal TT in this study, 27 patients underwent HCDU. The two-dimensional sonographic images showed swelling and thickening of the scrotal wall. The morphology of the ipsilateral testis included swelling, equal size or shrinkage, and these different presentations may be associated with the duration of TT. At the early stage of torsion, the size of the testis does not show a significant change; however, with prolonged torsion time, testicular swelling or shrinkage will occur.¹² Three patients had a fuzzy display of their ipsilateral testes, which was associated with an ischaemia-induced inflammatory response and adhesion to surrounding tissues after torsion; therefore, the testis could not be distinguished from the surrounding tissue. However, the identification of an irregular or fuzzy testis is very subjective. Perinatal testicular tissues do not tolerate ischaemia, and ischaemic necrosis can easily occur, thus causing a non-homogeneous echo pattern within the twisted testis. Among the patients with perinatal TT in our study, 26 patients had a non-homogeneous echo pattern and the majority (17 cases) were prenatal TT cases. None of the prenatal TT cases had a homogeneous testicular parenchymal pattern, while five postnatal TT cases presented with a homogeneous echo pattern, possibly owing to the shorter ischaemic time. With the extension of ischaemic time, the echogenicity of the ischaemic testicular tissues enhances non-homogeneously, and some ischaemic testes show liquefactive necrosis. 10 (33.3%) cases had circular “string of bead-like” or “eggshell-like” hyperechoic areas and 9 of these 10 cases were prenatal TT. These sonographic characteristics are specific features of perinatal TT which are rare in childhood TT. These circular hyperechoic areas were located at the junction between the tunica albuginea and the testicular parenchyma and were likely due to tunica albuginea calcification.^{16–18}

During colour Doppler imaging, the absence of blood flow on CDFI within the testicular parenchyma has a high specificity for

the diagnosis of perinatal TT, with the majority occurring in the prenatal TT cases [*i.e.* 16 (94.1%) cases]. Five cases had a small amount of blood flow, with the majority (4/5) presenting in the postnatal TT cases. However, newborn babies have a limited testicular blood flow that is difficult to display. Therefore, evaluation of the perinatal testicular blood flow requires HCDU. In addition, the colour gain and pulse repetition frequency should be carefully adjusted and comparison with the contralateral testicle should be performed.^{19,20} Moreover, the blood flow should be compared between the two testes. Thus, for patients with BTT, it is even more difficult to determine torsion and ischaemia.

In our study, no blood flow signals during the study suggested the absence of blood flow; the reduction in blood flow signals by 1–2 points suggested a reduction in blood flow. For patients with BTT, blood flow signals of 1–2 points in both testes suggested a reduction in blood flow; no blood flow signal meant absence of blood flow. Among the 27 patients (with a total of 31 testes) who underwent HCDU, 25 patients did not have obvious blood flow, 5 patients had a small amount of blood flow and 1 patient had a faintly visible flow. These results were inconsistent with previous reports from the literature which showed no blood flow in the twisted testes.^{17,21} This discrepancy may be associated with the duration of TT. In the early stage of torsion, the testicular artery is twisted and ischaemic, but the testicular vein is still patent and can be observed using CDFI. In addition, one NTT case reported by Singhal et al²² had more blood flow in the affected testis than in the contralateral testis because of repeated extravaginal torsion/detorsion that caused reactive inflammatory oedema in the testis and increased blood supply. Therefore, the presence of testicular blood flow does not rule out TT; however, lack of a blood flow signal is highly suggestive of TT.

The accuracy of pre-operative ultrasonic diagnosis in the present study was 92.6%. Because perinatal TT is rare, the diagnosis may be missed, as circular “string of bead-like” or “eggshell-like” calcification foci are easily misdiagnosed as teratoma (as occurred in two of our patients). Furthermore, HCDU examination can identify the early stage of perinatal TT, which is important for testicular salvage. We observed that 7 affected testes out of a total 16 testes from 13 patients with postnatal NTT were salvaged, with a salvage rate of 7/16 or 43.8%. The salvage rate for postnatal cases is comparable with previous reports.^{8,10,14,15,23–26}

Our study had several limitations including its retrospective nature and the limited number of cases. In addition, we did not explore how the use of ultrasound can reduce the surgical exploration rate, an important topic for future studies.

In conclusion, significant differences in sonographic features can help distinguish prenatal TT from postnatal TT. In neonates with acute scrotal symptoms, the possibility of TT should be considered and HCDU examination should be performed in an expedient manner. This is especially important in postnatal TT where HCDU examination can not only identify TT but can also increase the salvage rate by prompting quick surgical intervention, as demonstrated in our study.

REFERENCES

1. Diamond DA, Borer JG, Peters CA, Cilento BG Jr, Sorcini A, Kaefer M, et al. Neonatal scrotal haematoma: mimicker of neonatal testicular torsion. *BJU Int* 2003; **91**: 675–7. doi: <http://dx.doi.org/10.1046/j.1464-410X.2003.04201.x>
2. Epifanio M, Baldissera M, Esteban FG, Baldisserotto M. Mature testicular teratoma in children: multifaceted tumors on ultrasound. *Urology* 2014; **83**: 195–7. doi: <http://dx.doi.org/10.1016/j.urology.2013.07.046>
3. Gunther P, Schenk JP, Wunsch R, Holland-Cunz S, Kessler U, Troger J, et al. Acute testicular torsion in children: the role of sonography in the diagnostic workup. *Eur Radiol* 2006; **16**: 2527–32. doi: <http://dx.doi.org/10.1007/s00330-006-0287-1>
4. Boettcher M, Krebs T, Bergholz R, Wenke K, Aronson D, Reinshagen K. Clinical and sonographic features predict testicular torsion in children: a prospective study. *BJU Int* 2013; **112**: 1201–6. doi: <http://dx.doi.org/10.1111/bju.12229>
5. Kalfā N, Veyrac C, Baud C, Couture A, Averous M, Galifer RB. Ultrasonography of the spermatic cord in children with testicular torsion: impact on the surgical strategy. *J Urol* 2004; **172**(4 Pt 2): 1692–5; discussion 1695. doi: <http://dx.doi.org/10.1097/01.ju.0000138477.85710.69>
6. Lam WW, Yap TL, Jacobsen AS, Teo HJ. Colour Doppler ultrasonography replacing surgical exploration for acute scrotum: myth or reality? *Pediatr Radiol* 2005; **35**: 597–600. doi: <http://dx.doi.org/10.1007/s00247-005-1411-0>
7. Callewaert PR, Van Kerrebroeck P. New insights into perinatal testicular torsion. *Eur J Pediatr* 2010; **169**: 705–12. doi: <http://dx.doi.org/10.1007/s00431-009-1096-8>
8. Kaye JD, Levitt SB, Friedman SC, Franco I, Gitlin J, Palmer LS. Neonatal torsion: a 14-year experience and proposed algorithm for management. *J Urol* 2008; **179**: 2377–83. doi: <http://dx.doi.org/10.1016/j.juro.2008.01.148>
9. Riaz-Ul-Haq M, Mahdi DE, Elhassan EU. Neonatal testicular torsion; a review article. *Iran J Pediatr* 2012; **22**: 281–9.
10. Rhodes HL, Corbett HJ, Horwood JF, Losty PD. Neonatal testicular torsion: a survey of current practice amongst paediatric surgeons and urologists in the United Kingdom and Ireland. *J Pediatr Surg* 2011; **46**: 2157–60. doi: <http://dx.doi.org/10.1016/j.jpedsurg.2011.06.013>
11. Nandi B, Murphy FL. Neonatal testicular torsion: a systematic literature review. *Pediatr Surg Int* 2011; **27**: 1037–40. doi: <http://dx.doi.org/10.1007/s00383-011-2945-x>
12. Traubici J, Daneman A, Navarro O, Mohanta A, Garcia C. Original report. Testicular torsion in neonates and infants: sonographic features in 30 patients. *AJR Am J Roentgenol* 2003; **180**: 1143–5. doi: <http://dx.doi.org/10.2214/ajr.180.4.1801143>
13. Broderick KM, Martin BG, Herndon CD, Joseph DB, Kitchens DM. The current state of surgical practice for neonatal torsion: a survey of pediatric urologists. *J Pediatr Urol* 2013; **9**: 542–5. doi: <http://dx.doi.org/10.1016/j.jpuro.2012.12.010>
14. Martin AD, Rushton HG. The prevalence of bell clapper anomaly in the solitary testis in cases of prior perinatal torsion. *J Urol* 2014; **191**(Suppl. 5): 1573–7. doi: <http://dx.doi.org/10.1016/j.juro.2013.09.013>
15. Cuervo JL, Grillo A, Vecchiarelli C, Osio C, Prudent L. Perinatal testicular torsion: a unique strategy. *J Pediatr Surg* 2007; **42**: 699–703. doi: <http://dx.doi.org/10.1016/j.jpedsurg.2006.12.047>
16. Arena F, Nicotina PA, Romeo C, Zimbaro G, Arena S, Zuccarello B, et al. Prenatal testicular torsion: ultrasonographic features, management and histopathological findings. *Int J Urol* 2006; **13**: 135–41. doi: <http://dx.doi.org/10.1111/j.1442-2042.2006.01247.x>
17. van der Sluijs JW, den Hollander JC, Lequin MH, Nijman RM, Robben SG. Prenatal testicular torsion: diagnosis and natural course. An ultrasonographic study. *Eur Radiol* 2004; **14**: 250–5. doi: <http://dx.doi.org/10.1007/s00330-003-2019-0>
18. Brown SM, Casillas VJ, Montalvo BM, Albores-Saavedra J. Intrauterine spermatic cord torsion in the newborn: sonographic and pathologic correlation. *Radiology* 1990; **177**: 755–7. doi: <http://dx.doi.org/10.1148/radiology.177.3.2243983>
19. Ahmed SJ, Kaplan GW, DeCambre ME. Perinatal testicular torsion: preoperative radiological findings and the argument for urgent surgical exploration. *J Pediatr Surg* 2008; **43**: 1563–5. doi: <http://dx.doi.org/10.1016/j.jpedsurg.2008.03.056>
20. Roth CC, Mingin GC, Ortenberg J. Salvage of bilateral asynchronous perinatal testicular torsion. *J Urol* 2011; **185**(Suppl. 6): 2464–8. doi: <http://dx.doi.org/10.1016/j.juro.2011.01.013>
21. Ricci P, Cantisani V, Drudi FM, Carbone I, Coniglio M, Bosco S, et al. Prenatal testicular torsion: sonographic appearance in the newborn infant. *Eur Radiol* 2001; **11**: 2589–92. doi: <http://dx.doi.org/10.1007/s003300100868>
22. Singhal A, Agarwal A, Metuge J, Olsavsky T. Neonatal testicular torsion with an unusual sonographic feature. *J Clin Ultrasound* 2012; **40**: 243–6. doi: <http://dx.doi.org/10.1002/jcu.21889>
23. Guerra LA, Wiesenthal J, Pike J, Leonard MP. Management of neonatal testicular torsion: which way to turn? *Can Urol Assoc J* 2008; **2**: 376–9.
24. Djahangirian O, Ouimet A, Saint-Vil D. Timing and surgical management of neonatal testicular torsions. *J Pediatr Surg* 2010; **45**: 1012–5. doi: <http://dx.doi.org/10.1016/j.jpedsurg.2010.02.032>
25. Sorensen MD, Galansky SH, Striegl AM, Mevorach R, Koyle MA. Perinatal extragenital torsion of the testis in the first month of life is a salvageable event. *Urology* 2003; **62**: 132–4. doi: [http://dx.doi.org/10.1016/S0090-4295\(03\)00402-3](http://dx.doi.org/10.1016/S0090-4295(03)00402-3)
26. Jensen R, Ellebæk M, Rasmussen L, Qvist N. Low success rate of salvage surgery for testicular torsion in newborns. *Dan Med J* 2015; **62**: A4997.