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Role of ultrasound in the follow-up of intra-abdominal testes post Fowler-Stephens orchiopexy

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ABSTRACT

Objective: To review the role of various ultrasound (US) modalities in their ability to determine testicular viability in prepubertal testes following Fowler-Stephens orchiopexy (FSO).
Material & Methods: Our prospective study included all patients from the year 2012 to 2017 with intra-abdominal testes (IAT) who had one-stage or staged FSO in our tertiary centre. Follow-up was done at 6 months to assess testicular viability and testicular position by clinical examination, and this was correlated with conventional and Doppler US results then.
Results: This study included 28 IAT in total, who had one-stage (n = 16) and staged (n = 12) laparoscopic FSO. Median age was 1.27 years. Testicular atrophy was noted by clinical examination in 6 testes. In these 6 testes, conventional US confirmed an atrophic testicular nubbin and both Color Doppler US (CDU) and Power Doppler US (PDU) failed to show any parenchymal testicular vessels. Spectral Mode Analysis (SMA) also showed no significant arterial waveform.
As for the remaining 22 viable testes by clinical examination, conventional US showed normal testicular morphology in all, while CDU and PDU confirmed adequate parenchymal blood flow in only 15 and 20 testes respectively. SMA revealed a normal arterial resistive index in only 21 testes.
Conclusion: There is no evident role for US in the follow-up of prepubertal testes post-FSO as US results are strongly correlated to clinical examination findings. Blood flow assessment in prepubertal testes following FSO can be difficult, unclear and undetectable in cases. This can be due to the prepubertal testicular stage, technique or unrecognized testicular atrophy despite normal morphology.
Level of Evidence: Level IV: Case series with no comparison group.

Laparoscopic Fowler Stephens orchiopexy (FSO) remains the gold standard in the management of intraabdominal testes (IAT) with short spermatic vessels [1–3]. However, there is no consensus on what constitutes an adequate determination of testicular viability postoperatively. Most surgeons would regard a clinically felt testis, as opposed to just a testicular nubbin, felt within the scrotum or groin, as adequate criteria to confirm testicular viability following FSO [2]. However, some surgeons still prefer a testicular ultrasound (US) to further confirm this [4–6]. The earlier group presume that the mere ability to physically feel the testis following FSO proves its adequate blood supply. However, there is no strong evidence in the literature supporting this. The latter group have utilized testicular US to compare preoperative or intraoperative testicular volume with that postoperatively, or measure adequacy of intra-testicular blood flow following surgery [4–6]. The latter parameter is considered more important, as any impairment of intra-testicular blood flow can potentially affect the fertility potential of that testis [7, 8], specifically after the division of spermatic vessels and gubernaculum in a FSO. Moreover, there was no correlation found between testicular volume and fertility potential when assessed during orchiopexy [9–11].

In the limited authors who do use testicular US for confirmation of testicular blood flow, adequate testicular blood flow was merely mentioned without clear documentation of the measurement parameters used nor normal reference range followed [4–6]. This is crucial as testicular blood flow in normal pre-pubertal testes cannot be detected in some children in the general population [12–14] and in those detectable, resistive index measurements are different to those expected of post-pubertal testes [14]. A previous, in-depth correlation too between clinical examination findings and ultrasound findings post-FSO have not been previously examined nor validated.

The aim of our prospective study was to review the role of various US modalities in their ability to determine testicular viability in prepubertal

Abbreviations: IAT, Intraabdominal testes; FSO, Fowler Stephens orchiopexy; US, Ultrasound; CDU, Color Doppler ultrasound; PDU, Power Doppler ultrasound; SMA, Spectral mode analysis; PSV, Peak systolic velocity; EDV, End-diastolic velocity; RI, Resistive index; IIR, Internal inguinal ring.

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testes following FSO. Our hypothesis was that different US modalities can effectively determine testicular viability post-FSO and that US results of testicular viability are not necessarily correlated to those determined by clinical examination.

1. Material and methods

Following Institutional Review Board approval, our prospective study was enrolled and all patients with impalpable undescended testis who attended our tertiary centre from January 2012 till December 2017 were initially registered. Diagnostic laparoscopy was done to all those patients and only those with IAT and short spermatic vessels were later recruited. These were defined as type 3A, 3B and 4A of our "updated Ain Shams classification of impalpable undescended testes" (Table 1) [15]. All other types of impalpable undescended testes according to our above classification or those who were offered vessel sparing laparoscopic orchiopexy were excluded. Equally excluded, were those whom had hormonal treatment or have syndromes related to undescended testes. No patients were lost for follow up.

According to surgeons' preference, a one-stage or two-stage laparoscopic FSO was done by one of four experienced, laparoscopic pediatric surgeons. The procedure was entirely standardized among the four surgeons to minimize any possible technical variables. The second-stage surgery in a staged laparoscopic FSO was done 12–16 weeks later. In patients with bilateral intra-abdominal testes who had one-stage laparoscopic FSO, one side was done in the first setting and the contralateral testis postponed 3–4 weeks later. On the other hand, if a two-stage laparoscopic FSO was chosen for bilateral cases, a three-interval surgery was done. In the first interval surgery, a unilateral first-stage FSO was only done. This was followed by a second interval surgery 12–16 weeks later, with a unilateral second-stage and a contralateral first-stage FSO. The final interval was the contralateral second-stage FSO.

All patients were followed up at 6 and 12 months postoperatively following the final stage of surgery to assess testicular viability and testicular position by clinical examination. A viable testis by physical examination was defined as a testis that can be felt in the scrotum or groin, as opposed to only feeling a testicular nubbin. A testicular nubbin, however, was considered as an atrophic testis if felt by clinical examination. Testicular position was noted whether it was felt in the scrotum or the groin. A conventional and Doppler scrotal US was also done at the same follow-up visits at 6 and 12 months postoperatively. Conventional US was used to confirm testicular viability via determining normal testicular morphology and parenchymal homogeneity by US, and to rule out testicular ascent post-surgery. Doppler US including color Doppler US (CDU), power Doppler US (PDU) and spectral mode analyses (SMA) with resistive index (RI) measurement were done to assess intra-testicular blood flow.

Table 1
Updated Ain Shams classification of impalpable undescended testes [15].

Type 1
A: Blind ending vas & vessels with closed IIR
B: Vas & Vessels exiting closed IIR
Type 2
Peeping testis
Type 3
Open IIR + testis proximal to IIR + vessels ending short of IIR
A: Non-looping vas
B: Looping vas into the canal
Type 4
Closed IIR + testis away from IIR > 2 cm
A: Testis is high (iliac)
B: Testis is down (pelvic)
Type 5
Syndromes associated with impalpable UDT
(e.g. Prune belly syndrome, Persistent mullerian duct)

IIR = Internal inguinal ring.

All ultrasound examinations were done by one of our three experienced pediatric radiologists. No sedation was required. A high-resolution linear array transducer (GE LOGIQ P6 PRO) with a frequency of 7.5–12 Hz was used for all scans. Conventional gray scale images in 3 orthogonal planes were performed to assess for normal testicular morphology and parenchymal homogeneity. If the testis could not be felt, the spermatic cord was tracked downwards along its presumed course to identify either an atrophic testicular nubbin or a viable testis that has ascended upwards.

CDU was then applied to detect parenchymal testicular vessels using low flow settings. High color gain settings, low flow filter and low velocity scale were used to optimize detection of weak arterial flow. Capsular testicular blood vessels were not considered as confirmative of adequate testicular blood flow as they can be hard to distinguish from scrotal blood vessels in children. A cut-off baseline of at least 2 parenchymal blood vessels was considered as adequate intra-testicular blood flow [16].

PDU was then followed to further help map intra-testicular parenchymal blood vessels. SMA was conducted on IAT that managed to prove adequate parenchymal blood flow by either CDU or PDU. The sample volume and spectral flow angle settings were optimized to ensure the attainment of ideal arterial waveforms and elimination of aliasing artifacts. Two consecutive arterial waveforms were drawn from each individual parenchymal arterial vessel identified with a total of four waveforms from each examined testis when at least 2 parenchymal blood vessels were identified. Those that only showed one parenchymal blood vessel had only two arterial waveforms drawn for that testis. Peak systolic velocity (PSV) and end-diastolic velocity (EDV) were measured and resistive index (RI) calculated of each intra-testicular artery as (PSV-EDV)/ PSV. An average of all RI measurements taken for that examined testis was then recorded.

Kappa statistics was used to compute the agreement between two investigational methods; Kappa's over 0.75 is excellent, 0.40 to 0.75 is fair to good, and below 0.40 is poor. A significance level of $p < 0.05$ was used in all tests. All statistical procedures were carried out using SPSS version 20 for Windows (SPSS Inc., Chicago, IL, USA).

2. Results

Our study involved 28 IAT in total during the period from January 2012 to December 2017. It included 20 patients with unilateral IAT and 4 patients with bilateral IAT. Laparoscopic one-stage FSO or staged-FSO were done in 16/28 (57.1%) and 12/28 (42.9%) of the IAT respectively. The patients' ages ranged from 1 to 5.5 years, with a median of 1.27 years.

Testicular atrophy was noted by clinical examination in 6 out of the 28 IAT (21.4%) at their 6 months' follow-up (4/16 following one stage FSO; 2/12 following staged FSO). Testicular atrophy was noted clinically in those 6 IAT by not being able to feel a testis, but rather feeling a testicular nubbin, in the scrotum or groin. In all mentioned 6 IAT, conventional US excluded testicular ascent and also confirmed the atrophic testicular nubbin with no normal testicular morphology nor parenchymal homogeneity expected for a normal testis. Both CDU and PDU performed on those 6 above IAT also failed to show any parenchymal testicular vessels. This was also further confirmed by SMA which showed absence or significantly dampened blood flow and no significant arterial waveform drawn. Hence, no arterial RI could be measured. Only one out of those 6 atrophic IAT showed what resembled a capsular blood vessel which was probably a misinterpreted scrotal blood vessel, as he was just less than 1 year.

As for the remaining 22 IAT where a testis could be felt by clinical examination at 6 months' follow-up, they were all felt within the scrotum. All 22 IAT showed normal testicular homogeneity and morphology on conventional US (Figure 1). CDU showed adequate parenchymal blood flow in 15 out of those 22 IAT (Figure 2), while it was inadequate in the remaining 7 IAT (Figure 3). PDU further confirmed adequate

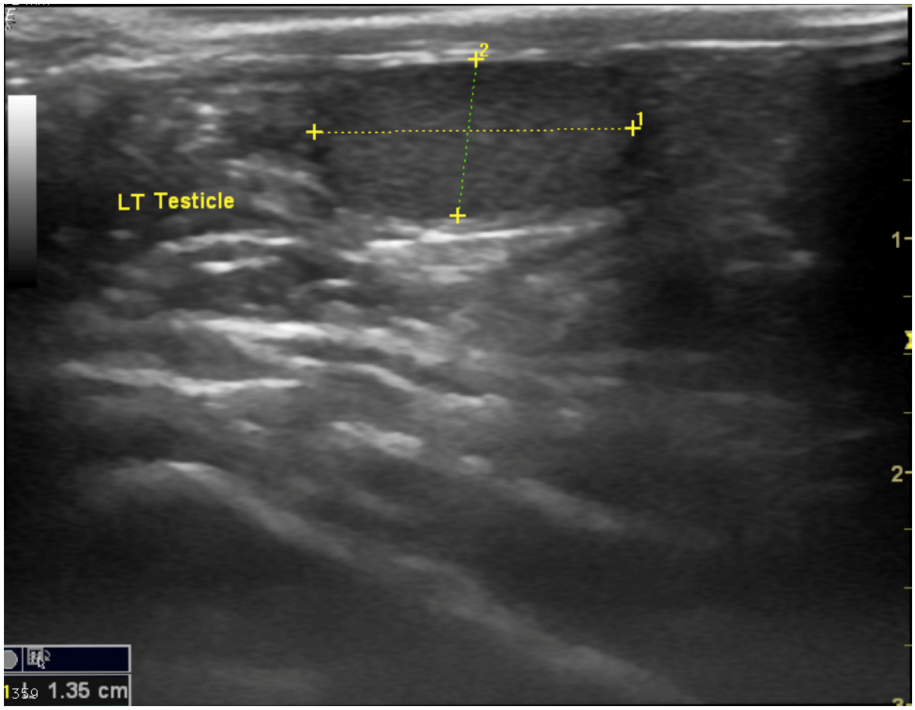

Fig. 1. Conventional US showing normal testicular morphology and parenchymal homogeneity for a testis post-FSO.

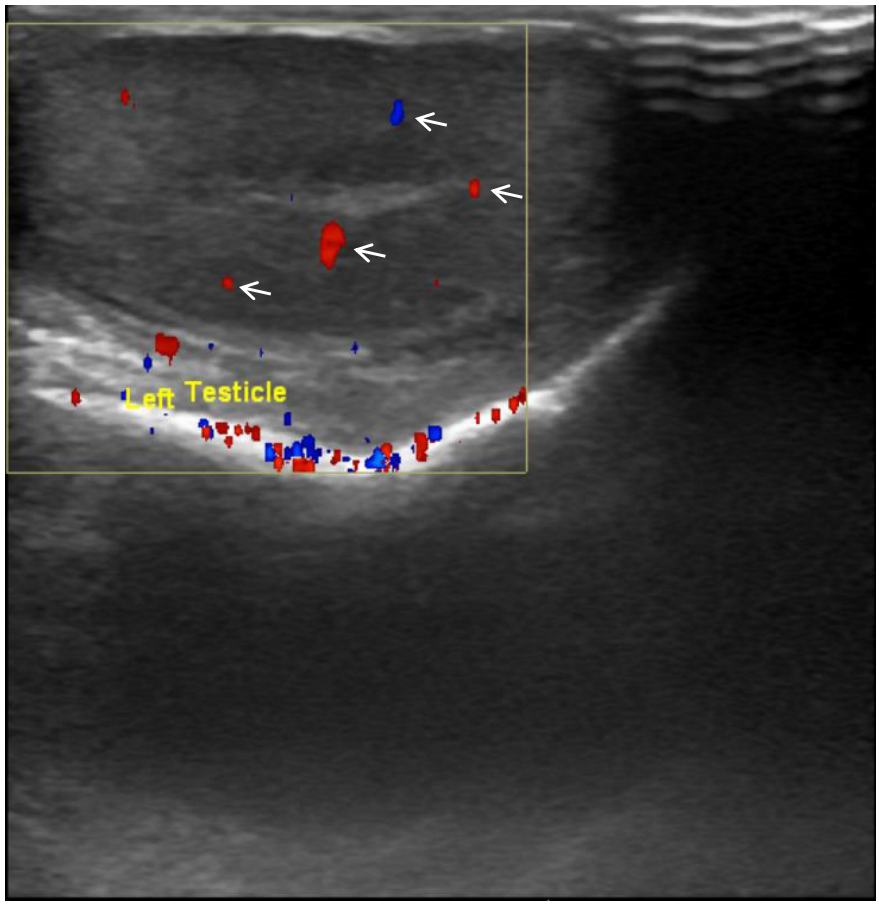

Fig. 2. CDU image showing adequate parenchymal blood flow (more than 2 parenchymal blood vessels -marked as white arrows) for a testis post-FSO.

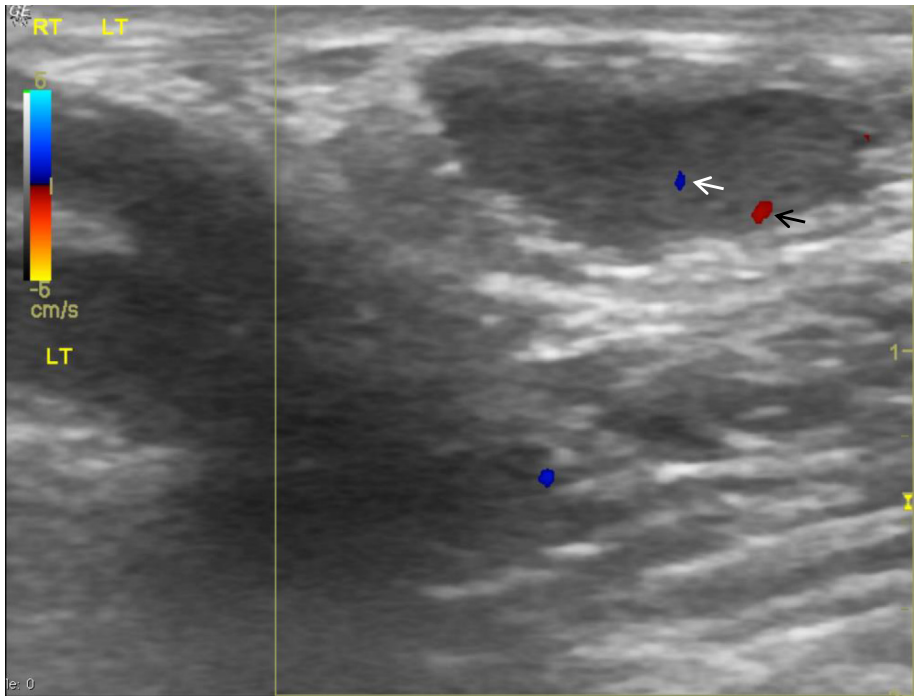

Fig. 3. CDU images showing inadequate parenchymal blood flow (less than 2 parenchymal blood vessels -marked as white arrow) for a testis post-FSO. The color signal at the testicular periphery, marked by a black arrow, was deemed artefactual.

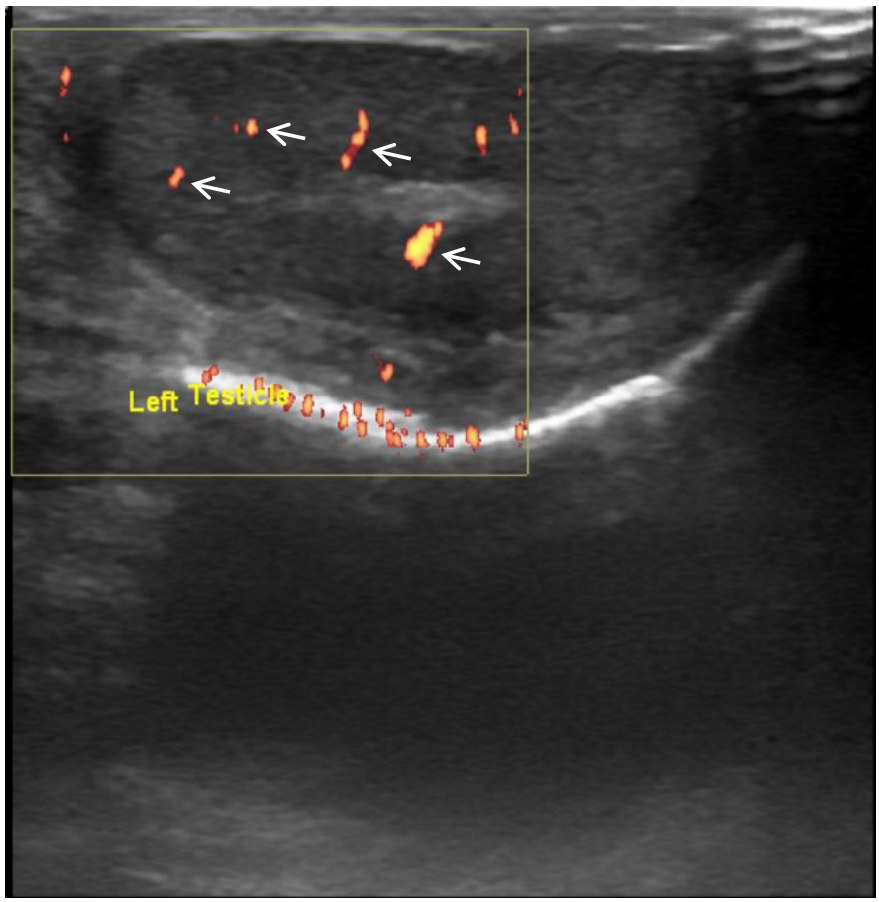

Fig. 4. PDU image showing adequate parenchymal blood flow (two or more parenchymal blood vessels -marked as white arrows) for a testis post-FSO.

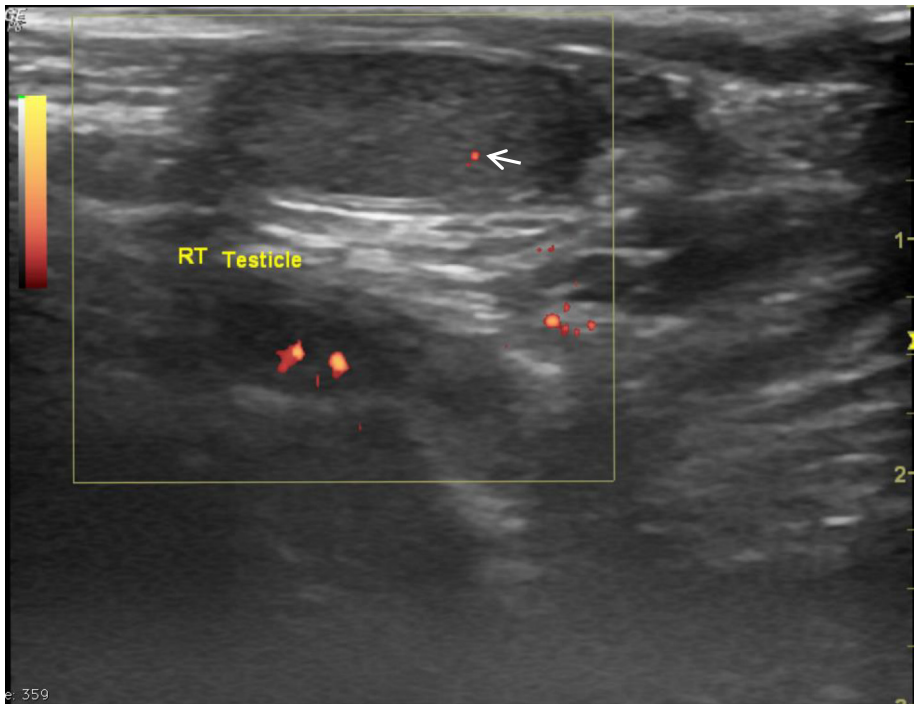

Fig. 5. PDU images showing inadequate parenchymal blood flow (less than 2 parenchymal blood vessels -marked as white arrow) for a testis post-FSO.

parenchymal blood flow (Figure 4) in all 15 IAT previously seen as adequate by CDU, in addition to 5 out of the 7 IAT seen as inadequate by CDU. Despite this, two IAT still showed inadequate blood flow by PDU (Figure 5) where one of them showed a single parenchymal blood vessel and hence inadequate blood flow, while the other showed none.

In the 20 IAT with adequate parenchymal blood flow on combined CDU and PDU, SMA revealed a normal arterial RI lying within the normal reference range expected for pre-pubertal testes (RI 0.39–1) [14]. In further breakdown of the RI measured in those 20 IAT, no diastolic blood flow was detected in 6 out of those 20 IAT (30%), with a RI of 1 being given (Figure 6. The remaining 14 IAT (70%) showed RI being less than 1 (Figure 7).

In the two IAT with inadequate parenchymal blood flow found on combined CDU and PDU, one of them had only one parenchymal blood vessel detected by PDU and this showed no diastolic blood flow on SMA. Hence, a RI of one was given to it. The other intraabdominal testis showed no parenchymal blood flow and consequently, SMA showed absent blood flow with no arterial waveform drawn.

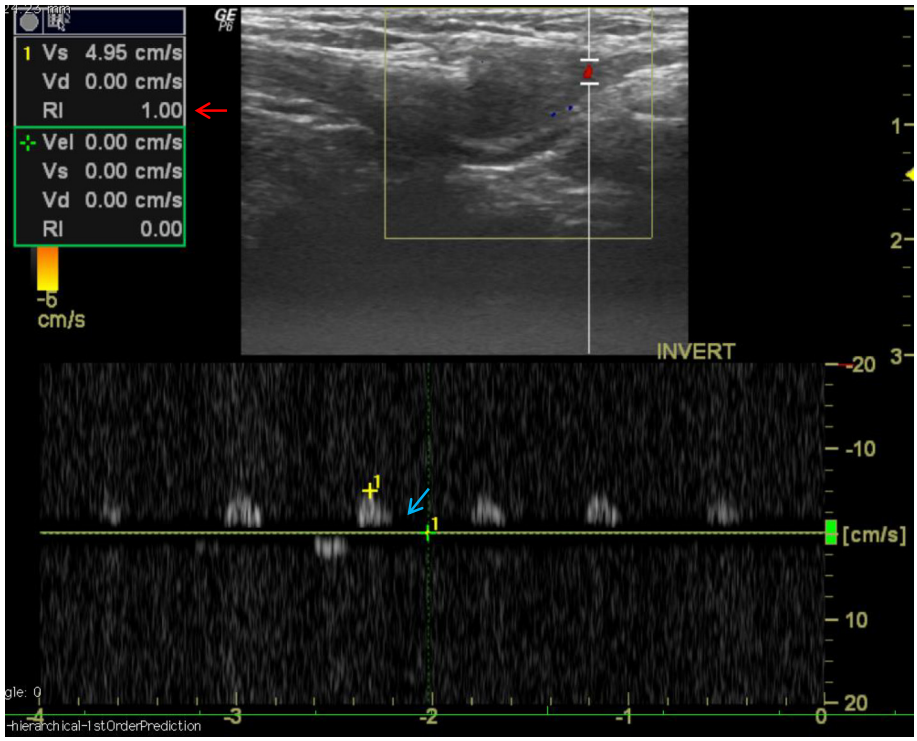

Fig. 6. SDA image showing a normal, yet very high, intra-testicular arterial RI (red arrow) with absent normal diastolic blood flow (blue arrow) in a testis post-FSO.

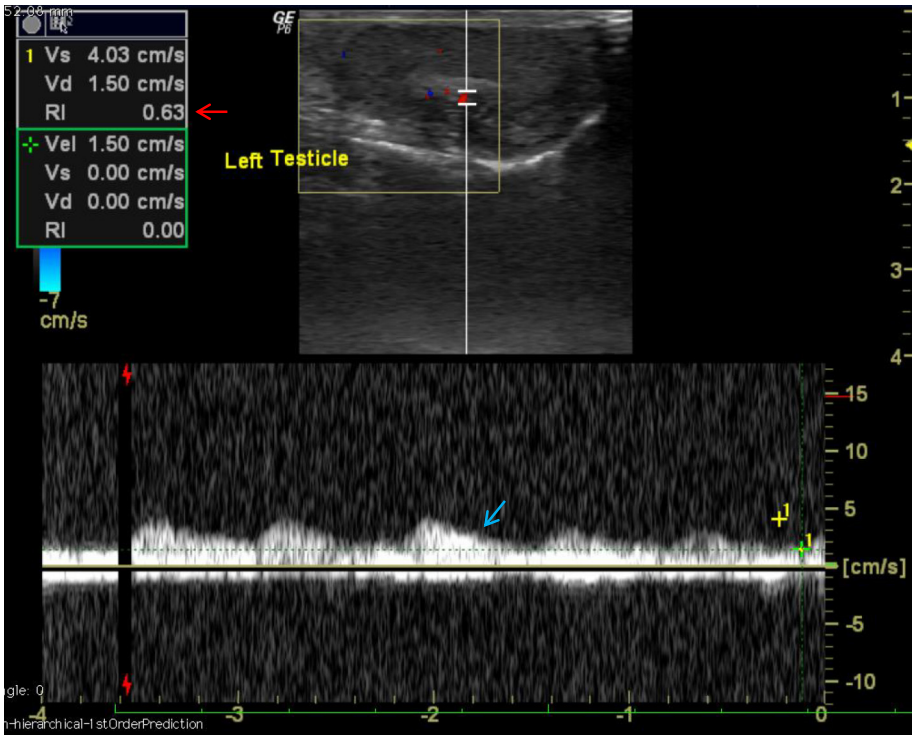

Fig. 7. SDA image showing a normal intra-testicular arterial RI (red arrow) with adequate diastolic blood flow (blue arrow) for a testis post-FSO.

There was no change noted in either the clinical or ultrasound findings found at 12 months' postoperative follow up to those at 6 months' follow up. There was an excellent statistical correlation found between clinical examination findings and results of either conventional US, PDU, or SMA in either follow up visits. On the other hand, CDU only showed a fair correlation in results (Table 2). The mean intra-testicular RI measured in testes following laparoscopic one-stage FSO was 0.71 +/− 0.14 while that in two-stage FSO was 0.69 +/− 0.1. This was found to be statistically insignificant ($p = 0.7$) although the sample size was not big enough to allow more accurate comparisons.

3. Discussion

Clinical assessment of testicular viability is still routinely done by feeling for a testis as opposed to a testicular nubbin, in the scrotum or the groin. These, alongside evaluation of testicular position whether it is in the groin or scrotum, remain the two most commonly used outcome measures in IAT post-FSO [2, 3]. Our study found that clinical examination was able to reliably identify all testes that atrophied, as clinical findings of atrophy were in complete agreement to US findings in those cases. Likewise, physical examination findings of testicular viability were also accurate at determining normal testicular morphology on conventional ultrasound. Only a couple of those testes did not have normal Doppler flow which could be related to the prepubertal testicular stage, ultrasound technical difficulties or unrecognized testicular atrophy despite normal morphology. Clinically, this lack of Doppler flow despite normal morphology has unknown repercussions.

Normal intra-testicular blood flow assessment in prepubertal testes is, however, limited and not always possible which could explain our above failure in depicting normal blood flow in those limited couple of testes. CDU color coding depicts the blood flow velocity based on Doppler frequency shift and direction of flow [17]. PDU color coding, however, is based on the magnitude of the Doppler signal rather than the Doppler frequency signal. It does not show flow direction nor different

Table 2
Correlation of US results to clinical examination findings post-FSO.

	Viable testes confirmed by clinical examination (n = 22)	Statistical agreement between US results and clinical examination findings (Kappa statistics*)	p-Value
Conventional US morphology:			
▪ Normal	▪ 100%	**1.0**	**0.001**
▪ Abnormal	▪ 0%		
CDU adequacy of blood flow:			
▪ Adequate	▪ 68%	0.479	0.005
▪ Inadequate	▪ 32%		
PDU adequacy of blood flow			
▪ Adequate	▪ 91%	**0.811**	**0.001**
▪ Inadequate	▪ 9%		
SMA-measured RI:			
▪ Normal	▪ 95%	**0.9**	**0.001**
▪ Abnormal	▪ 0%		
▪ Non detectable	▪ 5%		
▪ Mean RI	▪ 0.69 +/− 0.11		

*Kappa's over 0.75 is excellent, 0.40 to 0.75 is fair to good, and below 0.40 is poor.

velocities [18]. Despite combined usage of CDU and PDU, it can sometimes fail to detect intra-testicular blood flow in prepubertal testes. Luker et al. managed with combined CDU and PDU to detect intra-testicular flow in only 22 of the 24 normal pre-pubertal testes, while detected them all in the 49 normal post-pubertal testes. Barth et al., however, was able to show blood flow in all 68 normal prepubertal testes with combined CDU and PDU [16]. Some of those variations can be in part explained by the different sensitivities of different machines to detect low blood flow [19]. Some studies found PDU more sensitive than CDU in the detection of normal intra-testicular blood flow [16] while others did not [20]. Barth et al., used PDU to detect parenchymal blood flow in 66/68 (97%) of the pediatric testes while CDU only detected flow in 60/68 (88%) of them [16]. PDU superiority over CDU lies in the considerable gain that can be obtained without noise artifact, which makes it more useful in children especially in prepubertal testes [18]. Hence, PDU is routinely used when CDU fails to depict parenchymal flow in the testis. However, it is prone to movement which makes it difficult in the pediatric age [21]. We have tried to overcome this through persistence, trying again later or attempting to feed the child during the study. Our study confirms PDU's advantage in blood flow assessment in prepubertal testes, which in turn explains PDU's better correlation with clinical examination results.

The normal parameters and standards upon which Doppler ultrasound confirmed adequate intra-testicular blood flow following FSO is not described in previous orchidopexy studies [2]. It is known that CDU or PDU visualize intra-testicular, parenchymal blood vessels as small dots or dashes. This has led to the grading system used by some radiologists to grade the degree of intra-testicular blood flow where Grade 0 denotes no parenchymal blood vessels, Grade 1 being one parenchymal blood vessel and Grade 2 being more than one [16]. In our study, we took only Grade 2 as being confirmative of an adequate intra-testicular blood flow as it was our impression that Grade 1 is considerably equivocal. However, one of our two IAT that failed to show that Grade 2 level of parenchymal blood flow did show a Grade 1 level which might arguably be because of the difficulty of assessment of blood flow in small, prepubertal testes.

Spectral Doppler permits graphic display of flow velocities over time and allows for the calculation of blood flow PSV, EDV and RI. A few studies assessed intra-testicular blood flow following inguinal hernia repair using SMA to compare preoperative and postoperative PSV and RI [22, 23], while other studies compared the same parameters to that of the normal contralateral side [24]. However, we found this being not really applicable in IAT as preoperative assessment of intra-testicular blood flow is obviously not feasible since the testis is intraabdominal, and intraoperative assessment might prove very challenging and time consuming. Moreover, postoperative comparison to the contralateral normal testis is skewed and inaccurate as an intra-abdominal is by default, not normal and will hold invariably less blood supply, well before the division of the spermatic vessels and gubernaculum. Furthermore, it is obviously inapplicable in patients with bilateral IAT.

Intra-testicular RI measurement of more than 0.6 does suggest a possibly abnormal sperm count in infertile men and can be used as a reliable assessment in adult infertility clinics. The presence of a higher RI denotes an increased vascular resistance which can in turn impair spermatogenesis [7]. However, it is important to realize that intra-testicular RI measured in normal pre-pubertal testes with volume less than 4 cm3 (RI 0.39–1 with mean RI 0.87) is higher than that of normal post-pubertal testes with volume more than 4 cm3 (RI 0.43–0.75 with mean RI 0.57) [14]. The latter being similar to that of adults with normal RI (RI 0.5–0.7 with mean RI 0.6) [25]. More importantly, a large proportion of normal pre-pubertal testes with volumes 4 cm3 or less do not show diastolic blood flow and hence have a RI of 1 in the parenchymal blood vessels [14]. Likewise, our study showed that nearly a third of our IAT post-FSO whom were clinically felt in the scrotum and had adequate parenchymal blood vessels by combined CDU and PDU, failed to show diastolic blood flow on spectral mode and hence, a RI of 1 was given. Hence, this could be just a normal prepubertal testicular status as described by Palteil et al. [14]. Alternatively, it could be due to a technical problem during US assessment in young children or less likely, unrecognized testicular atrophy despite normal parameters measured otherwise.

There have been a few other parameters used in literature to confirm testicular viability following orchidopexy. Some authors have presumed that an operated testis is viable if it stays more than 50% in size or volume to the contralateral normal testis [26]. However, this assumption is arguable and is both inaccurate and non-specific. Others have used an orchidometer or US [27] to compare testicular volume before or during surgery with that after surgery. An ultrasound-generated testicular atrophy index (TAI = {normal contralateral testicular volume – volume of undescended testis}/ contralateral testicular volume × 100) was used by some for the above comparison [28]. However, testicular volume assessment by a Prader orchidometer is generally affected by inter-observer variation [29] although some authors found that it does show a good correlation between different assessors in pre-pubertal children and young adults [30]. Moreover, orchidometers in general were found too insensitive to detect testicular volume changes when compared to testicular ultrasound in patients with varicocele [31]. No correlation was found between testicular volume and germ cell count or histology in undescended testes when assessed during orchiopexy [9–11] and hence we opted to assess intra-testicular blood flow as it is more related to fertility potential in andrological patients [7, 8].

Our study failed to find a role for US in detecting testicular ascent following FSO, although it might be indicated should a testis or testicular nubbin not be clinically felt in the scrotum or groin following surgery. We recognize the limitations of our study in being a small study group without a normal control group for comparison. There was also no randomization of patients and two different surgical approaches of FSO were involved. Furthermore, difficulties in measuring prepubertal testicular blood flow and vagueness regarding what actually defines a normal entity made it difficult to assess our results more effectively. However, we believe that with the limited knowledge and US capabilities we currently have, follow-up US for patients following FSO is not justified in an era of cost containment within the current healthcare climate.

4. Conclusion

There is no evident role for US in the follow-up of prepubertal testes post-FSO as US findings are very strongly correlated to those of clinical examination. Assessment of intra-testicular blood flow in prepubertal testes following FSO can be difficult, unclear and undetectable in cases. It is uncertain whether in those cases this is related to the prepubertal testicular stage, technique or unrecognized testicular atrophy despite normal morphology. PDU far exceeds CDU in detection of parenchymal blood flow in prepubertal testes in general.

Conflict of interests

None.

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