Journal of Medical Ultrasonics (2019) 46:231–237
https://doi.org/10.1007/s10396-018-0923-9

ORIGINAL ARTICLE

A comparative study of shear wave elastography in the evaluation of undescended and retractile testes in a pediatric population

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Received: 11 September 2018 / Accepted: 30 November 2018 / Published online: 8 January 2019

Abstract

Purpose To evaluate the diagnostic value of shear wave elastography (SWE) in the evaluation of undescended and retractile testes (RT) in a pediatric population.

Methods We prospectively evaluated a total of 37 undescended testes (UDT), 15 RT, and 56 normal testes using SWE. The stiffness values were recorded for speed (m/s) and elasticity (kPa), and the mean stiffness values of groups were compared with each other.

Results The mean stiffness values of the UDT (13.80 ± 4.14 kPa, 2.14 ± 0.29 m/s) were higher than the mean SWE values of the normal testes (7.44 ± 2.11 kPa, 1.57 ± 0.21 m/s) ($p < 0.0001$). The mean stiffness values of the RT (9.64 ± 3.71 kPa, 1.75 ± 0.35 m/s) exceeded those of the normal testes ($p = 0.004$ for elasticity and $p = 0.02$ for speed). The mean stiffness value of the UDT was higher than the retractile ones ($p < 0.0001$ for elasticity and speed).

Conclusion The higher stiffness values of the UDT and the RT compared to normal testes are likely reflective of underlying pathological alterations; hence, we suggest that SWE might serve as a valuable adjunct for the management of UDT and RT by assessing and monitoring ultrastructural changes.

Keywords Shear wave elastography · Undescended testes · Retractile testes · Elasticity · Stiffness

Introduction

Shear wave elastography (SWE) is a novel sonographic method capable of quantitatively providing information regarding the stiffness of the relevant tissue by tracking shear waves passing through them [1]. The stiffness of the tissue yielded by SWE serves as a valuable surrogate marker for the composition of the examined lesion or organ. SWE evaluation of organs such as the breast, liver, and thyroid is well established and widely accepted by the scientific community [1–3]. In recent years, the testis has become a favorite subject of elastography evaluation. In addition to assessing testicular tumors, the diagnostic value of elastography in the evaluation of the testicular parenchyma in various testicular or scrotal disorders including testicular microlithiasis, hydrocele, varicocele, and undescended testes (UDT) has been explored in many studies, which have yielded positive results [4–7]. However, to our knowledge, no study has investigated the potential parenchymal changes of retractile testes (RT) using SWE.

Herein, our aim was to compare the stiffness values of UDT, RT, and normal testes using SWE to show the potential differences between them.

Materials and methods

Patient population

The local ethics committee approved this prospective study, which was conducted between January 2016 and January 2018. Informed consent was obtained from all participants. Patients with bilateral or unilateral UDT and patients with RT were included in the study. Healthy controls were selected from age-matched boys who were admitted to our radiology department without a history of testicular pathology. The indications for testicular examinations of the healthy controls included suspected precox puberty,

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suspicion of an inguinal hernia, and scrotal pain without any history of trauma. Patients with any history of trauma, malignancy, genetic disorders, or previous testicular operation were excluded from the study. RT was defined as any testis that was located at the upper scrotum or lower part of the inguinal canal and could be descended into the scrotum applying manual pressure but returned to its previous position by the cremasteric reflex [8–10]. Finally, a total of 37 UDT in 23 patients with UDT, 14 bilateral and 9 unilateral, and 15 RT in 9 patients, 6 bilateral and 3 unilateral, were included in the study. Normal testes of 22 healthy controls constituted the normal testes group (44 testes).

Sonographic evaluation

An observer (OT) with more than 10 years of grayscale ultrasound and more than 5 years of elastography experience evaluated all patients. The patients were instructed to lie in a comfortable supine position if the patient was old enough to follow commands. The observer performed examinations with the aid of the relatives of the patient if the patient was not old enough to be able to follow our instructions.

The testes were examined using an ultrasound scanner capable of SWE measurements using a linear array transducer (14 MHz) (Aplio 500 Platinum; Toshiba/Canon, Japan). First, the observer assessed the volume of the testes by placing the transducer onto the inguinal region for the UDT and onto the scrotum for normal and RT. The observer measured the testicular volume with an automated formula (testicular volume = width × height × depth × 10^{-3} × 0.523). The observer then initiated the SWE examination. During the SWE examination, care was taken to gently place the transducer onto the skin to avoid any compression that might affect the measurements. The observer kept the transducer as stable as possible during the evaluation. Longitudinal images were preferentially used, and if it was not feasible to obtain longitudinal images, particularly for the UDT, the observer conducted the examination using the axial plane. The stiffness of the tissues was depicted by a chromatic scale displaying a color spectrum ranging from blue to red that indicated the stiffness from the lowest to the highest. The observer adjusted the chromatic scale in the range of 0–30 kPa and 0.5–5 m/s to ideally perform the interpretation since the testicular parenchyma's stiffness value is considerably low compared to the other organs. The observer placed three regions of interest (ROIs) with a diameter of 3 mm onto the chromatic box, and the average of these three ROI values was calculated. The stiffness values were both recorded using m/s and kPa as the unit. Figures 1 and 2 show SWE evaluation of UDT and RT, respectively.

Statistical analyses

Statistical analyses were performed using the SPSS software version 21. The variables were investigated using visual (histograms, probability plots) and analytical methods to determine whether or not they were normally distributed. Descriptive analyses were presented using means and standard deviations for normally distributed variables. Student's *t* test was used to compare the stiffness values and volumes (parametric data) of the UDT, RT, and normal ones. Correlation coefficients between age and volume, and age and stiffness, were calculated using the Pearson test. A *p* value of less than 0.05 was considered to show a statistically significant result.

Results

The mean age of the patients with UDT was 57.85 ± 50.74 months (range 5–200 months), that of patients with RT was 90.16 ± 32.27 months (range 32–124 months),

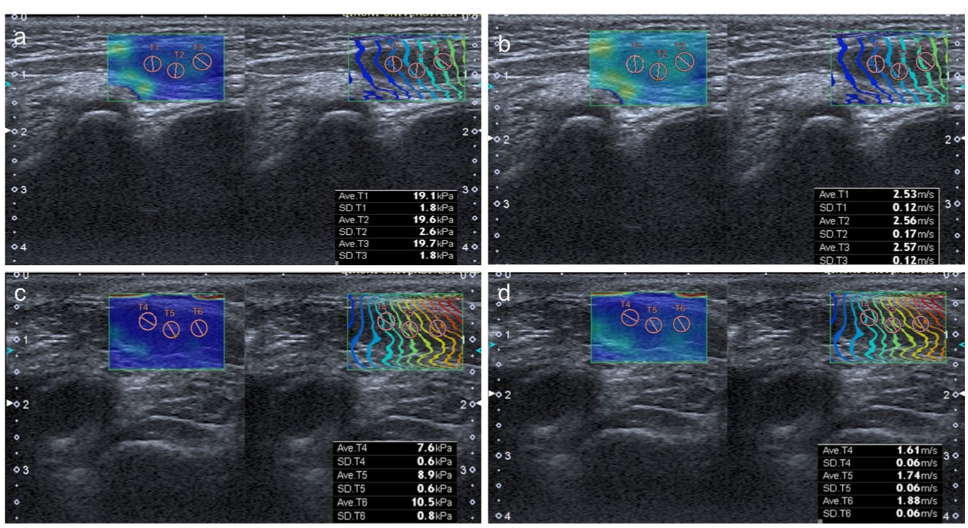

Fig. 1 A 15-month-old boy with a unilateral UDT. The SWE values of the UDT derived from three ROIs with a 3-mm diameter shows increased stiffness values in terms of elasticity (**a**) and speed (**b**) compared to normal contralateral testes (**c**, **d**)

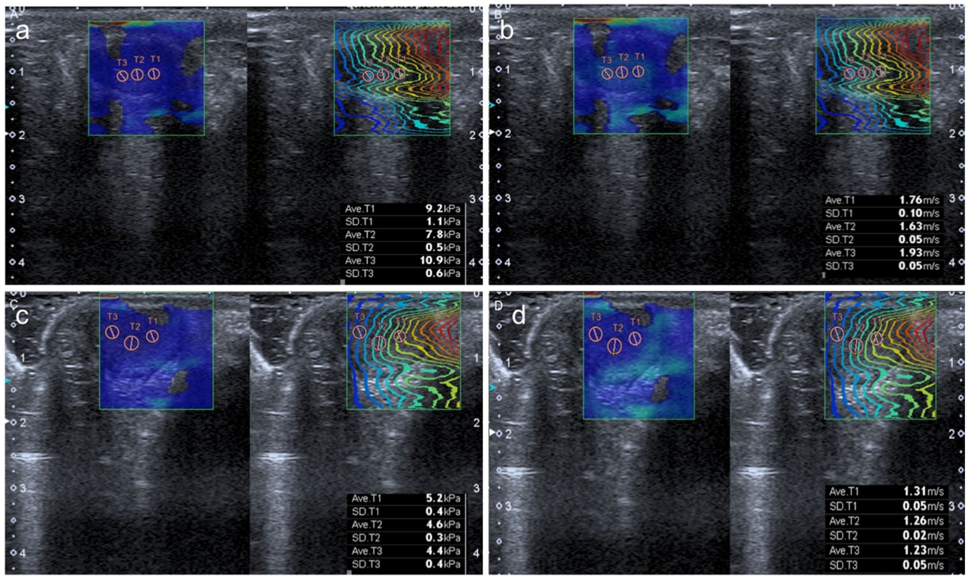

Fig. 2 An 18-month-old patient with a unilateral RT. The SWE values of the RT derived from three ROIs with a 3-mm diameter shows increased stiffness values in terms of elasticity (**a**) and speed (**b**) compared to normal contralateral testes (**c**, **d**)

and that of the healthy controls was 58.09 ± 50.56 months (range 3–163 months). There was no statistical difference between the ages of these groups ($p > 0.05$). The mean testicular volume of the UDT (0.50 ± 0.21 mL) was significantly lower than both the normal testes (0.73 ± 0.50 mL) and the RT (0.64 ± 0.13 mL) ($p = 0.002$ and $p = 0.01$, respectively). No significant difference was observed between the mean testicular volume of the RT and normal testes ($p > 0.05$). The mean stiffness values of the UDT expressed as elasticity and speed parameters were 13.80 ± 4.14 kPa and 2.14 ± 0.29 m/s, respectively. The mean SWE values of the normal testes were 7.44 ± 2.11 kPa and 1.57 ± 0.21 m/s, respectively ($p < 0.0001$). The mean stiffness values of the RT (9.64 ± 3.71 kPa and 1.75 ± 0.35 m/s) exceeded those of the normal testes ($p = 0.004$ for elasticity analyses and $p = 0.02$ for speed analyses). When we compared the stiffness values of the UDT and the retractile ones, we observed elevated values in favor of the UDT ($p < 0.0001$ for elasticity and speed analyses). No correlation was found between age and stiffness in each group ($p > 0.05$). We identified significant correlations between age and volume in patients with UDT and normal testes (UDT, $r = 0.54$ and $p < 0.0001$; normal testes, $r = 0.61$ and $p < 0.0001$). No correlations were found in patients with RT ($p > 0.05$) (Figs. 3, 4, 5).

Discussion

In the present study, we found that the mean testicular stiffness values of both UDT and RT exceeded the stiffness values of the normal testes. When we compared the mean stiffness values of the UDT and the RT, we detected a significant difference in favor of the UDT. The mean volume of the UDT was lower than that of the normal testes and the RT. There was no difference between the normal testes and RT in terms of volume.

UDT is a frequent anomaly in boys, with a prevalence ranging from 1 to 2% at 1 year of age, which poses particular risks including infertility, malignancy, and torsion [11]. Both the inguinal canal and abdomen are improper environments for testicular maturation, which significantly affects and alters normal testicular histology [12]. Histologic manifestations of UDT are well established and have been demonstrated by several reports: impairment of maturation, reduced number of germ cells, and reduced size of the seminiferous tubules accompanied by increased peritubular fibrosis [13, 14]. The changes are believed to occur commonly after 6 months of age; thus, the newest urological guidelines suggest orchidopexy earlier than 1 year of age if spontaneous descent does not occur [14, 15].

Testicular biopsy was the gold standard and only reliable method to identify the histological changes in UDT; yet, given its particular risks, it is omitted from clinical practice and no longer recommended in urologic guidelines [14, 15]. Therefore, until the current decade, testicular volumetric measurements and manual palpation were the only methods available to assess underlying histological changes in UDT. However, the correlations between testicular volume and testicular histology, and between testicular volume and future outcomes, have been a subject of debate within the scientific community [16, 17]. The results of studies concerning the volume of UDT are inconclusive, and although we found decreased mean testes volume in UDT compared to normal testes, we believe that testicular volume is not a good predictor of prognosis as well as histological status. Nevertheless, the stiffness values derived by SWE seem to be a feasible surrogate marker for noninvasive indirect histological evaluation of UDT. Our results, in line with the previous literature

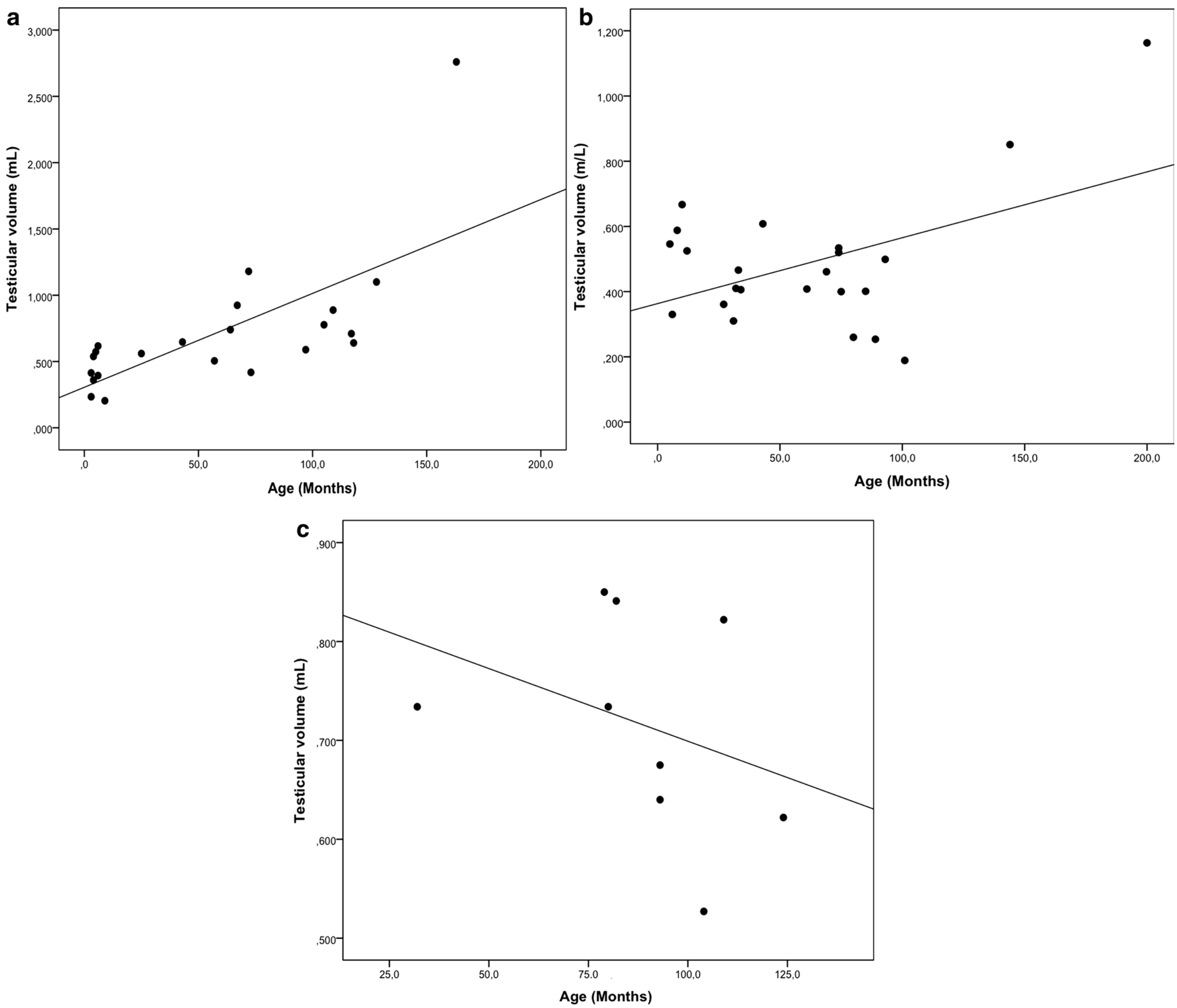

Fig. 3 Scatter plots of age and testicular volume in the healthy controls (**a**), UDT patients (**b**), and RT patients (**c**). Significant correlations were observed between the age and volume in patients with UDT and normal testes (UDT, $r=0.54$ and $p<0.0001$; normal testes, $r=0.61$ and $p<0.0001$). No correlations were found in patients with RT ($p>0.05$)

[4, 18], showing increased stiffness values in UDT, seem to mostly be due to testicular fibrotic changes.

The reported prevalence of RT ranges between 0.2 and 41% during the pre-pubertal period [10, 19]. Traditionally, RT was accepted as a normal variant, which was also supported by several histological reports claiming that RT had an identical histological composition with normal testes [8]. However, these assumptions have been vigorously challenged in recent years by a number of authors [13, 19, 20]. Caucci et al. [21] claimed that RT might be associated with adult infertility. Jedrzejewski et al. [22] and Goede et al. [20] demonstrated that RT had reduced volume compared to normal testes. These clinical works are also supported by histological studies, which demonstrated pathological alterations of RT. Nistal et al. [23] and a further study by Han et al. [13] demonstrated that RT had germ cell hypoplasia, tubular degeneration, and fibrotic changes like UDT, yet this process, particularly tubular degeneration, usually occurs in a mosaic fashion compared to the diffuse tubular degeneration in UDT [13]. Several mechanisms have been proposed as a cause of the histological alterations in RT, and exposure to improper temperature and venous stasis are so far the most popular ones [23]. We suggest that this histological background might explain the higher stiffness values of RT compared to normal testes, while RT had lower stiffness compared to UDT.

Although clinical guidelines concerning UDT are relatively more conclusive and established, the diagnostic

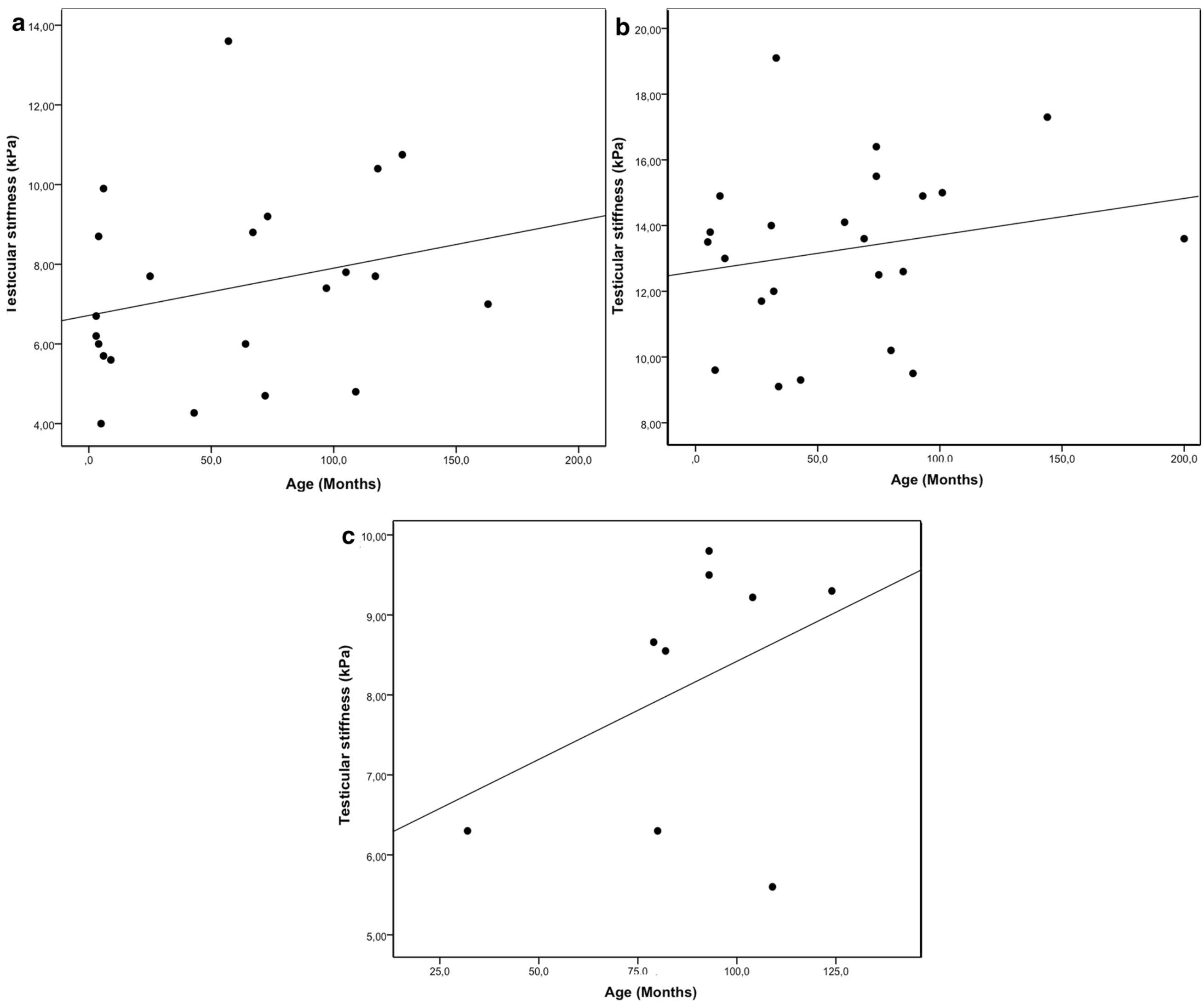

Fig. 4 Scatter plots of age and testicular stiffness (kPa) in the healthy controls (**a**), UDT patients (**b**), and RT patients (**c**). No correlation was found between age and stiffness in each group ($p > 0.05$)

algorithms, treatment strategies, and outcomes for RT are still being debated. The latest guideline from the European Society of Paediatric Urology recommends that patients with RT do not need surgical or medical treatment, yet these patients should be closely followed until puberty [15]. Orchidopexy is only recommended in cases of abnormal maturation or acquired cryptorchidism [15, 24]. The reported prevalence of RT requiring surgical correction owing to abnormal development ranges from 6.9 to 32% [19, 24, 25]. Interpreting the degree of RT injury might be very challenging, since it is not possible to determine how long the RT remained in the inguinal canal or the scrotum. Therefore, a noninvasive method to assess the potential underlying pathological alterations is highly desirable. Annual volumetric measurements using grayscale ultrasound is recommended in the follow-up period of RT, yet the diagnostic value of the testis volume as a surrogate marker for the histological alterations does not seem to be reliable, as is the case with UDT. We suggest that SWE might offer substantial contributions to the clinical management of RT.

Several drawbacks to the present study need to be acknowledged. First and foremost, we did not have histologic data to support our imaging findings, yet we suggest that our findings were consistent with those of the previous studies evaluating the histological aspects of UDT and RT. Second, our RT group was relatively small; thus, further studies with a larger population are needed to confirm our initial findings. Third, we were not able to assess interobserver variability since a single operator performed all examinations. Finally, the present study evaluated UDT and RT mostly from a radiological perspective; hence, we neither prospectively measured these testes with SWE to assess the potential changes

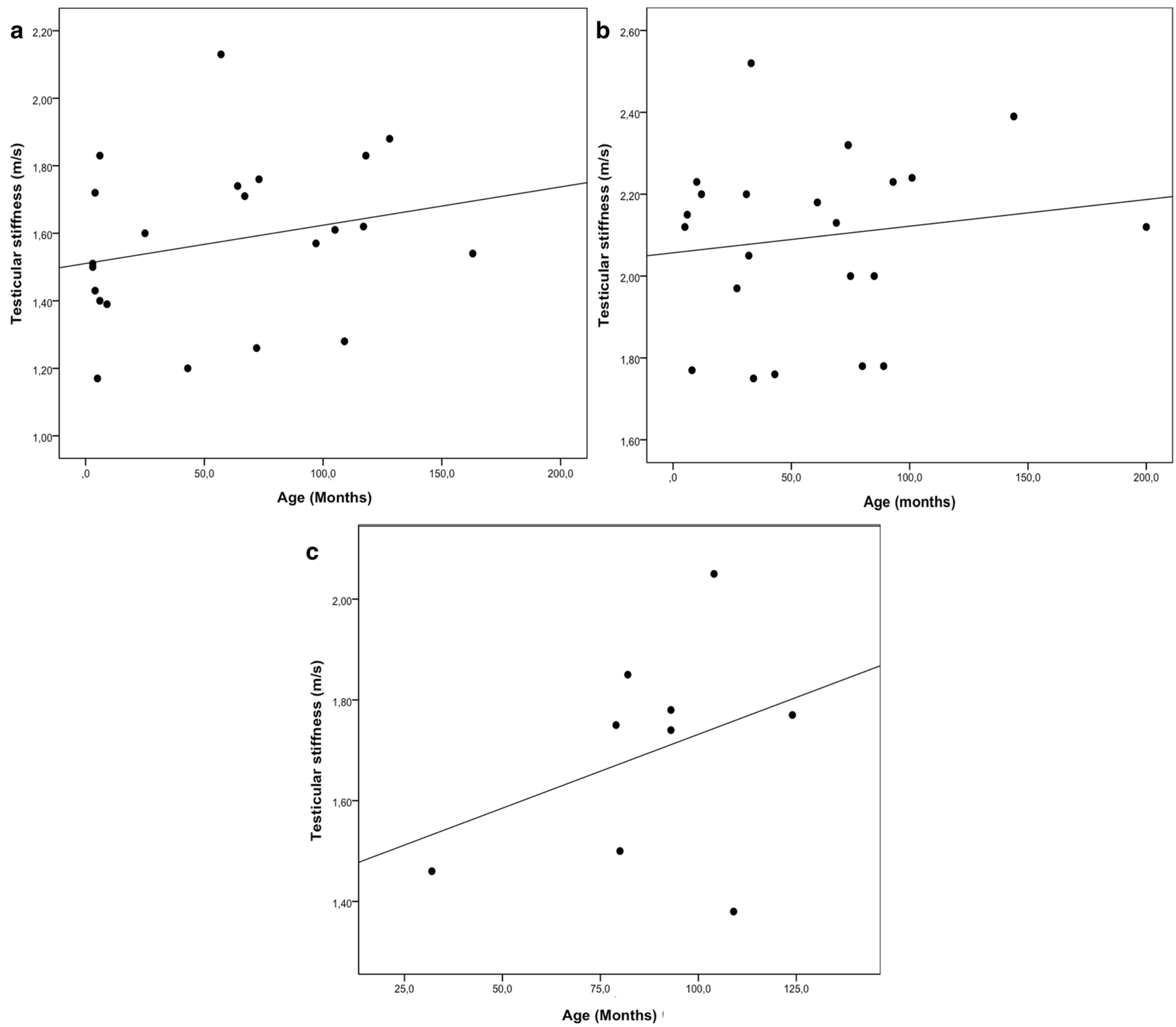

Fig. 5 Scatter plots of age and testicular stiffness (m/s) in the healthy controls (**a**), UDT patients (**b**), and RT patients (**c**). No correlation was found between age and stiffness in each group ($p > 0.05$)

of the testes in time nor compared our results with long-term histological or clinical outcomes of the testes and patients, respectively. Nevertheless, this study should be taken as one of the first steps in this area that warrants more comprehensive further research focusing on radiologic, pathologic, and clinical aspects of UDT and RT.

Conclusion

Higher stiffness values were found in UDT and RT compared to normal testes in the pediatric population. We suggest that SWE might serve as a valuable adjunct for the management of UDT and RT by assessing and monitoring ultrastructural changes.

Compliance with ethical standards

Conflict of interest Deniz Alis and Onder Turna have no conflicts of interest.

Ethical statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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