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Hypospadias anatomy: Elastosonographic evaluation of the normal and hypospadic penis

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Summary

Background
Hypospadias is one of the most common congenital anomalies in childhood. The aim of this study is to apply elastosonography on normal and hypospadic penis to verify the structural differences in tissues composition and stiffness.

Materials and methods
We analyzed medical chart of patients treated at our Institution for hypospadias during the period December 2005 and December 2014 (group 1). Other two groups were enrolled for this study: group 2-patients with hypospadias waiting for surgery and group 3-patients without hypospadias.

Inclusion and exclusion criteria were created; all patients underwent penile ultrasound and elastosonography. Elastographic index of elasticity was defined as soft, medium-hard or hard. We assigned the value 1 to soft tissue, 2 and 3 to medium-hard and hard respectively.

Results
During the study period 294 patients were treated for hypospadias. After reviewing medical chart 115 patients were considered for analysis (group 1). 22 patients were enrolled in group 2 and 38 patients were enrolled in group 3. Group 1: 7 proximal hypospadias, 29 penile hypospadias, 79 distal hypospadias. Patients with hypospadias had malformation also at corpus spongiosum and cavernosum respect to controls.

Elastography showed a corpus spongiosum stiffness defined as medium-hard or hard in all cases of the pathologic group and soft in all the subjects of the control group ($p < 0.05$).

Conclusions
Elastosonography showed how the hypospadia anatomy is deeply altered, even in an anatomical area far from meatal abnormality: corpus spongiosum in hypospadic penis seems to be globally stiffer and less elastic and cavernous corpora are less developed.

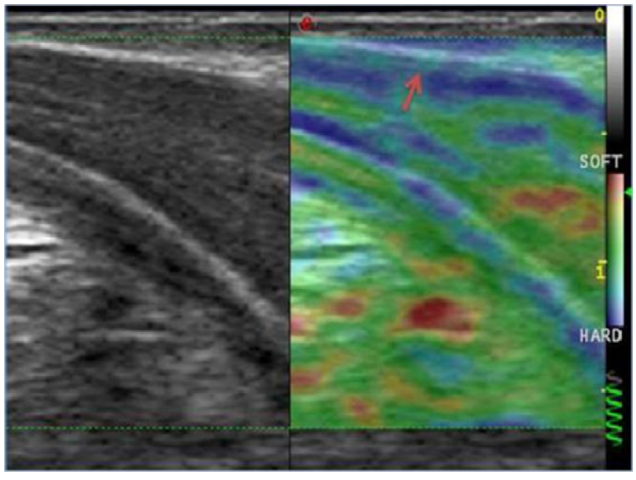

Figure Hypoaspadic penis, see hard structures (arrow)

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Introduction

Hypospadias is one of the most common congenital anomalies in childhood [1,2]. It is characterized by an anomalous development of the spongious body of the urethra resulting in a displaced urethral meatus, and it may be associated with penile curvature (ventral chordee) and foreskin defects. The penile curvature is due to fibrosis near the urethra and around the corpus cavernosum [3,4].

Chordee is observable in 35% of cases of hypospadic penis, and it is directly proportional to the grade of hypospadias [5–7].

Sonoelastography (tissue elasticity imaging) is an emerging ultrasound technique designed to evaluate the stiffness of biological tissues, while allowing to infer pathology in a way similar to palpation. Sonoelastography uses ultrasounds to determine differences in the relative elasticity of a tissue, which is a measure of tissue stiffness (also known as Young's modulus). It also has a role in demonstrating calcifications and, as shown in duplex studies, in identifying potential concomitant vascular compromise [8].

A compressive stress placed on the tissue causes a degree of deformation (strain) on the tissue itself; it was observed that the extent of deformation is inversely proportional to the stiffness of the tissue, and the amount of stress required to deform the tissue is directly proportional to the stiffness of the tissue [9–12].

The aim of this study was to assess the anatomy of the penis before and after surgery by using ultrasound and sonoelastography to evaluate the differences between the normal and hypospadic penis as well as the possible clinical applicability of such findings.

Materials and methods

The medical charts of patients treated at the authors' institution for hypospadias in the period between December 2005 and December 2014 were collected and analyzed (group 1). The study included two more groups: group 2, patients with hypospadias waiting for surgery; and group 3, patients without hypospadias.

Inclusion criteria

Group 1 included patients treated by the same surgeon for hypospadias at 12–24 months without associated anomalies and with a follow-up period of at least 1 year; group 2 included patients with hypospadias aged 12–24 months waiting for surgery without associated anomalies; group 3 included age-matched patients without hypospadias, without penile anomalies (i.e. phimosis), and without previous inguinal or scrotal surgery.

Exclusion criteria

Patients lost to follow-up and patients treated for urethral fistula at least 1 year after surgery were excluded.

Evaluation criteria

Each patient was assessed for type of hypospadias, presence of chordee, and foreskin abnormalities.

All patients received elastosonography and ultrasound imaging of the penis. The latter was used to evaluate the following aspects: urethral thickness; diameter of the corpus cavernosum and intercavernous angle; and thickness of the corpus spongiosum. Elastosonography recorded the elastographic index of elasticity of the corpus spongiosum and cavernosum corpora. The resulting elastogram, based on a color scale, was displayed on the B-mode image, which ranges from green to blue (in the web version). Green (in the web version) indicated tissue with the greatest elastic strain, that is the softest components, and blue (in the web version) indicated tissue with no strain, that is the hardest components. Elasticity was expressed using a semiquantitative three-point scale where 1 represented the most elastic tissues (predominantly green and red (in the web version)) and 3 represented the less elastic tissues (predominantly blue (in the web version)); 2 was a medium elastic tissue, where blue and green (in the web version) were mixed. All scans were performed by the same radiologist at the base of the penis, as far as possible from the region involved in the surgical procedure in all treated cases.

Technique

Sonoelastography was performed to evaluate fibrosis in the corpus spongiosum and in the corpus cavernosum by using a linear probe ultrasonograph (Esaote Gold Platform MayLab 60, Genoa, Italy) equipped with elasto software (ElaXto, Esaote, Cambridge, UK). First, B-mode images were obtained for each penis; then, sonoelastography was performed by applying light vertical pressure followed by decompression until a good-quality image was achieved.

Oral and written consent was obtained by the parents of each patient and the study was approved by the internal Institutional Review Board.

Statistical analysis was performed using the Student *t*-test, the chi-square test, the and Fisher exact test. A p value < 0.05 was taken to be significant. The analysis was conducted with the Statistical Package for Social Sciences (SPSS) software version 15 for Windows (SPSS Inc., Chicago, USA) and ANOVA where indicated.

Results

During the study period, 294 patients were treated for hypospadias. After reviewing the medical charts, 115 patients were considered for analysis (group 1). Twenty-two patients were enrolled in group 2 and 38 patients in group 3. There were no statistically significant differences in terms of age range between the groups ($p > 0.05$).

In group 1 there were seven proximal hypospadias, 29 penile hypospadias, and 79 distal hypospadias. There were 21 cases of chordee (18%) detected at objective examination and confirmed during surgery.

In group 2 there were two proximal hypospadias, seven penile hypospadias, and 13 distal hypospadias. There were three cases of chordee (13%).

Data about ultrasound and elastosonographic evaluation are reported in Table 1 and Figs. 1 and 2.

The results show that there was not a statistically significant difference in urethral diameter between the groups ($p > 0.05$). As for penile data, it was possible to find a statistical difference between the normal and hypospadic penis in the diameter of the corpus cavernosum ($p < 0.05$): the corpus cavernosum in patients with hypospadias was smaller than in the control group, although it is interesting to point out that untreated patients had a smaller diameter than group 1 ($p < 0.05$).

The findings regarding the corpus spongiosum and the intercavernous angle also revealed statistically significant differences between the groups ($p < 0.05$). Patients with hypospadias had altered anatomy even after urethroplasty and penis reconstruction.

Elastosonography imaging evaluation showed that patients with hypospadias (groups 1 and 2) had a stiffer penis than the control group, which was observed also at follow-up (1 year) after correct degloving ($p < 0.05$); 15 patients had pre- and postoperative elastosonography evaluation at 1 year. Data demonstrated that there was a reduction in stiffness, without statistically significant differences ($p = 0.08$), but with an encouraging trend towards improvement. It was not possible to determine a specific elastosonographic pattern for the different grades of hypospadias; also, the results showed that all cases of hypospadias had deeper anatomical defects (Figs. 3 and 4).

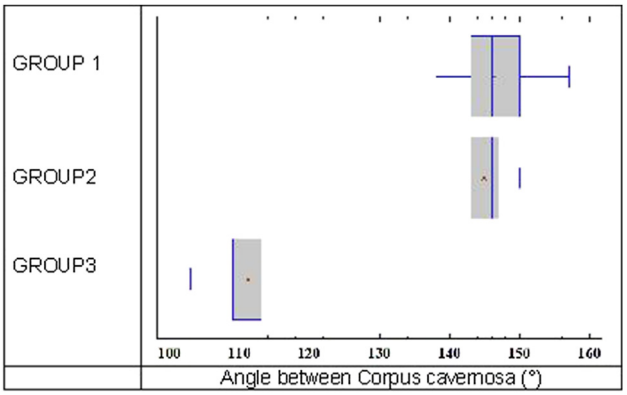

Figure 1 Box plot for angle between corpora cavernosa.

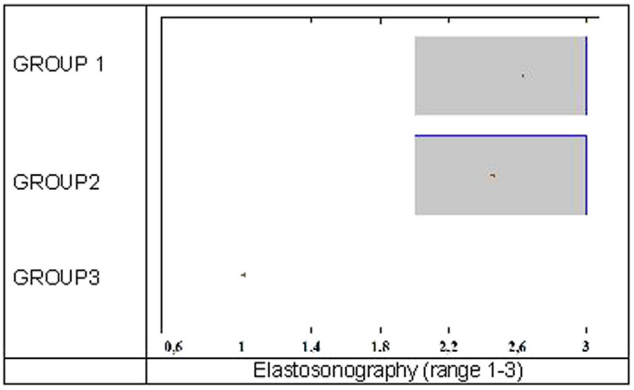

Figure 2 Box plot for elastosonography evaluation.

Discussion

Surgical outcomes in hypospadias repair are essential to better explain to parents the results that should be expected. Keeping this in mind, the surgical outcomes depend on many different factors, that is deformity of glans, position of urethral meatus, quality of urethral plate, presence of chordee and surgeon's experience and expertise.

During surgery, complete degloving of the penis represents a crucial step, since this allows accurate cutting of the chordee to better mobilize the urethra. Also, a skillfully performed degloving is usually associated with improved cosmetic results [6].

Meatal position is still the crucial factor that surgeons should consider before choosing the surgical technique. However, surgeons may have to change their initial choice intraoperatively, after observation of the new deeper "good" urethra.

There are currently no methods to identify such an occurrence preoperatively, even though such a method would help the surgeon to choose the optimal technique before starting surgery [13].

As reported in this study, patients with treated or untreated hypospadias have more than an urethral defect; patients with treated and untreated hypospadias have smaller corpus cavernosum and corpus spongiosum than controls.

It is possible that all these penile parameters clinically represent the embriological basis of hypospadias, when the penile urethra forms as a result of the fusion of the medial edges of the endodermal urethra folds, differentiating from corpus spongiosum and corpus cavernosum. Urethral closure is the final effect of the rotation of the corpus spongiosum [14,15].

Table 1 Ultrasound data.

Ultrasound and elastosonographic parameters	Hypospadias Groups 1 and 2	Healthy Group 3	$p < 0.01$
Sagittal diameter of the corpus spongiosum (mm)	1.91 ± 0.03	2.75 ± 0.07	<0.01
Sagittal diameter of the corpus cavernosum (mm)	4.25 ± 0.06	7.36 ± 0.12	<0.01
Transversal diameter of the corpus cavernosum (mm)	6.25 ± 0.08	9 ± 0.16	<0.01
Angle between the tangents to the medial surface of the two corpora cavernosa	147 ± 4.3	111 ± 3.7	<0.01
Elasticity of the corpus spongiosum	2.53 ± 0.4	1 ± 0	<0.01

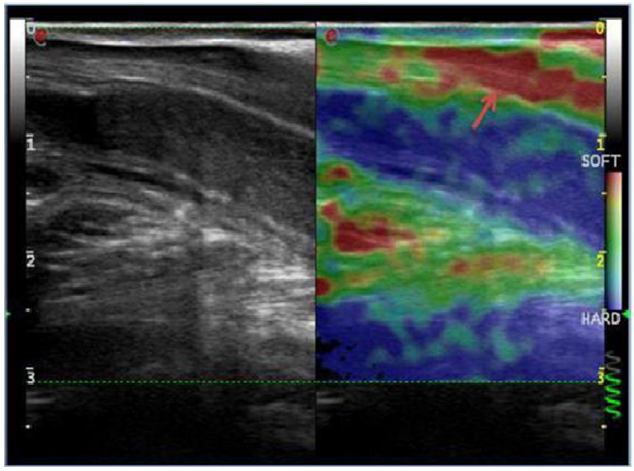

Figure 3 Normal penis. Arrow indicates grade 1 elasticity.

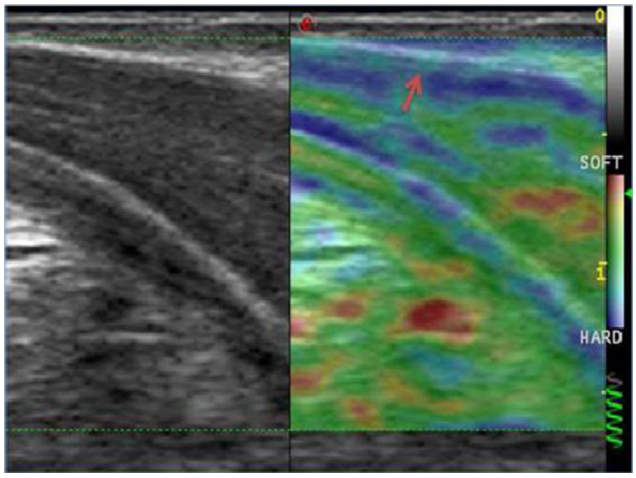

Figure 4 Untreated hypospadic penis. Arrow indicates grade 3 elasticity.

In hypospadic patients, it was also possible to observe a wider intercavernous angle, together with stiffer tissue than in controls. This size of this angle is important, especially after surgery, in order to prevent erectile dysfunction and a smaller penis in adulthood. During degloving it is essential to cut all the fibrous tissue around the penis to give space for reconstruction.

Sonoelastography is a useful imaging technique to evaluate the elasticity of a tissue and the results follow a color scale, where green (in the web version) indicates well vascularized tissues with good elasticity, and blue (in the web version) indicates stiffer tissues. Red (in the web version) represents medium stiffness. The value of this imaging technique is high, since it allows real-time assessment of the tissues and their stiffness, focusing on a specific area. Hard stiffness in the hypospadic penis represents the most common outcome of the surgical procedure; hypospadias is not an urethral disease alone, since it is the cause of many collateral signs such as reduced elasticity of the corpus spongiosum and corpus cavernosum, with a wider intercavernous angle or fibrosis in the ventral part of the penis, around the urethra and near the proximal urethra, where the corpus cavernosum divides and the angle is wider.

In this study, there was not a statistically significant difference in penis length between the groups, but this finding is specifically relevant when comparing untreated patients and controls.

There is scant literature about hypospadias and elastosonography, and this could represent a limit to the study, although this opens new possibilities to consider this method in future studies. Preoperative elastosonography could show the stiffer areas, especially at the base of the penis, and draw the surgeon's attention to the "good" urethra so that it is easier to plan the most suitable surgical procedures. Post-surgical follow-up in these patients is essential, especially for their parents; it is important to remember that correct and thorough pre-surgical counseling could reduce complications and parents' anxiety [16,17].

There is limited literature about penile function in adulthood after hypospadias repair, mainly because many studies did not use the correct questionnaire to record surgery results; the use of elastosonography in future studies may help compare treated and untreated patients in terms of quality of penile tissue and symptoms, such as erectile dysfunction or low urinary tract symptoms.

Conclusions

Elastosonography showed how the hypospadias "complex" can deeply affect penile anatomy, even in anatomical areas far from the meatal abnormality: the corpus spongiosum in the hypospadic penis seems to be globally stiffer and less elastic and the corpora cavernosa are less developed. These results could be used for a more successful preoperative counseling and, later, to monitor penile function in adulthood.

Conflict of interest

None.

Funding

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