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Article

Ultrasonic Evaluation of the Achilles Tendon in Patients Treated for Congenital Clubfoot

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Abstract: Background: clubfoot is a common congenital deformity. The Ponseti technique, involving early corrective manipulations followed by the application of long leg casts and Achilles tenotomy, is widely accepted as the preferred treatment. Rapid healing of the tendon after surgery has been documented, but the aspect regarding tendon structure and properties is not known. Three cases of Achilles tendon rupture in adolescent previously treated for clubfoot have been described in the literature. Since rupture is a rare event in this age group a possible correlation with previous surgery has been hypothesized. The primary aim of the study was to compare the ultrasound findings of the Achilles tendon, in patients treated for clubfoot, between patients treated with casting alone and the ones who underwent surgery (percutaneous tenotomy or Z-plasty lengthening). Methods: 22 asymptomatic patients, (34 feet) median age 12 years, previously treated for clubfoot, were recruited for this study; the patients underwent an Achilles tendon ultrasound examination during a follow-up outpatient visit. Results: a greater thickness and structural alterations with presence of hypoechoic areas of the operated tendons compared to those treated with plaster alone were observed (p value: 0.0498 and <0.001, respectively). Conclusions: the presence of ultrasound alterations in asymptomatic patients operated on for clubfoot requires careful control of the extrinsic factors of tendinopathy, to reduce the risk of subcutaneous rupture

Keywords: ultrasound; congenital clubfoot; tenotomy; subcutaneous rupture

1. Introduction

Clubfoot is a common congenital deformity, with a prevalence ranging from 1 to 6 per 1000 live births [1–4]. Due to frequent relapses it is considered a difficult disease to treat [5,6]. It is commonly treated with the Ponseti method, which involves manipulations followed by plaster casts and often tenotomy of the Achilles tendon. The obtained correction is maintained with a night brace until the age of 4-5 years[7–9]. Achilles tendon tenotomy is a minimally invasive procedure and it is performed in a variable percentage of cases, up to 85% [8,10,11]. In the event of a recurrence, the plaster cast and Achilles tenotomy procedure are repeated, in ambulatory patients by percutaneous lengthening [12,13]. Z-plasty lengthening of the tendon is performed both in "complex" feet, or neglected or relapsed feet [10]; Achilles tenotomy or Achilles tendon lengthening are therefore essential procedures to obtain good results in congenital clubfoot treatment. The results of Achilles tenotomies have been extensively studied, as regards healing times. Many Authors showed complete restoration

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of the continuity of the tendon fibers 3-6 weeks after surgery [14–17], and good functional recovery, with no restrictions in sport performance or activity [18,19]. The natural history of tendon healing after tenotomy or Z-plasty lengthening in clubfoot is not well understood [20]. As far as we know the healing process of the Achilles tendon after lengthening at the myotendinous junction has been reported in CP [21]; tendon features after Z-plasty lengthening have been described in rats, we found no data in humans [22].

Three cases of Achilles tendon rupture in adolescent previously treated for clubfoot have been described in literature. Since rupture is a rare event in this age group (globally the cases described are 5) a possible correlation with previous surgery has been hypothesized [23–25]. The primary aim of the present study is to compare the ultrasound findings of the Achilles tendon among patients previously treated for congenital clubfoot, between patients treated with casting alone and the ones who underwent surgery (percutaneous tenotomy or Z-plasty lengthening). Secondary aim was to carry out a descriptive analysis of the ultrasound parameters detected both on tendons undergoing tenotomy and those undergoing Z-plasty, with or without prior tenotomy.

2. Materials and Methods

Study design

This is a cross-sectional observational study

Setting and time

Over an 8-month period (October 2021- May 2022) 22 patients (8 girls and 14 boys), previously treated for clubfoot, were recruited for this study. The patients underwent an Achilles tendon ultrasound examination during a follow-up outpatient visit, at the Pediatric Orthopedics Clinic of Città di Pavia Institute, in Pavia, Italy.

Population

Globally 22 patients (14 males and 8 females) were included in the present study, with a total number of 34 tendons. The median age value at the time of the survey was 12.0 years (IQR 8.0-16.0). The deformity was unilateral in 10 patients, bilateral in the remaining 12, for a total of 34 pathological feet. Achilles tendon surgery was performed in 20 cases (11 patients underwent exclusively percutaneous tenotomies, 9 subsequently underwent lengthening with Z-plasty.), the mean interval since surgery was 9,8 years. In 14 cases the correction was obtained with plaster cast alone.

Variables and endpoints

Demographical data and clinical information (regarding the type of treatment and the type of surgery) were collected.

Ultrasound measurements of the Achilles tendon were reported.

The primary endpoint is the tendon thickness (measurement expressed in mm) in neutral position. Secondary endpoints were the followings: the tendon thickness in dorsiflexed position, the presence of vascularization, of hypoechoic areas and respectively of calcifications. Finally, in the unilateral forms, we compared the ultrasound findings of the healthy feet with those of the pathological side.

Data sources and data collection

The examination was carried out by the same operator with a Hitachi Arietta 65 ultrasound machine using a linear probe. Because tissues of fibrillar structure, such as tendons, have reduced echogenicity based on the angle of the transducer, attention was paid to the correct positioning of the probe, to avoid mistakes in interpretation of pathological defects. Patients layed in the prone position with the ankles extending over the edge of the table. Each foot was studied both in neutral and in dorsiflexion position. Tendon images were viewed in real-time in longitudinal and transverse planes;

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the section site was identified 2.0 cm above the calcaneal insertion. Diffuse or localized hypoechoic areas in the superficial layer of the tendon, near the perithenonium, and the presence of calcifications were sought. Areas of vascularization and the number of vessels present were evaluated by means of color Doppler ultrasound.

Sample size considerations

Primary goal of the present study is to compare the ultrasound features of the Achilles tendons between the ones conservatively treated and the ones who underwent surgery. The primary endpoint was the tendon thickness in neutral position. Variation of the tendon diameters in dynamic, found during the dorsiflexion maneuver, could be explained by the possibility that the measures would change in relation to the elasticity of the tendon itself.

Agarwal et al [14] performed an ultrasound examination on 37 Achilles tendons (in 26 patients suffering from congenital clubfoot, with mean age 17 weeks and who underwent a tenotomy intervention). The mean Achilles tendon thickness was 2.52 mm before the tenotomy, 3.82 mm three weeks after tenotomy, 3.77 mm six weeks after surgery and 4.03 at 1 year of age. From the 6th to the 12th month after surgery a thickening of the Achilles tendon was observed. It therefore seems that, over time, the thickness of the tendon subjected to tenotomy tends to increase. Actually, the natural history of tendons subjected to tenotomy is not yet well known.

Sample size calculation

Considering a mean value of the Achilles tendon thickness in neutral position equal to 4.9 mm (ds = 1.24) for the group of tendons with congenital clubfoot which underwent surgery and a mean value of 3.7 mm (ds = 0.71) for the group of tendons with congenital clubfoot conservatively treated, a total number of 34 tendons with CCF, of which 20 treated surgically and 14 treated conservatively, allows to estimate a mean difference of 1.27 mm between the average values of the two groups with the Student t test, ensuring a power > 90% and an alpha error equal to 0.05.

Statistics

Categorical variables were expressed as counts and percentages, continuous variables were described with mean and standard deviation and with median and interquartile range (IQR: 25th–75th percentile). In this way a complete description of the data were provided, including mean and median as measures of central tendency, with the mean being affected by extreme values (outliers) and the median not being affected; standard deviation and IQR are reported as measures of dispersion. The normality of the distribution was checked with the Shapiro-Wilk test.

The comparisons between two groups for continuous variables were performed with the Mann–Whitney non parametrical test, given the non parametrical distribution of the data. Associations between categorical variables were studied with the Pearson's $\chi 2$ or with the Fisher's exact test, depending on the frequency distribution of the contingency table.

All tests were 2-sided; the significance level was set at $\alpha = 0.05$. A p value < 0.05 was considered statistically significant. Data analysis was performed using the STATA statistical package (version 17 or later; Stata Corporation, College Station, 2009, Texas, USA).

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3. Results

The results are summarized in Table 1.

Table 1.

TENDON MEASUREMENTS	Healthy tendon (10)	Casting alone (14)	Tenotomy (11)	Z plasty Lenghtening (9)
Tendon thickness in neutral position (mm)	Mean (sd): 4.15 (0.87) Median (iqr): 4.1 (3.8 ; 4.8)	Mean (sd): 4.16 (0.91) Median (iqr): 4.2 (3.6 ; 4.7)	Mean (sd): 5.24 (1.12) Median (iqr): 5.3 (4.2 ; 5.9)	Mean (sd): 4.66 (1.16) Median (iqr): 4.5 (4.2 ; 4.8)
Tendon thickness in dorsiflexion position (mm)	Mean (sd): 3.87 (0.86) Median (iqr): 3.85 (3.4 ; 4.3)	Mean (sd): 3.71 (0.71) Median (iqr): 3.75 (3.4 ; 4.1)	Mean (sd): 5.34 (1.40) Median (iqr): 5.1 (4.5 ; 6.0)	Mean (sd): 4.56 (0.89) Median (iqr): 4.6 (4.1 ; 5.5)
Average difference between tendon thickness in neutral position and in dorsiflexion, in percentage	Mean (sd): 6.76 (8.53) Median (iqr): 10.67 (0; 13.64)	Mean (sd): 9.35 (12.68) Median (iqr): 9.73 (0; 15)	Mean (sd): -1.09 (8.17) Median (iqr): 1.81 (-7.14 ; 5.71)	Mean (sd): 0.66 (13.67) Median (iqr): 0 (0; 4.65)

**a positive number stands for a reduction in AP diameter changing from neutral to dorsiflexed position, while a negative number stands for an increase in AP diameter changing from neutral to dorsiflexed position.*

ULTRASOUND FINDINGS	Healthy tendon	Casting alone	Tenotomy	Z plasty Lenghtening
Vascularization – N (%)	0 (0 %)	0 (0 %)	1 (9.09%)	1 (11.11%)
Hypoechoic areas – N (%)	1 (10%)	2 (14.29%)	9 (81.82%)	7 (77.78%)
Calcifications	1 (7.14%)	0 (0 %)	0 (0 %)	0 (0 %)

The average tendon thickness was greater in the surgically treated feet than in those treated with casting alone, with statistically significant difference both in the neutral position and in dorsiflexion (p value 0.0498 and p value 0.0013 respectively). In tendon treated with casting alone there was an average thickness reduction of 9,73 % in the dorsiflexed position compared to the neutral position, higher than that of surgically treated tendons (1.81 % and 0 %, in tenotomy and Z plasty lengthening respectively); this means that the tendon subjected to stretching alone remains more elastic than the operated one, with a percentage of reduction in thickness in dorsiflexion very similar to that of the healthy tendon (10.67%).

Vessels were observed on Doppler ultrasound in 2 tendons among operated feet, no one was present in the conservatively treated feet. An insertional calcification was observed in one of the healthy control tendons, whereas no calcification was present in the surgically treated tendons. We have no explication for this isolated observation.

Irregularity of the tendon structure with hypoechoic areas in the superficial tendon layers were observed in 16 surgically treated and 2 conservatively treated tendons, with a statistically significant difference (p value <0.001).

The comparison between tendons undergoing tenotomy and those undergoing Z-plasty, with or without prior tenotomy, showed no statistically significant differences in tendons thickness, both in neutral and dorsiflexed position.

In summary, the operated tendons had a greater thickness and a less homogeneous structure compared to the tendons treated with stretching alone; furthermore, the thickness reduction in dorsiflexion was greater in conservatively treated tendons, similar to what is observed in healthy tendons.

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4. Discussion

A surgical procedure on the Achilles tendon (tenotomy or Z-lengthening) is an integral part of the treatment of clubfoot [8,9,12,13]. We investigated ultrasound parameters in the Achilles tendons of asymptomatic patients treated in the past for congenital clubfoot. Statistically significant observed data were a greater thickness of the operated tendons compared to those treated with plaster alone (with no difference between the tenotomized ones and those with Z-plasty); furthermore operated tendons presented structural alterations, with a greater presence of hypoechoic areas. These ultrasound characteristics are similar to those observable in case of tendinopathy, even in the absence of subjective symptoms. Our results are different from those observed by other Authors, which have documented tendon healing within a few weeks after tenotomy, observing minimal ultrasound anomalies during follow-up, that did not seem to affect function [14,17,24,25]. The Authors however report data at a shorter distance from the operation, at 6 and 4 weeks respectively [14,26]. Furthermore, during the collection data, one of the patients analyzed in our study suffered a rupture of the right Achilles tendon, as she walked (Figure 2). The patient was a volleyball player, she was in good health, she had taken any medications, in particular quinolones, and she had no other risk factors for tendinopathy. The ultrasound we previously carried out showed a thickening of the Achilles tendon and diffusely hypoechoic superficial areas (Figure 3) 2 cm from the insertion on the calcaneus. Few cases of subcutaneous rupture of the Achilles tendon, in adolescent undergoing Achilles tenotomy for clubfoot, are described in the literature. Since in adolescents there are usually no intrinsic factors predisposing tendinopathy, tendon alterations underlying subcutaneous rupture could be attributed to the previous surgery, as hypothesized by the other authors [27,28].

A limitation of this study is represented by the small sample size and to draw certain conclusions a larger number of patients would be desirable. It seems interesting to underline that in our patient the find of the ultrasound alterations corresponding to the site of the rupture, could confirm the hypotheses of the other Authors.

Figure 2. The intraoperative finding shows complete interruption of the Achilles tendon 2 cm at the calcaneal insertion. In addition to the areas of hemorrhagic infarction, there is a clear alteration of the macrostructure of the tendon.

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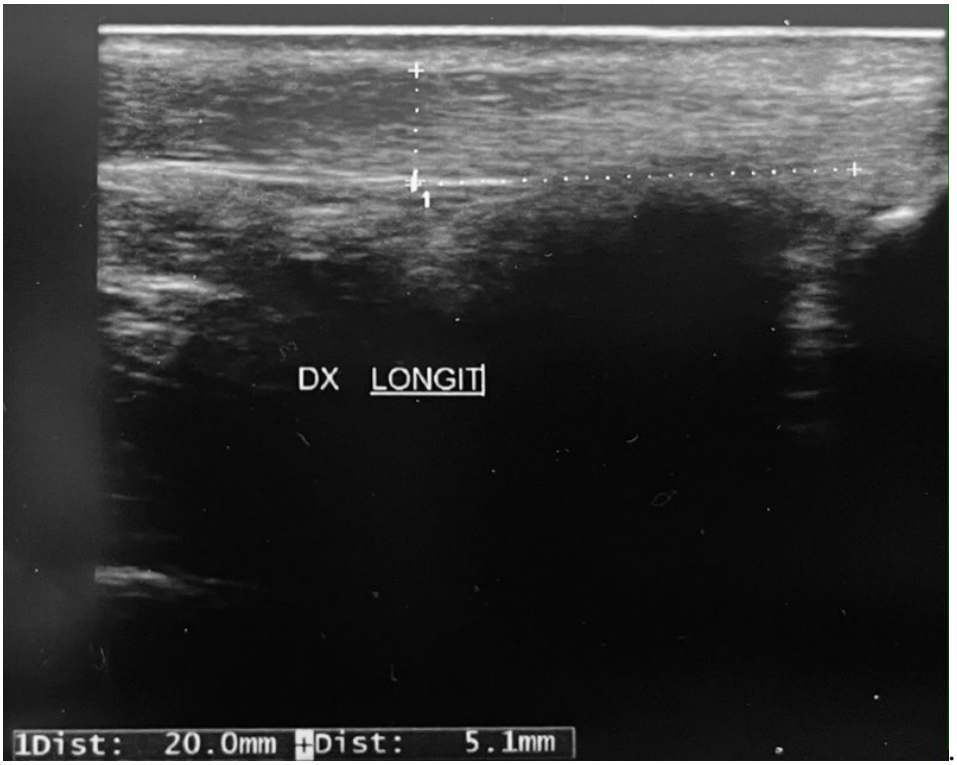

Figure 3. The ultrasound finding shows a thickening of the Achilles tendon and diffusely hypoechoic superficial areas 2 cm from the insertion on the calcaneus.

5. Conclusions

Clubfoot is a relatively common congenital pathology. Complete correction of the deformity often requires a surgical procedure on the Achilles tendon. Since some cases of subcutaneous tendon rupture have been described in these patients, ultrasound monitoring of those who practice intense sport could allow the identification of risk situations, which require training adjustments or other preventive regimens, to reduce the risk of rupture.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to specific ethical and privacy considerations.

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