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Clinical Characteristics of Acute Anterior Talofibular Ligament Injury in Children with Negative X-ray Fractures

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Abstract

The study aimed to explore the clinical characteristics of anterior talofibular ligament (ATFL) injury in children with negative X-ray fractures using musculoskeletal ultrasound.We analyzed a total of 85 children with low-energy ankle sprains who visited the orthopedic outpatient department of Jinan Children's Hospital from June 2023 to December 2024. All participants underwent X-ray and musculoskeletal ultrasound examinations.Based on the examination results, patients who showed fractures on X-rays and other soft tissue injuries such as ligaments on musculoskeletal ultrasound were further excluded.Finally, after strict screening, the included subjects were determined. Data on clinical examinations, X-rays, and musculoskeletal ultrasound examinations of all participants were collected. The degree of pain was assessed using the VAS pain scale, and the degree of ATFL injury was represented by the Kemmochi ultrasound standard.Finally, statistical analysis was conducted.The coincidence rate between the clinical diagnosis and ultrasound diagnosis of ATFL injury in 85 participants was 94.1%. The coincidence rate of X-ray and musculoskeletal ultrasound in the diagnosis of ankle fractures was 67.1%, and the Kappa value was 0.312. Ultimately, a total of 68 children with ATFL injury showing negative fracture results on X-rays were included, including 41 boys and 27 girls. The median age was 9.02 (95%CI, 8.36-9.68), with 26 cases on the left side and 42 cases on the right side. The median injury time was 24 hours (95%CI,24.00-37.27). The median VAS pain score was 4.0 points (4.0, 5.0). The most common musculoskeletal ultrasound classification was Kemmochi type V, accounting for 41.2%. In conclusion,ATFL injury is common in children with low-energy ankle sprain (94.1%). Clinical physical examination combined with musculoskeletal ultrasound diagnosis is of great significance. KemmochiV was the most common type of ATFL injury with negative X-ray fractures.

Keywords: children, anterior talofibular ligament injury, negative X-ray fractures, ultrasound

1. Introduction

Acute ankle sprain is a common sports injury in children, among which Anterior talofibular ligament (ATFL) injury accounts for approximately 70%-90%[1-3]. Missed diagnosis and improper treatment of acute ATFL injury in children lead to a high recurrence rate of ankle sprain (about 56%-74%), and about 20% of children may cause chronic ankle pain and ankle instability, and even lead to osteoarthritis in the long term, significantly reducing the quality of life and exercise ability of children [3-6]. Therefore, further research on the diagnosis and treatment of ATFL injury in children is of great significance.

Because the strength of ankle ligaments in childhood is usually higher than that of cartilage, ATFL injury is often accompanied by avulsion fractures of the distal fibula or talus [3, 7]. At present, the diagnosis and treatment of ATFL injury in children with obvious fractures under radiological examinations such as X-rays are relatively clear. However, conventional radiological examinations have significant limitations in the diagnosis of ankle sprains. On the one hand, X-rays have limited resolution for soft tissue injuries; on the other hand, they are difficult to display unossified cartilage injuries. Therefore, for children when fractures are not found on X-rays but ATFL injury is clinically suspected, it is necessary to further clarify whether there is ligament injury and whether there is a combined epiphyseal cartilage fracture [8, 9]. At present, MRI is an important method for diagnosing ATFL injury and epiphyseal cartilage fractures [8, 10]. However, due to the high cost, long examination time, long waiting time, the need for sedation in young children, MRI is often not easily accepted [2, 10-12].

Musculoskeletal ultrasound technology has the advantages of convenience, high accuracy, high resolution, low cost, easy operation, non-invasiveness and no radiation [13]. In recent years, the value of musculoskeletal ultrasound in the field of ankle joint injuries has begun to be studied [11, 12]. Previous studies have shown that

musculoskeletal ultrasound has the same sensitivity and accuracy as MRI in diagnosing ATFL injury [13, 14]. In 2016, Kemmochi et al. further refined the classification criteria of ATFL injury based on musculoskeletal ultrasound, dividing it into five types. Among them, type V is ATFL injury combined with avulsion fractures at the talus end or the distal fibula [2]. Therefore, musculoskeletal ultrasound technology can be used to conduct a preliminary diagnosis and assessment of ATFL injury in children with negative X-ray fractures, and can also conduct in-depth analysis of the clinical characteristics of ATFL injury.However, there is still relatively little research on this topic.

This study aims to explore the clinical characteristics of ATFL injury in children with negative X-ray fractures using musculoskeletal ultrasound,in order to provide a theoretical basis for the clinical diagnosis and treatment of ATFL injury in children.

2. Materials and Methods

2.1 Study Population

All protocols of this study complied with the principles of the Declaration of Helsinki and were approved by the Ethics Committee of Jinan Children's Hospital. All methods are carried out in accordance with relevant guidelines and regulations.

From June 2023 to December 2024, the orthopedic outpatient department of our hospital received 269 patients suspected of ankle sprains. Based on the established inclusion and exclusion criteria, we successfully recruited 85 eligible participants. The inclusion criteria include the following: 1). Aged between 5 and 15 years old; 2). First-time ankle sprain, all classified as low-energy injuries according to Clark's criteria[15]; 3). Injury occurring within 7 days; 4). Able to walk normally before injury; 5). Normal intelligence; 6). Physical examination shows swelling and pain in the lateral malleolus, limited movement, and a positive varus test. Conditions including multiple trauma, a history of musculoskeletal disorders or coagulopathy, problems with growth retardation, and a history of ankle sprain were excluded.Then based on the results, we further excluded patients with fractures on X-ray and musculoskeletal ultrasonography with other soft tissue injuries such as ligaments. After a strict screening process, the study subjects of this study were finally determined.

2.2 Study Methods

2.1.1 Clinical Examination

All participants underwent clinical physical examinations by professional pediatric orthopedic physicians. First, the case information was recorded, which covered the details of demography, injury mechanism, injury time, injury site and so on. Subsequently, a physical examination was performed and detailed notes were taken, including the specific location of soft tissue swelling and tenderness, pain level, weight-bearing capacity, and ankle valgus test results. After the clinical examination, all participants underwent ankle X-ray examination and musculoskeletal ultrasonography.

2.2.2 Imaging Studies

After the radiographs were completed, all images were reviewed by 2 radiologists.For musculoskeletal ultrasound examination, Philips EPIQ 5 and Philips EPIQ 7 color Doppler ultrasound imagers were selected. The examination was performed with an 18-5 MHz or 12-5 MHz high-frequency linear array probe. For examination of the ATFL, the posterior end of the probe was placed on the lateral malleolus, and the anterior end was placed slanting anteriorly and inwardly on the talus, with a thin band of echo in the longitudinal section.The continuous of ATFL, avulsion fracture of distal fibula or talus, joint effusion , and ligament blood flow were observed. All ultrasound examinations were performed by an experienced musculoskeletal ultrasound specialist.Ultrasound images were reviewed by two ultrasound physicians with expertise in pediatric orthopedics.

2.2.3 Clinical and Radiological Assessment

The degree of pain was assessed using the Visual Analogue Scale (VAS) facial pain scale, with a scoring range from 0 to 10 for pain from mild to severe; weight-bearing capacity assessment is classified as severe (unable to bear weight), moderate (able to bear partial weight with limping for 1-5 steps), or mild (able to bear partial weight with limping over 5 steps or pain-free) [8].

Negative assessment of X-ray fractures was conducted in the Picture Archiving and Communication System (PACS). If there were no fracture lines in both the anteroposterior and lateral positions of the ankle joint, it can be determined that the fracture is negative. At the same time, conditions such as the subfibular appendages need to be excluded.

The degree of ATFL injury was expressed by the Kemmochi ultrasonic standard [2]. This standard classifies ATFL injuries into 5 types: Type I, continuous ATFL with intact fiber structure; Type II, swollen ATFL with basically intact fiber structure; Type III, "elongation sign" of ATFL with disrupted fiber structure; Type IV, complete rupture of ATFL with the floating sign; Type V, combined with distal tibial or fibular avulsion fractures,with contralateral ankle joint imaging used for comparison.

2.3 Statistical Analysis

All clinical data were analyzed using SPSS 21.0 software. The consistency between X-ray and musculoskeletal ultrasound examinations was assessed using the Kappa test. Continuous variables were first tested for normality. Continuous variables that did not follow a normal distribution were presented as median M (Q1, Q3) or median M (95%CI), A two-sided P value < 0.05 was considered statistically significant.

3. Results

3.1 Analysis of Clinical Data Related to ATFL Injury

A total of 85 children with ankle sprains were recruited, including 49 boys and 36 girls, aged 5 to 15 years, with a median age of 9.0 years (95%CI, 7.0-11.2). Musculoskeletal ultrasound showed ATFL injury in 80 cases (94.1%), including 1 case of posterior talofibular ligament injury and 2 cases of tibifibular interfibular ligament injury. One case of calcaqneal ligament injury and one case of skin injury. The coincidence rate between clinical diagnosis and ultrasound diagnosis was 94.1%. Twelve cases of fractures were diagnosed by X-ray, all of which were distal fibular fractures.Forty cases of fracture were diagnosed by musculoskeletal ultrasound, including 38 cases of distal fibula fracture and 2 cases of talus fracture. The coincidence rate of musculoskeletal ultrasound and X-ray in diagnosing fractures was 67.1%, and the Kappa value of diagnostic consistency between the two was 0.312 (Table 1).

Table 1. Kappa consistency test for diagnosing fractures by musculoskeletal ultrasound and X-ray

	X-ray (n)		
Musculoskeletal Ultrasound (n)	Negative	Positive	Kappa value
Negative	45	0	0.312
Positive	28	12	

n, sample size

3.2 X-ray Negative ATFL Injury Children's Demographic Information and Clinical Features

As shown in Table 2, after further excluding 12 children with ATFL injury diagnosed as fractures by X-ray, a total of 68 children with ATFL injury with negative X-ray fractures were enrolled, including 41 boys and 27 girls, aged 5 to 14 years, with a median age of 9.02 (95% CI, 8.36-9.68) years, 26 cases on the left side and 42 cases on the right side. The median time to injury was 24 hours (95% CI, 24.00-37.27). The injury mechanism is ankle varus stress sprain caused by activities such as going down stairs and running, all of which are low-energy injuries. The median VAS pain score was 4.0 (4.0, 5.0) points. The weight-bearing status was mild in 29 cases, moderate in 32 cases and severe in 7 cases. According to the Kemmochi standard classification of musculoskeletal ultrasound: there were 2 cases of type I; Type II: 22 cases; Type III: 16 cases; There were 0 cases of type IV. There were 28 cases (41.2%) of type V.Among them, there were 26 cases of distal fibula injury and 2 cases of talus injury .

Table 2. Demographic information and clinical characteristics of children with ATFL injury with negative X-ray fracture

Variable	Data
Age (y, M, 95% CI)	9.02 (8.36-9.68)
Gender (n, %)	
Male	41 (60.3%)
Female	27 (39.7%)
Side (n, %)	
Left	26 (38.2%)
Right	42 (61.8%)

Mechanism of injury	Low-energy injury
Time of injury (h, M, 95% CI)	24.0 (24.00-37.27)
VAS pain score M (Q1,Q3)	4.0 (4.0, 5.0)
Weight-bearing status (n, %)	
Light	29 (42.6%)
Moderate	32 (47.1%)
Severe	7 (10.3%)
Kemmochi classification (n, %)	
I	2 (2.9%)
II	22 (32.4%)
III	16 (23.5%)
IV	0 (0)

M, median; 95%CI, 95% confidence interval; n, sample size; %, percentage; y, years; Q1, first quartile; Q3, third quartile.

4. Discussion

This study is the first to use musculoskeletal ultrasound to investigate ankle injury patients with negative X-ray fracture but positive clinical physical signs. The research results showed that ATFL injury is widespread among the recruited study population. ATFL injuries were most common in Kemmochi V type, accounting for 41.7%.

A total of 85 children with ankle injuries caused by low-energy injuries were recruited in this study. All the clinical physical examinations showed lateral ankle swelling and positive varus tests. Among them, 80 children (94.1%) were diagnosed with acute ATFL injuries by musculoskeletal ultrasound, confirming the high efficiency of clinical physical examinations in the screening of ATFL injuries. This is consistent with the research of Fredh et al., whose results indicated that the sensitivity of clinical physical examination in diagnosing ATFL injury could reach 95% to 100%[16]. However, the specificity of clinical physical examination is relatively low, and its diagnostic value for the degree of ATFL injury and fractures is not high [17]. Therefore, for children suspected of ATFL injury, X-ray examination is usually required.This study found that X-ray and musculoskeletal ultrasound had poor consistency in the diagnosis of fractures, with a Kappa value of 0.312, and a high rate of missed diagnosis of fractures. Apart from the fact that X-ray films cannot distinguish the epiphyseal cartilage, the choice of body position may be an important factor. Some studies suggested that the ATFL position can reduce the missed diagnosis rate of distal fibular avulsion fractures [7], but this position aggravates the pain of children, is not easy to operate, and younger children do not cooperate. The anteroposterior and lateral radiographs of the ankle used in our study may also have reduced detection rates.

The diagnosis of ATFL injury with negative X-ray fractures mainly relies on MRI and musculoskeletal ultrasound [10, 18]. Japanese scholar Takakura analyzed the diagnostic efficacy of musculoskeletal ultrasound and a series of X-rays for distal fibular avulsion fractures in children and concluded that the sensitivity of musculoskeletal ultrasound in diagnosing distal fibular avulsion fractures reached 94% compared with X-rays [7]. A latest systematic review, using MRI as a reference to observe the diagnostic accuracy of musculoskeletal ultrasound for acute ankle ligament injury, found that the sensitivity of musculoskeletal ultrasound in diagnosing ATFL injury reached 97%[14]. Kemmochi et al. classified musculoskeletal ultrasound ATFL injury. This study formulated corresponding treatment plans based on the classification and conducted follow-up through musculoskeletal ultrasound. Eventually, the overall excellent and good rate of treatment effect reached 95%[2]. Due to the low acceptance of MRI by family members in clinical practice, and in view of the high sensitivity and good therapeutic effect of musculoskeletal ultrasound in the diagnosis of ATFL injury in the previous literature, musculoskeletal ultrasound was selected and Kemmochi's ultrasound classification was used in this study. Based on this, we further analyzed patients with ATFL injury who had negative X-ray fractures. Among them, there were 40 cases of Kemmochi type I-III, and Kemmochi type V was more common, with 28 cases, accounting for approximately 41.2%. The results of our research results was higher than that of a Kemmochi et al. (type V. 20%)

There is controversy regarding the treatment of children with ATFL injury who have negative X-ray fractures [19]. Noh et al. pointed out that if cartilage fractures can be accurately distinguished, it is suggested that the treatment can be changed from the use of functional treatments such as bandages and braces to the use of plaster fixation [20]. Kemmochi et al. used ultrasound classification to implement individualized treatment strategies for patients. Among them, patients with type I to II were treated with adjustable bandage and foot and ankle brace, while patients with type III to V were treated with foot and ankle brace or plaster fixation[2].Based on the results of this

study, we suggest that Kemmochi Type V injury can be evaluated by musculoskeletal ultrasound in children with negative X-ray fractures with ATFL, and that plaster fixation or brace treatment should be given priority.

This study has some limitations.First of all, although musculoskeletal ultrasound showed high sensitivity in the diagnosis of ATFL injury, MRI was not used as the reference standard in this study, which may lead to some bias in the diagnostic results. Secondly, Maeda et al. pointed out that the diagnostic rate of distal fibular cartilage fracture could be significantly improved in stress musculoskeletal ultrasound examination [21]; however, due to the lack of stress ultrasound examination in this study, there may be a certain risk of missed diagnosis.In addition, the sample size of this study is small, and subjective factors such as pain score, weight-bearing degree and ultrasound examination results have a great influence, which may have a certain bias on the study results.

5. Conclusion

ATFL injury is common in children with ankle sprain with low energy injury (94.1%), and clinical physical examination combined with musculoskeletal ultrasound is very important for its diagnosis. Among ATFL injuries with negative X-ray fractures, Kemmochi type V is the most common type, accounting for approximately 41.2% of ATFL injuries.For this type, plaster or brace fixation is recommended.

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