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ORIGINAL PAPER

OUTCOMES OF CLUBFOOT REHABILITATION IN PEDIATRIC PATIENTS TREATED WITH THE PONSETI METHOD: A PROSPECTIVE STUDY

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Abstract

Introduction. Congenital clubfoot is a common musculoskeletal birth defect involving a complex foot deformity. Without treatment, it can severely affect mobility, development, and quality of life. Early diagnosis and timely intervention are key to successful outcomes.
The objective of the study was to assess the clinical features and rehabilitation outcomes one year after treatment, and the influence of sociodemographic factors on functional recovery in children with congenital clubfoot.
Material and methods. A prospective observational study was conducted on 20 pediatric patients treated with the Ponseti method. Data included demographics, deformity severity, maternal occupation, residence, treatment adherence, and recurrence. Univariate analysis was used to examine associations with rehabilitation outcomes.

Résumé

Résultats de la rééducation du pied bot varus équin chez les patients pédiatriques traités par la méthode Ponseti: une étude prospective

Introduction. Le pied bot varus équin congénital est une malformation congénitale musculo-squelettique fréquente, caractérisée par une déformation complexe du pied. En l'absence de traitement, il peut altérer gravement la mobilité, le développement et la qualité de vie. Un diagnostic précoce et une intervention rapide sont essentiels à une prise en charge efficace.
L'objectif de cette étude était d'évaluer les caractéristiques cliniques et les résultats de la rééducation un an après le traitement, ainsi que l'influence des facteurs sociodémographiques sur la récupération fonctionnelle chez les enfants atteints de pied bot congénital.
Matériel et méthodes. Une étude observationnelle prospective a été menée auprès de 20 patients

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Results. Of the 20 patients (12 boys, 8 girls; mean age at treatment 25.1 days), 65% achieved full recovery, 30% showed improvement, and 5% experienced treatment failure. Poorer outcomes were significantly associated with moderate to severe deformities (RR = 4.0, 95% CI: 1.3–12.1, p = 0.031), rural residence (RR = 7.3, 95% CI: 1.1–50.3, p = 0.017), and having a mother who was a homemaker (RR = 7.3, 95% CI: 1.1–50.3, p = 0.017). The severity of deformity was also linked to recurrence.

Conclusions. The Ponseti method is effective in the functional rehabilitation of congenital clubfoot in pediatric patients, and its outcomes are influenced by socioeconomic and maternal factors. These findings underscore the need for targeted public health initiatives, particularly in rural areas, and highlight the importance of caregiver education and early intervention.

Keywords: congenital clubfoot, Ponseti method, pediatric orthopedics, treatment outcome, maternal factors.

List of abbreviations:
RR – relative risk
CI – confidence interval
SD – standard deviation
KAFO – knee-ankle-foot orthosis

Résultats. Sur les 20 patients (12 garçons, 8 filles; âge moyen au moment du traitement 25,1 jours), 65% ont récupéré complètement, 30% ont présenté une amélioration et 5% ont connu un échec du traitement. Des résultats moins favorables étaient significativement associés à des déformations modérées à sévères (RR = 4,0, IC à 95%: 1,3–12,1, p = 0,031), à la résidence en milieu rural (RR = 7,3, IC à 95%: 1,1–50,3, p = 0,017) et au fait d'avoir une mère au foyer (RR = 7,3, IC à 95%: 1,1–50,3, p = 0,017). La gravité de la déformation était également liée à la récidive.

Conclusions. La méthode Ponseti est efficace pour la rééducation fonctionnelle du pied bot congénital chez l'enfant, et ses résultats sont influencés par des facteurs socio-économiques et maternels. Ces résultats soulignent la nécessité d'initiatives de santé publique ciblées, notamment en milieu rural, et mettent en évidence l'importance de la formation des aidants et d'une intervention précoce.

Mots-clés: pied bot congénital, méthode Ponseti, orthopédie pédiatrique, résultats du traitement, facteurs maternels.

Introduction

Congenital clubfoot is a complex deformity of the foot and ankle characterized by several features: the forefoot is adducted, internally rotated, and pointed downward, the heel is drawn inward, and some muscles and ligaments are shortened and contracted[1,2]. Additionally, many studies have highlighted that oligohydramnios (low amniotic fluid) and the position of the fetus in the uterus can increase the likelihood of clubfoot in newborns[3]. Clubfoot typically presents with distinctive characteristics, such as the top of the foot being turned inward and downward, which increases the arch and causes the heel to turn inward[4,5]. In some cases, the foot may be rotated so severely that it appears to be upside down[5]. Additionally, the affected foot or the big toe may be shorter than the other foot. The calf muscles on the affected side are often smaller than those on a normal foot. Another sign is that the sole of the foot may have deep creases, and the instep is higher than usual[4,6].

Congenital clubfoot is one of the most common birth defects in the musculoskeletal system, with an incidence of approximately 1.18 per 1,000 live births worldwide; this rate varies by region. In Southeast Asia, the incidence is 1.8 per 1,000, while in Africa it is 1.31 per 1,000[7]. This frequency has also been noted in unpublished studies in Vietnam[8].

The exact cause of congenital clubfoot remains unclear. However, numerous studies have indicated that the occurrence of clubfoot in newborns is associated with several factors. First, there is a familial factor: if a child has a parent with clubfoot, the likelihood of the child having the condition is between 3-4%; if both parents are affected, the likelihood increases to 30%[9]. Secondly, studies have shown that the incidence of clubfoot is higher in males than in females. Thirdly, certain maternal factors during pregnancy, such as the use of alcohol, tobacco, obesity, diabetes, and infections, are associated with a higher risk[10,11].

Children with congenital clubfoot require early diagnosis and treatment within 1-2 weeks after birth to achieve the best outcomes[9,12]. The main methods for treating clubfoot include conservative treatment, which involves physical therapy, manual manipulation, and casting, as well as surgical options like percutaneous

tendon release combined with the use of shoes and braces[13]. Among these, the Ponseti method, developed by Ignacio Ponseti in 1940[14], has proven highly effective. Surgical techniques are typically reserved for cases who are diagnosed late or when the deformity is severe. If not identified and treated promptly, clubfoot can lead to various complications[15]. Children may struggle with walking, often using the side of the foot or even the top of the foot, resulting in calluses and increased susceptibility to cuts. Long-term consequences can include ankle joint degeneration, pelvic misalignment, scoliosis, and impact on the development of calf muscles[16]. Additionally, children with clubfoot may face challenges in daily activities, education, and social integration due to feelings of inferiority[17].

Currently, there is no definitive preventive measure for clubfoot, but maintaining a healthy pregnancy, having regular prenatal check-ups, and conducting screening tests can help reduce the risk of this condition[17]. Most importantly, early detection and adherence to treatment are crucial for the successful management of congenital clubfoot[17]. At the Can Tho Orthopedic and Rehabilitation Hospital, located in Can Tho City (10°2′N, 105°47′E), 169 km south of Ho Chi Minh City[18], the facility is a pioneer in treating clubfoot in the Mekong Delta, Vietnam. According to hospital statistics, the prevalence of congenital conditions, including clubfoot, ranged from approximately 6-7% between 2017 and 2019[19]. To enhance effectiveness and minimize invasiveness in treating clubfoot, the hospital prioritizes conservative treatment methods, including the Ponseti casting technique combined with physical therapy, percutaneous tendon release, and the use of braces[9]. We recognize the importance of family involvement in adhering to treatment, particularly during the brace-wearing phase, to reduce the recurrence rate of the condition.

The objective of the study was to evaluate the current prevalence of clubfoot, treatment outcomes, and factors associated with outcomes in children, aiming to improve treatment effectiveness for this deformity.

Materials and methods

Study Design

A prospective observational study was conducted to assess the one-year treatment outcomes of 20 pediatric patients diagnosed with congenital clubfoot—based on medical history, clinical examination, and diagnosis—who were treated using the Ponseti method at Can Tho Orthopedic and Rehabilitation Hospital from February 2022 to October 2023.

Inclusion criteria: children diagnosed with congenital clubfoot based on medical history, physical examination, and clinical diagnosis, who received treatment using the Ponseti method at Can Tho Orthopedic and Rehabilitation Hospital, between February 2022 and October 2023.

Exclusion criteria: patients with syndromic or neurogenic clubfoot, incomplete medical records, or those lost to follow-up during the one-year treatment period.

Study Content

The study consists of three parts:

Part 1: General Information. This includes data on age, sex, severity of the condition, maternal history, and socioeconomic status of the patients.

Part 2: Rehabilitation results. Children who came to the hospital for examination and treatment were admitted, treated, monitored and evaluated for rehabilitation results after 1 year of treatment.

Patient admission: each child underwent a thorough history and clinical examination to confirm the diagnosis of congenital clubfoot. The Pirani classification method[20] was used to assess the severity of clubfoot, categorizing it into three levels: mild, moderate, and severe.

Treatment and monitoring

- Patients were treated with manual manipulation and casting using the Ponseti method, followed by outpatient follow-up as guided by the physician.
- Each week, the child would attend for examination and cast change.
- Depending on the degree of improvement, the doctor would assess and recommend the use of a Ponseti orthotic brace after completing the manipulation phase, usually after about 5-6 casts.
- For those with persistent tightness of the Achilles tendon post-casting, a tendon release procedure would be performed, followed by continued casting for approximately three weeks. Once the tightness decreased, the child would begin wearing the orthotic brace, typically until they reach 36 months of age.

Assessment of foot functional recovery outcomes

- Successful recovery: when the child regains 80–100% of foot function compared to healthy peers of the same age.
- Functional improvement: when the child regains 50–<80% of foot function compared to healthy peers of the same age.
- Treatment failure: when the child regains less than 50% of foot function compared to healthy peers of the same age.

Data collection: clinical outcomes and treatment progress were recorded by the research team through interviews with the mothers and direct assessments by physicians and casting technicians.

Table 1. Characteristics of age, gender, birth weight, and clubfoot diagnosis in patients

Variable (n =20)	*Frequencies*	*Percentage*
Age at the initiation of treatment, day Mean (SD), min, max	25.1 (26.3), 5, 120	
Birth weight (grams): Mean (SD), min, max	2940 (209.4), 2600, 3300	
Sex		
Boys	12	60.0
Girls	8	40.0
Imaging diagnosis during pregnancy		
Ultrasound	20	100
Double Test	13	65.0
Triple Test	4	20.0
Detection of clubfoot during pregnancy		
Yes	10	50.0
No	10	50.0

We illustrate the treatment process for three typical clinical cases (Appendix 1):

- Clinical case 1: severe congenital clubfoot on the left side (Images 1a, 1b, 1c, 1d, 1e).
- Clinical case 2: severe congenital clubfoot on both sides (Images 2a, 2b, 2c, 2d, 2e, 2f, 2g, 2h, 2i).
- Clinical case 3: severe congenital clubfoot on both sides, accompanied by bilateral congenital hip dislocation and hypoplasia of the patella (Images 3a, 3b, 3c, 3d, 3e, 3f, 3g).

Part 3: Factors influencing treatment outcomes**.** This part identifies factors affecting treatment outcomes, including sex, severity of the condition, maternal history, socioeconomic status, and treatment adherence (defined as attending follow-up appointments and following home treatment instructions as prescribed by the physician).

Statistical analysis

Data were entered using Excel and analyzed with SPSS version 20.0. Descriptive information is presented as frequencies (n) and percentages (%). To assess factors associated with treatment success rates, the Chi-square test (χ^2) was used to examine relationships between categorical variables. When more than 20% of the expected cell counts were less than 5, or any individual cell had an expected value less than 1, the Fisher's Exact test was applied as an alternative. Risk ratios (RR) with 95% confidence intervals were calculated, and statistical significance was defined as a p-value < 0.05.

Results

This study describes the treatment status of 20 cases of congenital clubfoot recorded at the treatment facility during the research period. The mean age of the patients was 25.1 days (SD = 26.3), ranging from 5 to 120 days. In terms of gender distribution, there were 12 boys (60.0%) and 8 girls (40.0%), indicating a slightly higher prevalence among males. The basic characteristics of the patients are presented in Table 1.

The mean age at the initiation of treatment was 25.1 days (SD = 26.3), ranging from 5 to 120 days. The mean birth weight was 2940 grams (SD = 209.4), with a minimum of 2600 grams and a maximum of 3300 grams. In terms of sex distribution, there were 12 boys (60.0%) and 8 girls (40.0%), indicating a slightly higher prevalence in males. Regarding imaging diagnosis during pregnancy, all participants underwent ultrasound (100%), while 65.0% had a Double Test, and 20.0% underwent a Triple Test.

Notably, clubfoot was detected prenatally in 50.0% of the cases, suggesting that half of the cases were identified during pregnancy, while the remaining half were detected postnatally.

The most common morphology was mild clubfoot on the right side (mild – right), accounting for 35% of the total cases. This was followed by mild bilateral clubfoot (mild – bilateral) with a rate of 25%. Moderate bilateral cases constituted 10%, while mild clubfoot on the left side (mild – left) represented 15%. Notably, there were two cases (10%) of severe clubfoot associated with hip dislocation and bilateral patellar hypoplasia—a complex and rare clinical form. Only one case (5%) was classified as severe bilateral clubfoot without accompanying abnormalities (Figure 1).

Mild severity clubfoot accounted for the highest proportion in both genders, particularly on the right side, with 3 girls and 5 boys affected. Mild cases on the left side were noted in two girls and one boy, while mild bilateral cases were found in one girl and two boys. Moderate severity affecting both sides

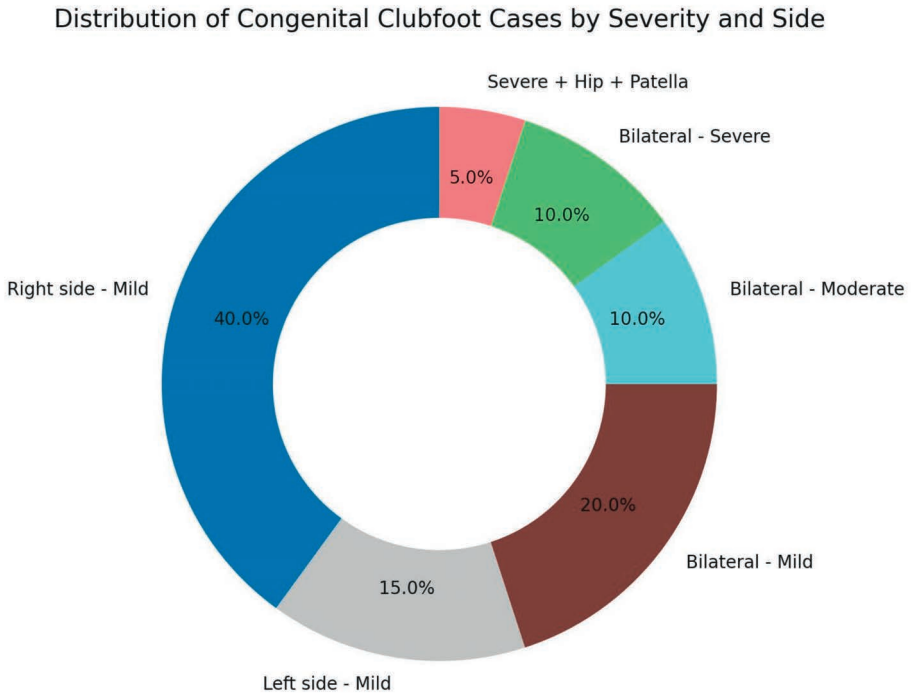


Figure 1. Distribution of congenital clubfoot cases by severity and side.

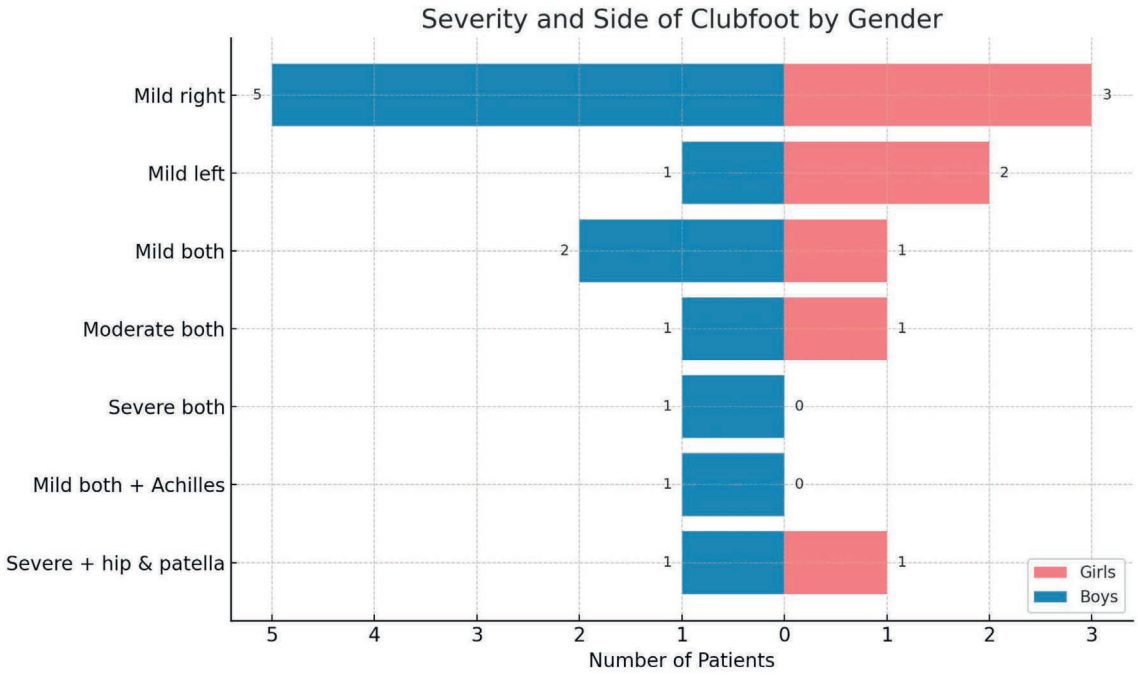


Figure 2. Severity and side of clubfoot by sex

was observed in one girl and one boy. In terms of severe cases, only one boy was affected bilaterally. Additionally, one boy had mild bilateral clubfoot accompanied by bilateral Achilles tendon contracture. Notably, one girl and one boy were diagnosed with severe bilateral clubfoot associated with bilateral hip dislocation and congenital patellar hypoplasia. Overall, the incidence was higher in boys than in girls, with most cases being mild, most commonly affecting the right foot. Although rare, complex associated abnormalities were present in both genders (Figure 2).

After one year of treatment, 13 children (65%) achieved successful recovery, defined as 80–100% restoration of foot function comparable to that of

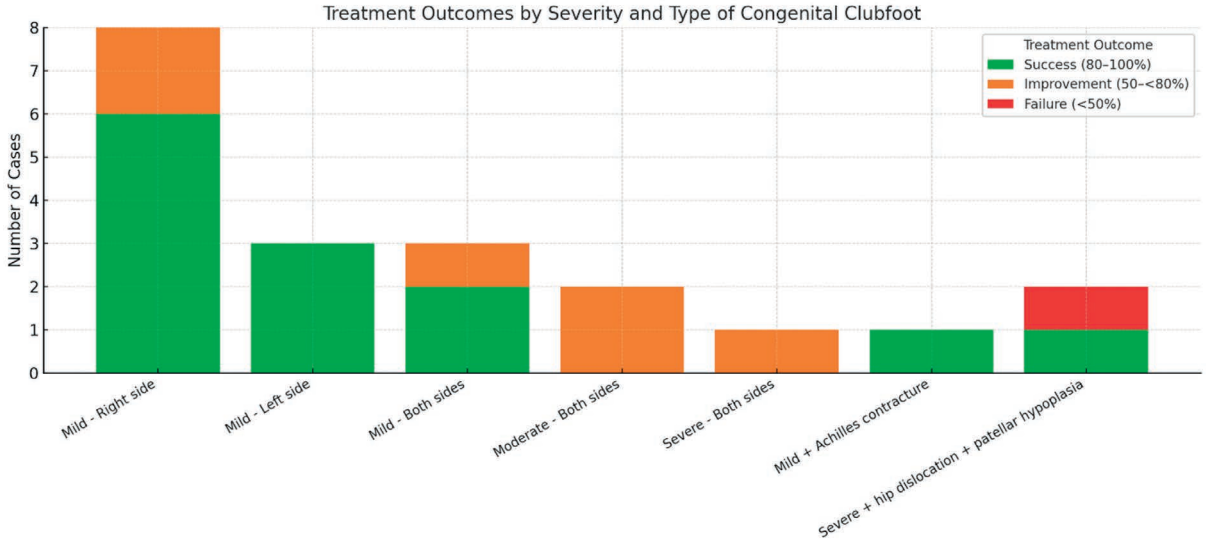


Figure 3. Treatment outcomes by severity and type of congenital clubfoot

a healthy child. Six cases (30%) showed improvement, with 50–80% functional recovery, while only one case (5%) was classified as a treatment failure, with less than 50% functional recovery. Most successful outcomes were observed in mild cases, particularly on the right side. Severe and complex cases, including those with hip dislocation and patellar hypoplasia, were less responsive to treatment, with one case resulting in failure. These findings highlight that early and mild cases tend to respond best to treatment, while more complex conditions may require advanced or prolonged interventions (Figure 3).

Among the unsuccessful treatment cases, there was one severe case involving a girl with severe clubfoot associated with hip dislocation and bilateral patellar hypoplasia—a complex and rare clinical form. This case underwent a total of 12 casting sessions, with multiple failures due to incomplete pelvic structure. The prolonged use of a brace caused the child discomfort and distress, leading to extended treatment duration. Currently, the child's condition has improved to less than 10% compared to a normal child. The remaining unsuccessful cases were attributed to the severity of clubfoot and the parents' lack of treatment adherence, including missed follow-up appointments and improper at-home care, such as not following the Ponseti method for casting, brace use, and physical therapy (Figure 3).

Among the 20 cases, the severity levels of the patients were as follows: 15 patients (75.0%) had mild severity, 3 patients (15.0%) had moderate severity, and 2 patients (10.0%) had severe severity. Most patients (90.0%) were accompanied by other associated deformities, while 10% had isolated clubfoot. The mean number of casts applied per patient was 3.9 (SD = 2.3), ranging from 1 to 8. Casting-related complications were relatively uncommon, with pressure ulcers in 1 case (5.0%) and cast slippage in 2 cases (10.0%), while 85.0% experienced no complications. Treatment methods included Achilles tendon release in 12 patients (60.0%), brace shoes for 17 patients (85.0%), and physical therapy for 20 patients (100%). Thirteen cases (65.0%) showed no recurrence, while five cases (25.0%) experienced recurrence requiring re-casting, and two cases (10.0%) had recurrence necessitating surgical intervention (Table 2).

The factors associated with foot rehabilitation in pediatric patients with clubfoot are summarized in Table 3. Three key factors were found to significantly influence rehabilitation outcomes: place of residence, severity of the deformity, and the mother's occupation. The elements are presented specifically as follows:

- Sex: no significant difference was observed between boys and girls in terms of successful recovery after treatment, with RR of 0.5 (95% CI: 0.2–1.7) and a p-value of 0.251.
- Severity level: Severe or moderate clubfoot cases had a lower rate of successful recovery (20.0%) compared to mild cases (80.0%). The RR of 4 (95% CI: 1.3–12.1) and p-value of 0.031 suggest that more severe cases are less likely to have a successful outcome.
- Treatment adherence: cases of children who did not adhere to treatment (including home treatment methods and/or timely follow-up appointments) had a lower success rate (40.0%) compared to those who adhered to treatment (73.3%). This indicates that non-adherent cases are less likely to achieve successful outcomes. However, this difference did not reach statistical significance, with RR of 2.3 (95% CI: 0.7-6.8) and a p-value of 0.176.
- Residence: children living in rural areas had significantly lower rate of successful foot rehabilitation (33.3% success rate) compared to those from urban

Table 2. Treatment characteristics of 20 children with clubfoot

Varible	*Frequency*	*Percentage*
Severity level		
Mild	15	75.0
Moderate	3	15.0
Severe	2	10.0
Accompanied by other associated deformities		
Yes	18	90.0
No	2	10.0
The average number of casts applied Mean (SD), min, max	3.9 (2.3), 1, 8	
Complications from casting		
Pressure ulcers	1	5.0
Cast slippage	2	10.0
No complications	17	85.0
Treatment options		
Achilles tendon release (n =20)	12	60.0
Use of brace shoes (n =20)	17	85.0
Physical therapy (n =20)	20	100.0
Recurrence		
No recurrence	13	65.0
Recurrence requiring re-casting	5	25.0
Recurrence requiring surgery	2	10.0

Table 3. Factors associated with functional recovery outcomes of the foot following treatment of clubfoot in pediatric patients

Values	*Total*	*Improvement, Failure (n = 7)*	*Success (n = 13)*	*RR (95% CI)*	*p-value*
Sex, n (row %)					
Boys	12	3 (25.0)	9 (75.0)	0.5 (0.2-1.7)	0.251
Girls	8	4 (50.0)	4 (50.0)		
Severity level, n (row %)					
Severe/Moderate	5	4 (80.0)	1 (20.0)	4 (1.3-12.1)	**0.031***
Mild	15	3 (20.0)	12 (80.0)		
Treatment adherence, n (row %)					
No	5	3 (60.0)	2 (40.0)	2.3 (0.7-6.8)	0.176
Yes	15	4 (26.7)	11 (73.3)		
Residence, n (row %)					
Rural	9	6 (66.7)	3 (33.3)	7.3 (1.1-50.3)	**0.017***
Urban	11	1 (9.1)	10 (90.9)		
Maternal education, n (row %)					
≤ 9 years	7	4 (57.1)	3 (42.9)	2.5 (0.8-8.1)	0.128
> 9 years	13	3 (23.1)	10 (76.9)		
Maternal occupation, n (row %)					
Housewife	9	6 (66.7)	3 (33.3)	7.3 (1.1-50.3)	**0.017***
Other occupations	11	1 (9.1)	10 (90.9)		
Poverty status, n (row %)					
Yes	2	1 (50.0)	1 (50.0)	1.5 (0.3- 6.9)	> 0.999
No	18	6 (33.3)	12 (66.7)		

*RR: risk ratio, CI: confidence interval, * Statistically significant difference*

areas (90.9% success rate). The RR of 7.3 (95% CI: 1.1-50.3) and a p-value of 0.017 indicate that living in a rural area is strongly associated with treatment failure.

– Maternal education: no significant association was found between maternal education level and success rate, with an RR of 2.5 (95% CI: 0.8–8.1) and a p-value of 0.128.

– Maternal occupation: children whose mothers were housewives had a significantly lower recovery rate (33.3%) than those whose mothers were employed in other occupations (90.9%). The RR was 7.3 (95% CI: 1.1–50.3) and the p-value was 0.017, indicating that maternal occupation was associated with the rehabilitation outcome of children with clubfoot.
– Poverty status: no significant difference in rehabilitation rates was found between children from families with or without poverty status. The RR was 1.5 (95% CI: 0.3–6.9) and p-value > 0.999.

Discussion

In our study of 29 cases of congenital clubfoot, we found that the incidence of clubfoot was higher in boys (60%) compared to girls (40%). This finding aligns with previously published epidemiological data[21,22]. The average age of children in this study at treatment initiation was 25.1 days, with the earliest case at 5 days and the latest at 120 days. According to a study by Yu-Bin Liu[23] monitoring treatment outcomes over five years, starting treatment between 28 days and 3 months of age was associated with a need for fewer casts, a lower recurrence rate, and early treatment before 28 days yielded the opposite results ($p < 0.05$). Other studies have indicated that the timing of treatment is not significantly related to treatment outcomes in clubfoot; rather, the severity of the deformity is the primary influencing factor[24,25,26].

One important point to note is that these deformities can be detected during pregnancy through ultrasound imaging or blood tests that identify chromosomal abnormalities. Although screening for fetal deformities seems straightforward, it faces significant challenges in the socioeconomic context of Vietnam[27], where the average income is low[22], particularly in impoverished rural areas. In our study, 10 out of 20 children (50%) were not diagnosed with deformities during pregnancy, which is a substantial figure. Early detection allows parents to prepare better for the treatment and care of their child in the future.

In addition, the number of children with congenital clubfoot affecting both feet is nearly equivalent to those with clubfoot in one foot. Most children presenting for treatment for congenital clubfoot had mild deformities (assessed using the Pirani scoring system), with 19 out of 29 cases (65.5%) classified as mild and 6 out of 29 (20.7%) as moderate (Figure 1). However, there were two children with bilateral clubfoot, both of whom had severe deformities. All the children underwent initial treatment using the Ponseti method, which is not only highly effective but also easy to implement, accessible, and affordable for most families[28]. Indeed, after several applications of the Ponseti casting method, the clubfoot deformities in the treated children showed significant improvement. Results indicated that 17 out of 29 cases (58.6%) achieved complete correction, while 10 out of 29 cases (34.5%) reached an acceptable level of correction.

However, two severely deformed clubfeet in one patient failed to respond to correction, indicating a positive correlation between the initial severity of the deformity and treatment outcome (clinical case 3, Appendix 1). This child presented with extremely severe deformities accompanied by associated anomalies, including bilateral congenital hip dislocation and patellar hypoplasia. These conditions posed significant challenges during the manipulation and casting process, resulting in frequent cast slippage after each session. Due to the unsuccessful outcome of casting, the patient was referred to the Children's Hospital in Can Tho for further management of the hip dislocation. Subsequently, the child returned to our hospital and continued treatment using bilateral KAFO (Knee-Ankle-Foot Orthosis) braces[29].

During treatment, complications arising from casting techniques are not only seen in the Ponseti method but also in other forms of casting for various conditions. According to the study by Võ Quang Đình Nam[30], the rate of cast slippage was 19 out of 112 clubfeet (16.9%), other complications included dermatitis (3 cases), skin ulceration (1 case), and rocker-bottom foot (1 case). In our study, the rate of cast slippage was slightly lower, occurring in 3 children with 6 out of 29 clubfeet (15%). Among these cases, two children had associated deformities including hip dislocation and patellar hypoplasia, which made it particularly difficult to maintain proper cast positioning. Additionally, 7 children (35% of cases) experienced recurrence of clubfoot. Of these, 5 required repeated casting, meaning they underwent more than five casting sessions, and 2 required a second Achilles tenotomy. These recurrences were due to a variety of factors. In addition to objective causes such as severe deformities and associated congenital abnormalities, several subjective factors were identified, including the quality of manipulation by technicians, the casting material used, physicians' ability to assess the condition and treatment progress, follow-up duration, and treatment adherence by the child's caregivers. Since clubfoot deformity directly affects both the physical and mental health as well as the overall quality of life of children—both now and in the future—successful treatment of this condition has a profound impact on affected patients. Identifying the factors that influence treatment outcomes plays a crucial role, as it enables the development of individualized treatment plans tailored to each patient's unique characteristics and needs, thereby enhancing therapeutic effectiveness. Our study

highlights three key factors that significantly impact treatment outcomes in children with clubfoot: place of residence, maternal occupation, and the severity of the deformity.

One of the most significant predictors of foot rehabilitation after one year of treatment is the severity of the initial deformity. Cases classified as severe or moderate had a significantly lower success rate of 20.0%, compared to 80.0% in mild cases. This finding aligns with existing literature, which suggests that more complex cases often require more intensive interventions and carry a higher risk of complications. The high-risk ratio of 4 highlights the importance of early diagnosis and implementing treatment strategies that correspond with the severity of the condition. In severe and complex cases, a multidisciplinary approach involving careful evaluation by specialists is essential to determine the optimal treatment plan. In particular, the Ponseti method must be applied with strict adherence to all aspects of its protocol—including manipulation, casting, percutaneous Achilles tenotomy, use of foot abduction braces, and monitoring for recurrence—to achieve the best possible outcomes. This conclusion has also been supported by previous studies, such as those conducted by Zhao[31], Hosseinzadeh[32] and Miller[33].

Secondly, residence emerged as a particularly important variable, with pediatric patients living in rural areas having a significantly lower rate of successful rehabilitation of 33.3%, compared to 90.9% for those in urban settings. This disparity may be attributed to several factors, including limited geographic access to treatment facilities and potential socioeconomic barriers faced by rural families[34]. The high-risk ratio (RR = 7.3) underscores that living in a rural area is a significant risk factor for treatment failure.

Finally, maternal occupation also plays an important role in determining treatment success. Children whose mothers were housewives reported a success rate of only 33.3%, compared to 90.9% for those whose mothers had other occupations. Housewives may face multiple challenges in daily life, including limited health awareness, household responsibilities, time constraints, transportation difficulties, and lack of financial independence[35,36]. These factors can negatively affect treatment adherence, ultimately reducing the effectiveness of care.

Addressing these disparities requires targeted healthcare support programs, such as transportation subsidies, living expense assistance, and full coverage of direct treatment costs—particularly since the number of children affected by this condition is relatively small. Additionally, raising awareness about clubfoot in rural communities is essential to encourage earlier and more active parental involvement in seeking treatment, as well as fostering greater community support, all of which may contribute to increased rates of foot rehabilitation for children with clubfoot.

Conclusions

The results of rehabilitation after one year of treatment for 20 children with congenital clubfoot using the Ponseti method were highly effective. This study once again reaffirms the superiority and efficacy of the Ponseti method compared to other treatment approaches, owing to its low cost and minimally invasive nature.

We recommend that hospitals collaborate with humanitarian programs to improve access and provide support for families in remote and underserved areas. Such efforts can offer children the opportunity to receive timely treatment, help eliminate stigma, promote social integration, and reduce the burden on both families and society.

These findings underscore the importance of considering social determinants in the treatment of pediatric clubfoot deformity and highlight the need for inclusive, equitable healthcare strategies to optimize outcomes for all children, regardless of their background.

Authors Contributions:

All authors made equally significant contributions to this research study. K.H.D. and L.V.N. designed the study details; V.P.T. and X.T.N. investigated the data and ensured accurate exclusions according to the study criteria. K.H.D., T.T.H.H., and N.N.Y.N. analyzed and interpreted the data and wrote the paper. T.T.H.N. contributed to the critical evaluation, reviewed the English, and revised the manuscript. L.V.N. shaped the final version. All authors approved the final version of the article.

Compliance with Ethics Requirements:

"The authors declare no conflict of interest regarding this article"

"The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law. Informed consent was obtained from all the patients included in the study"

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Appendix 1. Description of three typical cases of congenital clubfoot treated with the Ponseti method at Can Tho Orthopedic and Rehabilitation Hospital.

Clinical Case 1: A 4-month-old girl, with a birth weight of 2800g, was born full term and diagnosed with severe congenital clubfoot on the left side.



Image 1a. Left clubfoot before treatment



Image 1b. First cast application



Image 1c. Third cast application



Image 1d. After the fourth cast application



Image 1e. Completion of casting and wearing the brace

Clinical Case 2: A 5-day-old girl, with a birth weight of 3300g, was born full term and diagnosed with severe congenital clubfoot on both sides



Image 2a. Bilateral clubfoot before treatment



Image 2b. First cast application



Image 2c. Second cast application



Image 2d: After the second cast application



Image 2e: Third cast application



Image 2f: Fourth cast application



Image 2g. After the fourth cast application



Image 2h. Completion of casting and wearing the brace



Image 2i. Follow-up after 10 months of treatment

Clinical Case 3: A 2-month-old girl, weighing 3000g at birth, was diagnosed with severe bilateral congenital clubfoot, bilateral hip dislocation, hypoplasia of both patellae, and club hand on the right side



Image 3a. Bilateral clubfoot before treatment



Image 3b. First cast application treatment





Image 3c & 3d. Due to severe damage to the baby's leg structure, the cast slipped off multiple times, and the baby was prescribed an Achilles tendonectomy



Image 3e. Three weeks after bilateral Achilles tendon lengthening, the child continued with casting and underwent multiple sessions of manipulation to correct the foot position





Image 3f. Treatment with casting was unsuccessful, and the child was transferred to Children's Hospital in Can Tho for hip dislocation treatment.

Image 3g. She returned to the hospital and continued treatment using bilateral KAFO (Knee-Ankle-Foot Orthosis) braces.

Appendix 2. Ponseti Treatment Protocol at Can Tho Orthopedic and Rehabilitation Hospital

The Can Tho Orthopedic and Rehabilitation Hospital treats congenital clubfoot in children using the Ponseti method, a process approved by Decision No. 08/QĐ-CHPHCN dated December 25, 2014.

1. Ponseti Casting Technique

Ponseti casting should begin as early as possible after birth. The procedure should be performed in a way that ensures comfort for both the infant and their family. The baby should be allowed to breastfeed during the manipulation and casting process. Casting is carried out by either a physician or a trained casting technician. Treatment can be done on both deformed feet simultaneously or one foot at a time.

- **Correction of the medial longitudinal arch**: The first step is aligning the forefoot with the hindfoot. In newborns, the medial arch is soft and flexible, and simply supinating the forefoot is usually sufficient to create a normal longitudinal arch—not too high and not too flat. Proper alignment of the forefoot with the hindfoot is essential to achieve an effective abduction of the foot and to correct forefoot adduction and inward rotation.
- **Manipulation**: This involves abducting the foot beneath the stabilized head of the talus. To achieve simultaneous correction of all components of the clubfoot deformity, it's crucial to establish a pivot point for manipulation—the talar head.
- **Identifying the talus head**: Palpate both malleoli using the thumb and index finger of one hand, while the other hand holds the toes and metatarsals. Next, slide the thumb and index finger forward to locate the talar head, which lies just anterior to the lateral malleolus. The lateral aspect of the talar head can be felt protruding under the skin.
- **Stabilizing the talus**: Place the thumb over the talar head to stabilize it and create a pivot point for foot abduction. The index finger of the same hand should be placed behind the lateral malleolus. (This technique helps stabilize the ankle joint and prevents posterior displacement of the fibula by the calcaneofibular ligament during correction.)
- **Foot manipulation**: While keeping the foot in a supinated position, abduct it as much as possible without causing discomfort. Hold the position for about 60 seconds with gentle pressure, then release. The navicular and anterior part of the calcaneus will gradually shift outward as the clubfoot deformity is corrected. The foot must never be pronated during this process.

Throughout the casting phase, usually from the first to the fourth or fifth cast, the forefoot adduction and heel varus deformities should be fully corrected. Palpation between the medial malleolus and the navicular tuberosity helps assess the degree of navicular correction. When clubfoot is properly corrected, the distance between the medial malleolus and navicular is about 1.5 to 2 cm, and the navicular covers the anterior aspect of the talar head.

Full correction of the arch, adduction, and varus deformities should be achieved by the fourth or fifth cast. In very stiff feet, more casts may be necessary. Equinus (heel elevation) deformity can often be corrected with additional casting if the foot is flexible. However, if adequate correction of equinus is not achieved by the fourth cast, a percutaneous Achilles tenotomy is required.

2. Casting, molding, and removal procedures for each treatment session

Success with the Ponseti technique requires meticulous casting skills. We use plaster of Paris for casting as it is more cost-effective and allows for more accurate molding than fiberglass.

Steps in casting and molding:

- Perform initial manipulation.
- Apply padding and wrap the cast.
- Continuously mold the cast as it hardens.
- Extend the cast above the knee.
- Trim the cast.

Cast Removal:

The cast should be removed in the clinic just before applying a new one. Avoid removing the cast at home before the clinic visit, as the correction achieved may regress significantly while waiting for the next cast. Remove the upper portion (above the knee) first, followed by the lower leg section.

3. Achilles tendon tenotomy procedure

Before performing a percutaneous Achilles tenotomy, it is essential to determine whether sufficient correction of clubfoot deformity has been achieved through casting. This procedure is done to gain the necessary dorsiflexion to complete the treatment. It is considered when the heel can be abducted beneath the talus, allowing for safe upward foot bending (dorsiflexion) without compressing the talus between the calcaneus and tibia.

Adequate abduction before tenotomy is confirmed when:

- The anterior process of the calcaneus can be palpated beneath and lateral to the talus.
- Foot abduction reaches approximately 60° relative to the tibial axis.
- The calcaneus is in a neutral or mildly valgus position.

Percutaneous Achilles tenotomy procedure:

- Provide counseling and obtain informed consent from the family; prepare necessary instruments.
- Administer local anesthesia, then perform a small incision (~1 cm above the calcaneus) to cut the Achilles tendon.
- Apply a post-tenotomy cast.
- Remove the cast after 3 weeks.

4. Bracing protocol following final cast

After the final cast is removed, the foot is maintained in maximum abduction (~75°). If a tenotomy was performed, the cast is retained for an additional 3 weeks. Bracing is then initiated to maintain correction. The brace consists of open-toe shoes attached to a metal bar. This setup maintains foot abduction and prevents recurrence by holding the heel and forefoot in the corrected position.

Without the brace, the foot tends to rotate inward again. The medial soft tissues will only stay stretched if the brace is used immediately after cast removal. The child's knees remain free while braced, allowing them to kick and stretch their calf muscles. Abduction and slight dorsiflexion of the feet help sustain calf and Achilles tendon elongation.

Brace application details:

- Begin bracing immediately after the last cast is removed.
- The brace includes open-toe shoes mounted on an adjustable metal bar.
- In unilateral cases:
  - Clubfoot side: 75° external rotation.
  - Normal side: 45° external rotation.
- In bilateral cases: Both feet: 70° external rotation.
- The bar should be wide enough so the heels align with shoulder width.
- Bend the bar 5–10° outward to encourage foot dorsiflexion.

Brace wear schedule:

- 24 hours/day for the first 3 months.
- Then 14–16 hours/day: 12 hours at night + 2–4 hours during the day.

In general:

- Severe cases may require bracing up to age 4.
- Milder cases may use braces until age 2.
- Most children should wear the brace until age 3–4, as long as it does not affect sleep or cause discomfort at night.

Note:

The Ponseti method, when combined with percutaneous Achilles tenotomy, typically yields excellent outcomes. However, recurrence occurs in up to 80% of cases when post-treatment bracing is not followed. Conversely, the recurrence rate drops to just 6% among families that adhere to the bracing protocol. Thus, the Ponseti treatment program can be considered in two phases:

- Phase 1 (casting): performed by physicians or trained technicians.
- Phase 2 (bracing): maintained by the child's parents or caregivers.