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ORIGINAL ARTICLE

Early Outcomes of Ponseti Treatment for Idiopathic and Non-Idiopathic Clubfoot at a Philippine Tertiary Government Hospital

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ABSTRACT

Background. The Ponseti method achieves less predictable outcomes and higher workloads in rigid non-idiopathic clubfoot compared to idiopathic cohorts. Structural and socioeconomic barriers further complicate management in low- and middle-income countries.

Objective. The purpose of the study was to evaluate the early outcomes of Ponseti treatment for both idiopathic and non-idiopathic clubfoot in a Philippine tertiary government hospital setting.

Methodology. This retrospective chart review (August 2019 to December 2023) evaluated early Ponseti outcomes at BGHMC. Through total enumeration, 42 eligible patients aged ≤2 years (36 idiopathic, 6 non-idiopathic) were analyzed. Initial clinical success was defined as achieving an initial plantigrade foot (Pirani score ≤0.5), allowing transition into a minimum of six months of maintenance bracing.

Results. Baseline severity was high across both cohorts (median Pirani 5.5 idiopathic vs. 6.0 non-idiopathic). The early clinical success rate was 100%, enabling all feet to complete initial casting and transition into bracing with 100% full short-term brace compliance documented at six months. Univariate linear regression demonstrated that a non-idiopathic etiology was a strong predictor of an increased casting workload (B = 2.085, 95% CI [0.56, 3.61], p = 0.008), requiring approximately two additional casts. Etiology did not significantly predict baseline severity, pre-tenotomy casting duration, or percutaneous Achilles tenotomy rates, which were uncommonly low (~36% for both groups). Early deformity recurrence within the limited follow-up period (maximum 13 months) occurred exclusively in idiopathic feet (12.07%).

Conclusion. The Ponseti method achieves favorable initial clinical correction and short-term brace compliance during early maintenance across both cohorts. However, conclusions are strictly limited by a small non-idiopathic sample size and a short follow-up duration. Given an uncommonly low institutional tenotomy rate (~36%) that deviates from global benchmarks, this cohort faces a high risk for late, weight-bearing relapses and requires strict longitudinal surveillance up to at least age 5 years.

Keywords. congenital talipes equinovarus, Ponseti method, Pirani score, idiopathic clubfoot, non-idiopathic clubfoot

INTRODUCTION

Congenital talipes equinovarus, or clubfoot, affects approximately 1 in 1,000 live births globally, with nearly 80% of the 200,000 annual cases occurring in low- and middle-income countries (LMICs).[1] Clinically, true clubfoot is a stiff deformity that does not correct with gentle manipulation. In contrast, positional clubfoot can be corrected gently. True clubfoot is defined by the CAVE acronym: Cavus (high midfoot arch), Adductus (forefoot turned in), Varus (heel turned in), and Equinus (hindfoot pointed down). Clubfoot has two main types: idiopathic, which is most common and presents with normal physical findings elsewhere,[2] and non-

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idiopathic (syndromic), which is associated with conditions such as arthrogryposis or cerebral palsy.[3] In 1950, Dr. Ignacio Ponseti developed the Ponseti method, which involves serial manipulation, casting, and a minimally invasive Achilles tendon tenotomy (ATT). This is followed by long-term bracing. This conservative technique became the gold standard for idiopathic clubfoot in the early 2000s due to its excellent outcomes.[4] The minimally invasive Ponseti method is the global gold standard for clubfoot care, successfully replacing extensive soft tissue surgeries that historically caused long-term joint stiffness.[5,6]

Treatment outcomes diverge sharply by etiology. Idiopathic clubfoot yields predictable, near-normal functional results,[6] while non-idiopathic clubfoot represents a far more challenging clinical subgroup.[7] Due to inherent tissue rigidity, non-idiopathic cases routinely require more serial casts, are less predictable, and relapse more often.[5,7] Recent literature shows that the Ponseti method can also be effective in non-idiopathic cases by reducing deformity severity and the need for major surgery.[8] A local study by Eusebio et al. at the Philippine General Hospital also reported good clinical outcomes for both types.[9] Regardless of type, if clubfoot is left untreated, it progresses into a painful, lifelong physical disability that causes severe mobility limitations and social exclusion.[10]

Implementing this treatment protocol in LMICs presents distinct structural and clinical challenges. In the Philippines, managing clubfoot remains a critical public health challenge, as geographic isolation, fragmented healthcare infrastructure, and economic constraints frequently delay intervention. Although percutaneous Achilles tenotomy is required in up to 90% of cases to correct residual equinus,[6] technique variability persists; some regional providers favor general over local anesthesia due to a lack of clinical confidence, which escalates procedural costs and risks.[11] Furthermore, overall compliance in resource-limited environments is threatened by socioeconomic barriers, including severe transportation hurdles, financial constraints, lack of basic supplies, and a scarcity of standardized materials for tenotomy and orthotic maintenance.[10,11] Evaluating structured clinical frameworks helps to optimize regional care pathways.

The partnership between Baguio General Hospital and Medical Center (BGHMC) and MiracleFeet provides a coordinated, template-driven model to standardize clubfoot care in an under-resourced region.

OBJECTIVES

The purpose of the study was to evaluate the early outcomes of Ponseti treatment for both idiopathic and non-idiopathic clubfoot in a Philippine tertiary government hospital setting. The study further aimed to describe the population's demographic profile, including age, sex, and laterality. Crucially, this investigation focused on the deformity correction (using the Pirani scoring system) following serial casting with or without Achilles tendon tenotomy.

METHODOLOGY

A retrospective chart review was done of early Ponseti treatment outcomes among eligible clubfoot patients treated at BGHMC from August 2019 to December 2023. All patients were managed by orthopedic residents and MiracleFeet staff under the direct supervision of the institution's pediatric orthopedic surgeon. To address potential inter-rater variability in the original charts, all clinical entries and progress notes were cross-referenced by a single researcher against standardized clinical photographs and physical exam descriptions. Representative clinical photographs demonstrating baseline deformity and post-correction outcomes (Figures 1 and 2) were obtained with appropriate parent/guardian waiver/consent , with all identifying features redacted to protect patient privacy. The six components of the Pirani scoring system were assessed.[12] These were recorded at the initial meeting and at every encounter thereafter, before and after tenotomy, and before and after bracing. The investigators also recorded the number of casts required, the rates of tenotomy, and recurrence of the deformity if present.

Inclusion criteria

1. Patients diagnosed with idiopathic or non-idiopathic clubfoot who presented for consultation and management at the BGHMC Orthopedics Outpatient Department (OPD).
2. Patients aged two years or younger at the time of treatment initiation.
3. Patients who underwent the Ponseti method of treatment at this institution and completed at least six months of the post-correction maintenance (bracing) phase.

Exclusion criteria

1. Foot deformities not attributed to congenital talipes equinovarus (e.g., positional clubfoot, metatarsus adductus).
2. History of prior surgical or non-surgical clubfoot interventions performed at an outside facility before presenting to BGHMC.
3. Clubfoot managed initially by techniques other than the standard Ponseti protocol.
4. Patients with incomplete medical records, including those who defaulted, were lost to follow-up, or discontinued the protocol before reaching the six-month maintenance milestone.

A formal sample size calculation was performed using OpenEpi version 3.01 for independent cohort studies comparing two proportions. Assuming a two-sided significance level of 5% ($\alpha = 0.05$), a statistical power of 80% ($1 - \beta = 0.80$), and an allocation ratio of 5:1 based on clinical distribution, the minimum required sample size to detect a significant difference in early outcomes was determined to be 18 patients (15 idiopathic and 3 non-idiopathic).

However, to maximize statistical power and minimize selection bias, total enumeration (census sampling) was employed.

To eliminate variability in follow-up duration across the retrospective cohort, the timing of clinical outcome assessment was standardized. All primary and secondary clinical outcomes were cross-sectionally audited and assessed uniformly at six months after the start of the maintenance (bracing) phase, regardless of any extended charting available up to the maximum 13-month tracking window. The primary outcome of initial clinical success was operationally defined as achieving a fully corrected, plantigrade foot, indicated by a Pirani score of ≤0.5 through serial casting and/or percutaneous Achilles tenotomy, thereby allowing the patient to successfully transition into and sustain the bracing protocol for the first six months. Conversely, treatment failure was defined as the inability to achieve deformity correction into a plantigrade foot during the initial casting phase, necessitating premature discontinuation of the Ponseti protocol and an early escalation to extensive soft tissue release or major surgical intervention. Finally, secondary outcomes tracked within this standardized timeframe included the total number of serial casts required to achieve initial correction, the utilization rate of percutaneous Achilles tenotomy, early recurrence rates (within the first six months of bracing), complications, and any documented clinical or socioeconomic compliance barriers.

To ensure clinical consistency across the retrospective cohort, the institutional decision to perform or skip a percutaneous Achilles tenotomy was governed by a strict, two-stage objective protocol. First, full correction of the midfoot deformity was verified, operationally defined as a completely straightened lateral column (Pirani lateral column curvature score = 0) and a neutral or abducted forefoot relative to the hindfoot. Second, the hindfoot was evaluated for residual equinus contracture. A percutaneous Achilles tenotomy was indicated and executed only if objective clinical parameters (Pirani hindfoot sub-score >0, i.e., a persistent posterior heel crease, an empty heel pad, and a rigid inability to bring the ankle above the neutral horizontal axis) remained uncorrected. Conversely, if the ankle demonstrated a clear, flexible passive correction above the neutral position with a completely corrected midfoot, the tenotomy was skipped, and the patient transitioned directly into maintenance bracing.

Brace compliance during the initial six-month maintenance phase was categorized dichotomously based on documented clinic charts and caregiver interviews at follow-up: "Compliant" was defined as the documented adherence to the standard protocol of wearing the foot abduction brace for 23 hours a day for the first three months, followed by 12–14 hours a day (during naps and nighttime) for the subsequent three months; "Non-compliant" was defined as any documented premature discontinuation, prolonged bracing holidays, or regular failure to meet the prescribed hourly wear time. Deformity recurrence was operationally defined as the clinical return of any clubfoot deformity component (cavus, adductus, varus, or equinus) after complete initial correction had been achieved, resulting in an increase of the total Pirani score to >0.5 or requiring a return to serial casting or secondary surgical intervention.

Statistical analysis was performed using SPSS Version 26.0. For descriptive statistics, continuous data were evaluated for normality using the Shapiro-Wilk test. Normally distributed data were expressed as mean ± standard deviation (SD) alongside clinical ranges, while skewed continuous data and ordinal clinical scores were presented as median and interquartile range (IQR). Categorical variables were expressed as frequencies and percentages (*n*, %). For the baseline patient cohort (N = 42), cross-group comparisons between the idiopathic and non-idiopathic populations were performed using the non-parametric Mann-Whitney U test for continuous variables and Fisher's exact test for categorical distributions to accommodate the small, unbalanced nature of the subgroups.

For the clinical intervention and treatment outcome data, the individual foot was designated as the primary unit of analysis. Univariate regression models were utilized to evaluate the relative impact of clubfoot etiology on treatment dynamics, employing linear regression for continuous outcomes and logistic regression for dichotomous outcomes. Longitudinal, within-group therapeutic efficacy from baseline to final post-casting was evaluated using the Wilcoxon signed-rank test. Two-sided p-values <0.05 were considered statistically significant, and the precision of primary categorical estimates was reflected via 95% confidence intervals (CIs). It must be noted that because the individual foot was treated as the primary unit of analysis across a cohort containing bilateral deformities, these models did not statistically adjust for inter-limb dependency or patient-level clustering. This lack of statistical adjustment for bilateral clustering represents a known limitation in the precision of our standard errors and regression coefficients.

This retrospective chart review was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki and complied with the Philippine Data Privacy Act of 2012. The study protocol received formal ethical review and approval from the Institutional Review Board / Research Ethics Committee (REC) of Baguio General Hospital and Medical Center (BGHMC). Because this study relied purely on historical medical records from a retrospective cohort covering August 2019 to December 2023, a formal waiver of active parental informed consent was requested and granted by the REC. To protect patient privacy and mitigate the heightened risk of re-identification inherent to the small, rare secondary conditions within the non-idiopathic subgroup, strict data anonymization protocols were enforced. All patient identifiers, including names, birth dates, hospital registry numbers, and specific geographic details, were completely stripped and replaced with unique alphanumeric codes during data extraction. No patient-identifying data was retained in the final analytic dataset.

Programmatic support for clinical data infrastructure was provided through the localized institutional partnership with the MiracleFeet Foundation's clubfoot clinic model. While

MiracleFeet facilitated standardized registry documentation frameworks and clinical software access, this research received no direct financial grants, funding, or corporate subsidies for its execution. The authors declare no conflicts of interest, and the programmatic support did not influence the study desi gn, analysis, or manuscript preparation.

RESULTS

A total of 42 patients were evaluated, comprising 36 idiopathic cases (85.71%) and 6 non-idiopathic cases (14.29%). Among the non-idiopathic cohort, the specific underlying etiologies identified were arthrogryposis (n = 2, 33.33%), constriction band syndrome (n = 2, 33.33%), CHARGE syndrome (n = 1, 16.67%), and neurogenic clubfoot (n = 1, 16.67%). The overall mean age at the start of treatment was 0.36 months (IQR 1.52; 0.23 - 1.75; range 0.03 - 18). No statistically significant difference in treatment initiation age was observed between the idiopathic (median 0.32 months, IQR 0.79) and non-idiopathic (median 1.00 month, IQR 1.79) (Table 1).

The majority of the study population was male (69.05%). Sex distribution was highly homogeneous between the idiopathic (69.44% male) and non-idiopathic (66.67% male) groups, showing no statistically significant difference (p = 1.00). Bilateral clubfoot was the most prevalent presentation overall (64.29%) and across both sub-cohorts (61.11% in idiopathic vs. 83.33% in non-idiopathic). Statistical analysis demonstrated no significant association between etiology and deformity laterality (p = 0.81) (Table 1).

The baseline clinical severity and initial Ponseti casting dynamics were analyzed across 69 feet (58 idiopathic, 11 non-idiopathic). Both groups presented with high baseline severity scores, yielding a median initial Pirani score of 5.5 (IQR 1.00; range 3.0–6.0) for idiopathic feet and 6.0 (IQR 0.38; range 5.0–6.0) for non-idiopathic feet (see Figure 1 for a representative example of a foot at initial presentation with a high Pirani score). The non-idiopathic cohort required a higher mean number of total corrective casts (6.33 ± 2.80 casts; range 3–10) compared to the idiopathic cohort (4.47 ± 2.24 casts; range 2–11). For the subset requiring a percutaneous Achilles tenotomy, the mean number of casts applied prior to the procedure was 5.50 ± 2.54 casts (range 3–10) in the idiopathic group and 5.50 ± 3.54 casts (range 3–8) in the non-idiopathic group. Percutaneous Achilles tenotomy was needed in 36.21% of idiopathic feet (n = 58) and 36.36% of non-idiopathic feet (n = 11). Fisher's exact test demonstrated no statistically significant difference in tenotomy rates between groups (p = 1.00), though this metric is highly constrained by the small non-idiopathic sample size. Because zero recurrences occurred in the non-idiopathic group (0%, 0/11



Figure 1. Representative clinical photograph of an idiopathic clubfoot at initial presentation demonstrating high severity with a baseline Pirani score of 6.

Table 1. Demographic and Baseline Characteristics of Clubfoot Patients (N = 42 Patients)

Characteristics	Total (N = 42)	Idiopathic (n = 36)	Non-idiopathic (n = 6)	*p*-value
Age at initiation, in months, Median (IQR) [Range]	0.36 (1.52) [0.03–18]	0.32 (0.79) [0.03–18]	1.00 (1.79) [0.23–13]	0.11 [a]
Sex, n (%)				1.00 [b]
Male	29 (69.05%)	25 (69.44%)	4 (66.67%)	
Female	13 (30.95%)	11 (30.56%)	2 (33.33%)	
Laterality, n (%)				0.81 [b]
Unilateral, Right	7 (16.67%)	7 (19.44%)	0	
Unilateral, Left	8 (19.05%)	7 (19.44%)	1 (16.67%)	
Bilateral	27 (64.29%)	22 (61.11%)	5 (83.33%)	
Non-Idiopathic Etiologies, n (%)				
Arthrogryposis	2 (4.76%)		2 (33.33%)	
Constriction Band Syndrome	2 (4.76%)		2 (33.33%)	
CHARGE Syndrome	1 (2.38%)		1 (16.67%)	
Neurogenic	1 (2.38%)		1 (16.67%)	

[a] Calculated using Mann-Whitney U test

[b] Calculated using Fisher's exact test



Figure 2. Side profile clinical photograph of the same clubfoot at the 6-month maintenance phase, demonstrating full clinical correction and maximum passive dorsiflexion out of the brace.

feet) compared to 7 in the idiopathic group (12.07%, 7/58 feet), standard logistic regression suffered from quasi-complete separation. Evaluated by Fisher's exact test, etiology was not significantly associated with early deformity recurrence (p = 0.587). Given the small non-idiopathic sample size and short follow-up duration, this lack of statistical significance cannot be used to infer true parity in recurrence risk. Safety profiles during casting demonstrated a 100% absence of complications uniformly across both groups (Table 2).

Both cohorts experienced a highly significant longitudinal reduction in deformity severity, with the median final Pirani score dropping to 0 for both groups. When evaluated by individual feet, the early clinical success rate, defined as achieving an initial plantigrade foot (Pirani score ≤0.5) enabling brace transition, was 100%. To clinically validate this full correction despite the low institutional tenotomy rate, Figure 2 demonstrates a side profile of a patient's foot at the 6-month maintenance phase in maximum passive dorsiflexion. At the patient level (N = 42), the mean duration of follow-up from the initiation of primary casting to the final recorded clinic visit was 10.4 ± 2.1 months (range 7.5–15.5 months), incorporating both the active serial casting phase and a mean duration of 6.8 ± 0.9 months (range 6–13 months) strictly within the maintenance bracing phase. Documented caregiver diaries and clinical interviews revealed a 100% full short-term brace compliance rate (N = 42) at the standardized 6-month indexing checkpoint. Returning to individual feet as the unit of analysis, early deformity recurrence within this limited tracking window occurred exclusively within the idiopathic group, affecting 12.07% of limbs (n = 58 feet); no recurrences were captured in the small non-idiopathic group (n = 11 feet; Fisher's exact p = 1.00) (Table 3).

Table 2. Clinical Baseline and Ponseti Treatment (N = 69 Feet)

Variables	Idiopathic Feet (n = 58)	Non-idiopathic Feet (n = 11)
Initial Pirani Score, Median (IQR)	5.5 (1.00)	6.00 (0.38)
Casting Requirements		
Total casts, Mean ± SD [Range]	4.47 ± 2.24 [2–11]	6.33 ± 2.80 [3–10]
Casts before tenotomy, Mean ± SD [Range]	5.5 ± 2.54 [3–10]	5.5 ± 3.54 [3–8]
Percutaneous Achilles Tenotomy [c]		
Performed, n (%) [95% CI]	21 (36.21%) [23.96, 49.93]	4 (36.36%) [10.93, 69.21]
Not Performed, n (%)	37 (63.79%)	7 (63.64%)
Complications During Casting, n (%)		
Skin Abrasions/Pressure Sores	0 (0%)	0 (0%)
Cast Slippage	0 (0%)	0 (0%)
None	58 (100%)	11 (100%)

[c] Tenotomy was performed uniformly across cohorts if residual equinus persisted (Pirani hindfoot sub-score >0 with inability to dorsiflex the ankle above neutral) following full correction of midfoot deformities.

Table 3. Early Outcomes, Compliance, and Recurrence (N = 69 Feet)

Outcome Measures	Idiopathic Feet (n = 58)	Non-idiopathic Feet (n = 11)
Post-Casting Deformity Score		
Final Pirani Score, Median (IQR)	0	0
Within-group change (Pre vs Post), p-value [d]	<0.001*	0.03*
Early Clinical Outcome, n (% [95% CI])		
Success	58 (100%) [93.84, 100.00]	11 (100%) [71.51, 100.00]
Failure	0 (0%)	0 (0%)
Brace Adherence Rates, n (%)		
Full Compliance	58 (100%)	11 (100%)
Partial Compliance	0 (0%)	0 (0%)
Non-Compliance	0 (0%)	0 (0%)
Deformity Recurrence, n (% [95% CI])	7 (12.07%) [4.99, 23.29]	0 (0%) [0.00, 28.49]

* p <0.05

[d] Within-group longitudinal analysis tracks the direct, unstratified therapeutic drop in severity scores from baseline to the removal of the final post-tenotomy cast.

For all univariate regression models evaluated across 69 feet, etiology was treated as a binary variable with idiopathic clubfoot serving as the reference baseline category (coded as 0) to assess the relative impact of non-idiopathic cases. Consequently, effect sizes are expressed as unstandardized linear coefficients (B) for continuous outcomes, and as odds ratios (OR) relative to a baseline of 1.00 for dichotomous outcomes (Table 4).

Non-idiopathic etiology was identified as a strong and statistically significant predictor of an increased casting workload (B = 2.085, 95% CI [0.56, 3.61], p = 0.008), indicating that non-idiopathic feet required an average of approximately two additional corrective casts compared to idiopathic feet. Conversely, etiology did not serve as a statistically significant predictor for any other clinical outcome

Table 4. Univariate Regression Analysis of Factors Associated with Clubfoot Treatment Outcomes (N = 69 Feet)

Outcomes	Regression Model Type	Effect Size	95% Confidence Interval (CI)	*p*-value
Initial Pirani Score	Linear Regression	B 0.201	[-0.484, 0.885]	0.560
Total Casts Required	Linear Regression	B 2.085	[0.56, 3.61]	0.008*
Casts Before Tenotomy	Linear Regression	B 0.024	[-2.9, 2.95]	0.987
Tenotomy Performed	Logistic Regression	OR 1.007	[0.26, 3.85]	0.992
Deformity Recurrence	Fisher Exact Test	N/A (0 vs 12.07%)	N/A	0.587

* $p < 0.05$

[e] The confidence interval upper bound for deformity recurrence approaches infinity because zero recurrences were observed within the non-idiopathic subgroup (n = 11 feet), resulting in a quasi-complete separation in the logistic model.

evaluated, including initial Pirani severity (B = 0.201, 95% CI [-0.484, 0.885], p = 0.560), the number of casts required before tenotomy (B = 0.024, 95% CI [-2.9, 2.95], p = 0.987), the likelihood of undergoing a percutaneous Achilles tenotomy (OR = 1.007, 95% CI [0.26, 3.85], p = 0.992), or the odds of deformity recurrence (OR = 7.286, 95% CI [0.00, >999.99], p = 0.438). However, these non-significant predictive findings must be interpreted with extreme caution due to the low statistical power inherent to the highly unbalanced and small non-idiopathic subgroup (n = 11 feet). The broad confidence intervals, particularly for deformity recurrence, indicate that clinically meaningful differences in treatment dynamics cannot be excluded; a larger, more balanced multicenter cohort is needed to clarify these associations (Table 4).

The early clinical outcome was uniformly successful across the entire cohort, with 100% of both idiopathic (n = 58) and non-idiopathic (n = 11) feet achieving full correction during the initial casting and bracing transition phase. Because there was no variance in early clinical success, a logistic regression analysis could not be performed for this specific outcome (Table 3) .

DISCUSSION

Baseline demographics and initial severity

This study evaluated a cohort of 42 patients comprising 69 feet, with a distribution of 85.71% idiopathic and 14.29% non-idiopathic cases. The non-idiopathic cohort displayed diverse etiologies, namely arthrogryposis, constriction band syndrome, CHARGE syndrome, and neurogenic clubfoot. Demographics, including age at treatment initiation, sex distribution, and deformity laterality, were statistically homogeneous between the sub-cohorts (p >0.05). Both groups demonstrated high initial severity, presenting with a baseline median Pirani score of 5.5 for idiopathic feet and 6.0 for non-idiopathic feet .

While this high baseline clinical severity aligns with findings from other comparative studies where syndromic or secondary clubfoot deformities presented with severe initial indices,[13,14] the structural homogeneity at baseline within this cohort must be interpreted with caution. Because the non-idiopathic subgroup is highly limited (n = 11 feet) and clinically heterogeneous, our statistical power to detect subtle baseline demographic or clinical differences is restricted. Direct inference regarding population-wide baseline parity is therefore limited by the sample size.

Casting workload and pathophysiological dynamics

The data demonstrate a descriptive difference in the total casting workload required to achieve initial correction. Non-idiopathic feet required a higher mean number of total casts compared to idiopathic feet. In a univariate linear regression model, non-idiopathic etiology acted as a statistically significant predictor of an increased casting workload, adding approximately two corrective casts per foot. Descriptively, non-idiopathic cases required a longer casting phase before bracing in this cohort. However, given the heterogeneous diagnoses spanning rigid arthrogryposis, constriction band syndrome, CHARGE syndrome, and neurological pathologies, the subgroup is too small and diverse to draw meaningful, diagnosis-specific conclusions. These trends should be interpreted descriptively rather than as definitive proof of generalized syndromic casting behaviors.

Interestingly, for the subset of patients requiring a percutaneous Achilles tenotomy, the mean number of casts applied prior to the procedure was identical at 5.5 for both groups, and etiology was not a significant predictor of pre-tenotomy casting duration (p = 0.987). While this cohort did not yield a statistically significant association between etiology and pre-tenotomy casting duration or tenotomy rates, these final statistical models are highly constrained by low statistical power. Given the small non-idiopathic sample (n = 11 feet), the lack of statistical significance should not be interpreted as evidence of true parity in clinical behavior. This heavily restricts robust predictive inference and underscores the need for a larger, well-powered sample to determine whether clinically meaningful differences exist. Furthermore, because week-by-week serial Pirani data after each cast were not captured in this retrospective review, we cannot draw conclusions regarding the dynamic rate of early deformity reduction.

Tenotomy and safety profile

The rate of percutaneous Achilles tenotomy was nearly identical between the cohorts, being performed in 36.21% of idiopathic feet and 36.36% of non-idiopathic feet. Univariate

logistic regression confirmed that etiology did not significantly influence the likelihood of undergoing a tenotomy ($p = 0.992$, Table 4). While some literature found higher tenotomy rates to overcome resistant equinus in rigid syndromic cohorts,[7] we found that meticulous, sequential manipulation can achieve midfoot correction without inherently increasing surgical tendon release rates.

Crucially, the safety profile of the protocol was excellent. Both groups achieved a 100% absence of casting-related complications, with zero instances of skin abrasions, pressure sores, or cast slippage. This matches established data demonstrating that the Ponseti method remains a safe, minimally invasive alternative to primary extensive soft-tissue surgeries, effectively minimizing soft-tissue complications when proper molding techniques are utilized, even in rigid, atypical feet.[5,15]

The low tenotomy rate: local practice patterns and clinical risks

A critical finding of this study is the low rate of percutaneous Achilles tenotomy, which was performed in only 36.21% (95% CI [23.96, 49.93]) of idiopathic feet and 36.36% (95% CI [10.93, 69.21]) of non-idiopathic feet. This means that nearly two-thirds of the evaluated feet (63.79% and 63.64%, respectively) transitioned into bracing through casting alone. This tenotomy rate is substantially lower than international benchmarks, where tenotomy is required in 70% to 90% of Ponseti-treated cases to adequately address fixed equinus.[16,17]

This remarkably low tenotomy rate likely reflects local practice patterns, subjective surgeon preferences, distinct clinical decision thresholds, or potential gaps in documentation regarding precise ankle dorsiflexion angles before bracing. Crucially, a low tenotomy rate may indicate an underuse of the procedure or a clinical misinterpretation of spurious midfoot correction (rocker-bottom deformity) as true ankle dorsiflexion.

Skipping a tenotomy when residual equinus persists constitutes a severe deviation from the standard Ponseti guidelines. Literature indicates that inadequate release of a tight Achilles tendon may leave residual equinus and has been implicated as a factor in recurrent deformity once the child begins weight-bearing.[16,18] While 63.77% of this cohort transitioned directly to bracing without an initial tenotomy, longer longitudinal follow-up is mandatory to determine whether this conservative approach maintains true hindfoot correction or merely masks a high risk for late relapse.

Short-term efficacy, recurrence, and management

Longitudinal analysis demonstrated a drop in the median final Pirani score to 0 for both idiopathic ($p < 0.001$) and non-idiopathic ($p = 0.03$) groups at the time of final cast removal. All 69 feet achieved complete initial deformity correction during the immediate transition from casting to bracing, which coincided with a recorded 100% full compliance rate with prescribed bracing protocols. It must be emphasized, however, that these findings reflect early clinical correction rather than permanent, durable success.

Deformity recurrence during the available follow-up period occurred exclusively within the idiopathic group, affecting 7 feet (12.07%, 95% CI [4.99, 23.29]), while no recurrences were documented in the small non-idiopathic group (0%, 95% CI [0.00, 28.49]). Univariate logistic regression showed that etiology was not a statistically significant predictor of recurrence ($p = 0.438$). In the broader literature, non-idiopathic clubfeet show substantially higher relapse rates than idiopathic clubfeet (approximately 43% vs 10% to 12%), attributed to persistent neuromuscular imbalance.[5,7,19] Our findings are constrained by the short follow-up duration (maximum 13 months) and the small non-idiopathic sample ($n = 11$ feet).

Because this study only tracks patients through early bracing, these results represent short-term endpoints. A follow-up window of this duration is entirely inadequate to declare long-term success against recurrence, which most frequently occurs within the first 3 to 5 years of life.[18] Consequently, this entire cohort remains at a high risk for late relapses and requires continuous tracking up to at least age 5.

Furthermore, this retrospective data lacks granular details regarding the specific timing of recurrence after bracing initiation, the exact anatomical components involved (e.g., dynamic forefoot adduction vs. hindfoot varus), and the objective quantification of daily brace adherence beyond basic clinical charts. While the recorded recurrences in the idiopathic group were managed effectively using repeat serial casting without additional major surgical intervention during the available follow-up period, their long-term stability remains unverified. Nevertheless, these short-term outcomes strongly imply that when strict, absolute, and rigorous brace compliance is maintained, highly favorable initial corrections can be achieved using the Ponseti technique regardless of whether the clubfoot is idiopathic or non-idiopathic.[13,20]

Methodological limitations and clinical implications

Direct comparison between these findings and international historical data is limited by variations in study design, cohort sizes, treatment thresholds, and definitions of clinical success. The primary value of this study lies in its reflection of local programmatic data from a government hospital setting rather than a generalized validation of the Ponseti method. The interpretation of these outcomes is restricted by several key methodological limitations, including a retrospective design that relies heavily on historical medical records and exposes the data to documentation gaps. Furthermore, the small sample size ($n = 6$ patients, 11 feet) and high diagnostic heterogeneity of the non-idiopathic subgroup prevent any meaningful diagnosis-specific pooling. The short overall follow-up

duration, which reached a maximum of only 13 months, inherently misses late-stage relapses that typically manifest later. Additionally, a potential selection bias may have resulted from the exclusion of incomplete records or patients lost to follow-up, while the lack of objective, sensor-based brace-compliance metrics forced a reliance on subjective caregiver reports. Furthermore, reporting a median final Pirani score of 0 across both groups may inadvertently overstate the true clinical correction. While a Pirani score of 0 confirms excellent passive midfoot and hindfoot alignment at the immediate completion of the casting phase, it remains a purely static, morphology-based assessment. Because this clinical snapshot is not paired with standardized functional mobility scales, dynamic muscle balance assessments, or long-term weight-bearing outcomes, it may mask underlying muscle imbalances or early joint stiffness that predispose the foot to late relapses during ambulation.

Furthermore, a major statistical limitation arises from the non-independence of our data; because bilateral clubfoot was highly prevalent (64.29%), analyzing outcomes by individual feet (n = 69) without adjusting for patient-level clustering or intra-patient correlation artificially narrows the confidence intervals. Future well-powered studies should utilize Generalized Estimating Equations (GEE) or mixed-effects models to control this inter-limb dependency. Finally, the statistical power is also constrained by this unadjusted model, alongside a broader lack of standardized, validated functional or patient-reported outcome measures.

Despite these limitations, several vital clinical implications can be drawn for regional clubfoot programs. Regarding workload counseling, caregivers of children presenting with non-idiopathic clubfoot must be thoroughly counseled at baseline that the treatment course will likely require a longer casting phase and a higher overall casting workload. To ensure the standardization of protocols, clinical criteria for performing a percutaneous Achilles tenotomy must be strictly standardized locally, utilizing objective measures like a minimum of 15° passive dorsiflexion and a completely corrected hindfoot score, to actively eliminate the risk of clinical under-treatment. Finally, to maintain vigilance in follow-up, clinicians must not allow successful early midfoot correction or immediate bracing compliance to reduce their diagnostic vigilance, as late recurrences remain a high risk, particularly in patients in whom the Achilles tendon was not released. Longitudinal tracking must therefore be strictly maintained through age 5 to catch late-stage relapses.

CONCLUSION AND RECOMMENDATION

This study establishes a localized baseline programmatic report on the short-term outcomes and protocol adherence of the Ponseti method within a structured tertiary government hospital framework. These early findings suggest that the Ponseti method can achieve favorable short-term clinical correction in both idiopathic and selected non-idiopathic cases, with a 100% initial success rate in transitioning plantigrade feet into the maintenance bracing phase. However, definitive long-term effectiveness cannot be inferred from this study, as conclusions are strictly limited by the small non-idiopathic subgroup and a short follow-up window.

While non-idiopathic etiology was a statistically significant predictor of an increased casting workload, requiring an average of two additional corrective casts, this cohort did not demonstrate a clear association between etiology and the need for a tenotomy or pre-tenotomy casting duration. Nevertheless, the small sample size severely limits broader predictive inference, and these findings may be underpowered to rule out real clinical associations.

Crucially, given the uncommonly low institutional percutaneous Achilles tenotomy rate observed across both groups (~36%) compared to global benchmarks, this entire cohort must be considered at a high risk for late deformities and dynamic relapses. Therefore, this study must be framed as an evaluation of early protocol adherence and short-term maintenance rather than a definitive final clinical outcome.

Based on the short-term outcomes and identified programmatic parameters of this regional report, several key recommendations are proposed to optimize care pathways and future research directions. First, mandatory extended longitudinal surveillance must be actively maintained through the implementation of a strict, active tracking registry to monitor this specific cohort until at least age 5. Because nearly two-thirds of the evaluated feet transitioned to bracing without an Achilles tendon release, continuous clinical vigilance is essential to catch late-stage equinus relapses early. Second, future clinical investigations should expand to well-powered, prospective multicenter studies with extended follow-up periods necessary to evaluate true long-term recurrence rates, joint mobility, and functional patient-reported outcomes within the region.

Third, to bridge the gap between local conservative practice patterns and global protocols, the institution should adopt highly strict, objective indicators for the standardization of tenotomy criteria. Decisions to perform a percutaneous Achilles tenotomy should rely purely on verified mechanical parameters, such as a definitive failure to achieve at least 15 degrees of passive ankle dorsiflexion after full midfoot correction, to actively protect against potential clinical under-treatment. Finally, updating clinical data collection to capture week-by-week serial Pirani scores during the casting phase will optimize future audit quality, allowing clinicians to precisely track and mathematically model the dynamic velocity of deformity correction across different secondary etiologies.

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CREDIT AUTHOR STATEMENT

KPI: Methodology, Writing – original draft and preparation; **JMJ, MJDV, ANB:** Conceptualization; **IG, DB:** Writing – review and editing.

DATA AVAILABILITY STATEMENT

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AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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