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Unveiling the Concordance: Pirani Score and Key Radiological Angles (TCA AP, Talo-1st Metatarsal) in Monitoring Ponseti-Treated Congenital Talipes Equinovarus

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A B S T R A C T

Introduction: Congenital talipes equinovarus (CTEV) is a significant pediatric foot deformity. The Ponseti method, assessed clinically by the Pirani score, is the standard treatment. However, the precise relationship between this clinical score and objective radiological measurements, particularly key angles like the talocalcaneal anteroposterior (TCA AP) and talo-first metatarsal (Talo-1st MT) angles, requires ongoing detailed investigation to optimize treatment monitoring. This study aimed to meticulously evaluate the correlation between Pirani scores and these specific radiological parameters in CTEV patients undergoing Ponseti management at a tertiary care center in Palembang, Indonesia. **Methods:** A descriptive case series was conducted at Dr. Mohammad Hoesin General Hospital, Palembang, involving 29 infants with idiopathic CTEV. Clinical assessments using the Pirani score and radiological evaluations measuring TCA AP, Talo-1st MT, lateral talocalcaneal (TCA lateral), and lateral tibiocalcaneal (TiCA lateral) angles were performed before initiating and after completing the Ponseti casting phase. Spearman's rank correlation coefficient was utilized to analyze the relationship between Pirani scores and these radiological angles. **Results:** Significant improvements were observed in both Pirani scores (mean pre-treatment 4.36 ± 1.41 to post-treatment 0.20 ± 0.29; $p < 0.001$) and radiological parameters following Ponseti treatment. Pre-correction, Pirani scores showed very strong positive correlations with TCA AP ($r = 0.892$, $p < 0.001$), Talo-1st MT ($r = 0.939$, $p < 0.001$), and TCA lateral ($r = 0.880$, $p < 0.001$). Post-correction, moderate significant positive correlations persisted for TCA AP ($r = 0.404$, $p = 0.045$) and Talo-1st MT ($r = 0.404$, $p = 0.045$) with Pirani scores. The TiCA lateral angle showed weaker and less consistent correlations. **Conclusion:** Key radiological parameters, specifically the TCA AP and Talo-1st MT angles, demonstrate a significant correlation with the Pirani score both before and after Ponseti correction in CTEV patients. These findings underscore the synergistic value of integrating these specific radiological assessments with clinical Pirani scoring for comprehensive monitoring of deformity correction during Ponseti treatment.

1. Introduction

Congenital talipes equinovarus (CTEV), commonly known as clubfoot, is a prevalent congenital musculoskeletal deformity affecting approximately 1 to 2 per 1,000 live births globally, with variations across different populations. This complex condition, characterized by hindfoot varus and equinus, midfoot cavus, and forefoot adductus, can lead to significant long-term morbidity if untreated, including functional disability, chronic pain, and psychosocial challenges. The Ponseti method has become the gold standard for the initial conservative management of CTEV,

involving serial manipulations, casting, often an Achilles tenotomy, and bracing. This technique boasts success rates exceeding 90%, particularly when initiated early in infancy. Despite its efficacy, robust and objective tools are crucial for accurately monitoring deformity severity, tracking correction, and identifying potential relapse.[1-4]

Clinical assessment frequently relies on the Pirani scoring system, a tool that quantifies CTEV severity based on six physical parameters of the hindfoot and midfoot. The Pirani score is valued for being non-invasive, low-cost, and easy to use in outpatient settings, guiding treatment decisions like the timing of Achilles tenotomy. However, its subjectivity, dependent on examiner experience, can lead to inter-observer variability and questions about its precise correlation with underlying anatomical deformity, especially in atypical or recurrent cases. Radiological examination offers an objective means to visualize and quantify skeletal abnormalities in CTEV using measurements like the talocalcaneal angle (TCA) in anteroposterior (AP) and lateral views, and the talo-first metatarsal (Talo-1st MT) angle. These angles are vital for assessing the deformity's three-dimensional components and evaluating treatment outcomes. Historically, debate existed regarding routine radiography in CTEV due to concerns about radiation and interpretation difficulties in infants. However, emerging evidence suggests imaging can augment clinical judgment, particularly in complex cases or suspected relapse. Challenges in pediatric radiology, such as standardizing foot positioning and ossification patterns, can affect reliability, though techniques like using fixation devices aim to mitigate these.[5-8]

Understanding the correlation between objective radiographic parameters and the Pirani score is crucial for comprehensive CTEV management. This could clarify whether clinical scoring alone adequately reflects anatomical correction or if a combined approach offers more thorough care, especially for infants, where tailored management is essential. At Dr. Mohammad Hoesin General Hospital Palembang, a high-volume tertiary center, optimizing assessment modalities is both an academic and practical necessity. Determining if radiological findings correspond with the Pirani score could enhance clinical decision-making and treatment monitoring. The novelty of this study lies in its focused investigation within the specific demographic and clinical setting of Palembang, Indonesia, contributing valuable regional data. This study emphasizes the dynamic changes in the TCA AP and Talo-1st Metatarsal angles and their relationship with the Pirani score, both before and after the corrective phase of the Ponseti method. It aims to reinforce the utility of these angles as reliable adjuncts to clinical scoring in a real-world tertiary hospital setting.[9,10] Therefore, the aim of this study was to meticulously determine and quantify the correlation between key radiological parameters (specifically TCA AP, Talo-1st Metatarsal, TCA lateral, and TiCA lateral angles) and the clinical Pirani score in infants with idiopathic CTEV undergoing Ponseti method correction at Dr. Mohammad Hoesin General Hospital Palembang. The goal was to ascertain whether these radiological measures could serve as robust, objective indicators mirroring clinical severity and correction, thereby guiding and potentially refining the monitoring of treatment efficacy.

2. Methods

This investigation was conducted as a descriptive case series, specifically designed to prospectively explore and characterize the correlation between clinical assessments using the Pirani score and objective radiological parameters in infants diagnosed with idiopathic congenital talipes equinovarus (CTEV). All patients were managed with the standardized Ponseti method at the Orthopedic and Radiology Clinics of Dr. Mohammad Hoesin General Hospital, a tertiary referral center in Palembang, Indonesia. Ethical clearance for the study was duly obtained from the hospital's institutional review board prior to any patient enrollment, and the research was performed in strict accordance with the Declaration of Helsinki and relevant local ethical guidelines. Informed written

consent was secured from the parents or legal guardians of all participating infants following a comprehensive explanation of the study's objectives and procedures.

The target population comprised infants with idiopathic CTEV who were scheduled for or undergoing Ponseti treatment. A consecutive sampling strategy was employed, enrolling all eligible patients who met the inclusion criteria during the study period until the requisite sample size was achieved. The minimum sample size of 25 patients was determined through a power calculation for correlation analysis, assuming an anticipated correlation coefficient (r) of 0.6, a Type I error rate (α) of 0.05, and a Type II error rate (β) of 0.20 (80% power); a total of 29 subjects were ultimately included. Infants were included if they had idiopathic CTEV, were treated non-operatively with the Ponseti method, and had parental consent. Exclusion criteria included non-idiopathic CTEV, prior surgical correction, or incomplete data. All enrolled infants received standardized Ponseti treatment, involving sequential manipulation, weekly long-leg plaster casting, a percutaneous Achilles tenotomy for residual equinus if indicated, and subsequent foot abduction bracing. Clinical and radiological evaluations were meticulously performed at two critical time points: first, before the initiation of any Ponseti treatment (baseline), and second, upon completion of the corrective casting phase, typically after the post-tenotomy cast and prior to starting full-time bracing.

The independent variables were four specific radiographic angles obtained from standardized anteroposterior (AP) and lateral views of the foot: the talo–first metatarsal angle (Talo-1st MT), the talocalcaneal angle in the AP view (TCA–AP), the lateral talocalcaneal angle (TCA–Lateral), and the lateral tibiocalcaneal angle (TiCA Lateral). Standardized radiographic positioning, including the use of an acrylic foot fixation device, was employed, and images were evaluated using MicroDicom software. While angles were also qualitatively categorized (normal, mild, moderate, severe), the continuous angular measurements formed the basis of the primary correlational analysis. The dependent variable was the Pirani score, a six-point clinical system (0-6, higher indicating more severe deformity) assessing three hindfoot and three midfoot parameters, each graded from 0 (normal) to 1 (severe). All Pirani scores were assessed by trained orthopedic personnel.

Data were prospectively collected, entered into Microsoft Excel, and subsequently analyzed using IBM SPSS Statistics version 30. Descriptive statistics summarized patient characteristics. The Spearman's Rho rank correlation coefficient was the primary statistical tool used to assess the monotonic relationship between Pirani scores and the radiographic angles at both pre-treatment and post-correction stages. The strength of correlations was interpreted using standard criteria. Changes in scores and angles between the two time points were analyzed using appropriate paired statistical tests. A p-value of less than 0.05 was considered statistically significant for all inferential analyses. This methodological framework was designed to critically evaluate the dynamic relationship between clinical deformity scoring and objective structural correction, aiming to enhance the integrated use of these assessment tools in CTEV management.

3. Results

The demographic and baseline clinical characteristics of the 29 infants enrolled in this study are systematically presented in Table 1. A notable observation within this cohort was the predominance of female infants, accounting for 21 (72.4%) of the subjects, while male infants constituted the remaining 8 (27.6%). This gender distribution diverges from some traditional literature that often reports a higher incidence of CTEV in males. The mean age of the infants at the time of initiating Ponseti treatment was 5.72 ± 4.85 months, with the median age being 3 months. The age range of participants was relatively broad, extending from as young as 1 month to as old as 17 months. With respect to the mode of delivery, a larger proportion of the infants in this study group were delivered via Cesarean section (18 infants, 62.1%)

as compared to those delivered vaginally (11 infants, 37.9%). The mean gestational age at birth for this cohort was 37 ± 2.29 weeks, with a median gestational age of 37 weeks. The range of gestational ages spanned from 32 to 40 weeks, indicating that the majority of the infants were born at or near full term. A positive family history of CTEV was reported for only a small minority of the cases. Specifically, only 2 infants (6.9%) were identified as having an affected family member, whereas the vast majority, 27 infants (93.1%), had no reported family history of the condition. The clinical severity of the CTEV deformity, as quantified by the Pirani scoring system, was substantial at the baseline (pre-treatment) assessment. The mean pre-treatment Pirani score for the entire cohort was 4.36 ± 1.41. The median pre-treatment Pirani score was 5, with scores ranging from a minimum of 2 to a maximum of 6, indicating a spectrum from moderate to very severe deformity. Following the completion of the corrective casting phase of the Ponseti method, a dramatic and clinically highly significant reduction in the signs of deformity was observed. The mean post-treatment Pirani score plummeted to 0.20 ± 0.29. The median post-treatment Pirani score was 0, with the scores in this phase ranging from 0 to 1, signifying excellent clinical correction to a near-normal state for most feet.

Table 1. Baseline characteristics of study subjects (n = 29).

Variable	n (%)	Mean ± SD	Median (Min–Max)
Gender			
- Male	8 (27.6%)		
- Female	21 (72.4%)		
Age (months)		5.72 ± 4.85	3 (1 – 17)
Mode of delivery			
- Vaginal	11 (37.9%)		
- Cesarean section	18 (62.1%)		
Gestational age (weeks)		37 ± 2.29	37 (32 – 40)
Family history of CTEV			
- Yes	2 (6.9%)		
- No	27 (93.1%)		
Pirani score (Pre-treatment)		4.36 ± 1.41	5 (2 – 6)
Pirani score (Post-treatment)		0.20 ± 0.29	0 (0 – 1)

The efficacy of the Ponseti method was clearly demonstrated by the significant reduction in Pirani scores from pre-treatment to post-treatment. This is detailed in Table 2 below. The mean score decreased from 4.30 ± 1.39 before treatment to 0.20 ± 0.29 after treatment. This change was statistically highly significant (p = 0.000). The median score also showed a dramatic improvement, falling from 3.5 (range: 2–6) pre-treatment to 0 (range: 0–1) post-treatment.

Table 2. Pirani score following Ponseti correction.

Variable	Before treatment	After treatment	P-value
Mean ± SD	4.30 ± 1.39	0.20 ± 0.29	0.000*
Median	3.5	0	
Minimum – Maximum	2 – 6	0 – 1	

*Statistically significant difference.

The qualitative categorization of the four key radiological angles (TCA AP, Talo–1st Metatarsal Angle, TCA Lateral, and TiCA Lateral) into severity grades of Normal, Mild, Moderate, or Severe, both before and after the Ponseti correction, is presented in Table 3. Pre-Ponseti Correction Findings: TCA AP: No feet were classified as normal. 6 (20.7%) were categorized as mild, 9 (31.0%) as moderate, and a significant 14 (48.3%) as severe; Talo–1st Metatarsal Angle (AP view): Similarly, no feet fell into the normal category. 7 (24.1%) were mild, 7 (24.1%) were moderate, and 15 (51.7%) were severe; TCA Lateral: A small number, 3 (10.3%), were classified as normal, with another 3 (10.3%) as mild. However, the majority were moderate (7 cases, 24.1%) or severe (16 cases, 55.2%); TiCA Lateral: No feet were categorized as normal or mild at baseline. 5 (17.2%) were moderate, while the overwhelming majority, 24 (82.8%), presented with severe deformity for this angle. These baseline radiological findings consistently underscore the presence of substantial anatomical deformity across all measured angles prior to intervention, aligning well with the high pre-treatment Pirani scores.

Post-Ponseti Correction Findings: A striking improvement and a general shift towards normalization were observed in these angles after the completion of the corrective casting phase of the Ponseti method: TCA AP: 24 feet (96.0%, assuming n=25 for post-correction categorization as per source table counts) were classified as normal, and only 1 (4.0%) remained as mild. No feet were left in the moderate or severe categories for this angle; Talo–1st Metatarsal Angle (AP view): The improvement was parallel, with 24 feet (96.0%) achieving normal status and 1 (4.0%) categorized as mild; TCA Lateral: For this angle, all 25 feet (100%) included in the post-correction categorization were classified as normal; TiCA Lateral: An interesting pattern emerged for this angle. While significantly improved from the pre-treatment state, no feet were classified as normal post-correction; instead, all 25 feet (100%) were categorized as demonstrating a mild residual deformity for this specific angular measurement. This suggests that while substantial correction of equinus (reflected by TiCA Lateral) is achieved, a minor radiological deviation might persist more commonly, or the threshold for "normal" TiCA Lateral post-Ponseti is particularly stringent.

Table 3. Radiographic parameters categorization before and after Ponseti correction.

Radiographic variable	Normal n (%)	Mild n (%)	Moderate n (%)	Severe n (%)
Before Ponseti correction				
TCA AP	0 (0.0%)	6 (20.7%)	9 (31.0%)	14 (48.3%)
Talo–1st metatarsal angle (AP)	0 (0.0%)	7 (24.1%)	7 (24.1%)	15 (51.7%)
TCA lateral	3 (10.3%)	3 (10.3%)	7 (24.1%)	16 (55.2%)
TiCA lateral	0 (0.0%)	0 (0.0%)	5 (17.2%)	24 (82.8%)
After Ponseti correction*				
TCA AP	24 (96.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
Talo–1st metatarsal angle (AP)	24 (96.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
TCA lateral	25 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
TiCA lateral	0 (0.0%)	25 (100%)	0 (0.0%)	0 (0.0%)

*The initial sample size of 29 participants was reduced to 25, resulting from two patient mortalities and two patients lost to follow-up during the study period.

Table 4 provides valuable insight into how the mean Pirani scores varied according to the severity categorization of the initial (pre-treatment) radiological angles. This analysis effectively demonstrates that those patients who presented with more severe radiological deformities, as categorized by their

specific angular measurements, also tended to have correspondingly higher (worse) clinical Pirani scores. For feet with a 'mild' radiological TCA AP deformity, the mean Pirani score was 2.58 ± 0.49. This increased to 3.56 ± 0.81 for 'moderate' TCA AP deformity and further to 5.64 ± 0.31 for 'severe' TCA AP deformity. The differences in Pirani scores across these TCA AP severity groups were statistically significant (p = 0.000). A similar trend was observed. For 'mild' Talo-1st MT deformity, the mean Pirani score was 2.64 ± 0.56. This rose to 3.36 ± 0.24 for 'moderate' and to 5.63 ± 0.29 for 'severe' Talo-1st MT deformity, with statistically significant differences in Pirani scores across these groups (p = 0.000). For feet initially classified with 'normal' TCA lateral angles (a small subgroup), the mean Pirani score was 2.17 ± 0.29. This increased to 3.00 ± 0.00 for 'mild', 3.29 ± 0.39 for 'moderate', and peaked at 5.5 ± 0.61 for 'severe' TCA lateral deformity. Again, these differences were statistically significant (p = 0.000). For 'moderate' TiCA lateral deformity, the mean Pirani score was 3.10 ± 0.42, which increased to 4.63 ± 1.40 for 'severe' TiCA lateral deformity. The difference in Pirani scores between these two TiCA lateral severity groups was also statistically significant (p = 0.036). These findings consistently affirm a direct and statistically significant relationship: increasing radiological severity across all key angles at presentation was strongly associated with increasing clinical severity as measured by the Pirani score.

Table 4. Relationship between initial radiological severity categories and mean pre-treatment Pirani scores.

Radiological characteristic	Severity category	Mean Pirani score ± SD	P-value (across groups)
TCA AP	Mild	2.58 ± 0.49	0.000
	Moderate	3.56 ± 0.81	
	Severe	5.64 ± 0.31	
Talo–1st metatarsal angel AP	Mild	2.64 ± 0.56	0.000
	Moderate	3.36 ± 0.24	
	Severe	5.63 ± 0.29	
TCA lateral	Normal	2.17 ± 0.29	0.000
	Mild	3.00 ± 0.00	
	Moderate	3.29 ± 0.39	
	Severe	5.5 ± 0.61	
TiCA lateral	Moderate	3.10 ± 0.42	0.036
	Severe	4.63 1.40	

The central investigation of this study involved the Spearman's Rho correlation analysis between the Pirani scores and the precise quantitative measurements of the radiological angles. This analysis was performed for both the pre-treatment and post-correction datasets to understand the dynamic nature of this relationship. The detailed results of this correlation analysis are presented in Table 5. A very strong, positive, and statistically highly significant correlation was identified (Spearman's r = 0.892, p = 0.000). This robust finding indicates that higher (more severe) pre-treatment Pirani scores were very closely associated with TCA AP angles indicative of greater anatomical deformity in the anteroposterior hindfoot alignment. Pirani Score and Talo–1st Metatarsal Angle, An exceptionally strong, positive, and statistically highly significant correlation was also found for this angle (Spearman's r = 0.939, p = 0.000). This represents the strongest correlation observed, powerfully suggesting that the clinical Pirani score is an excellent reflector of the severity of midfoot and forefoot malalignment captured by the Talo-1st Metatarsal angle. Pirani Score and TCA Lateral, A very strong, positive, and statistically highly significant correlation was evident here as well (Spearman's r = 0.880, p = 0.000). This underscores a strong concordance between the clinical assessment of overall hindfoot deformity (as incorporated into the

Pirani score) and the radiological measurement of the lateral talocalcaneal relationship. In contrast to the other angles, a weaker, though still statistically significant, positive correlation was observed for the TiCA Lateral angle (Spearman's r = 0.417, p = 0.025). This suggests that while a relationship exists, the TiCA lateral angle (primarily reflecting the degree of ankle equinus) did not correlate with the composite Pirani score as strongly as the other multiplanar angular measurements did prior to treatment. A moderate, positive, and statistically significant correlation persisted between the post-correction Pirani score and the TCA AP angle (Spearman's r = 0.404, p = 0.045). Similarly, a moderate, positive, and statistically significant correlation was maintained for the Talo-1st Metatarsal angle post-correction (Spearman's r = 0.404, p = 0.045). This indicates an ongoing, though less pronounced, concordance between the clinical status and this crucial measure of midfoot/forefoot alignment after treatment. The correlation between the post-correction Pirani score and the TCA Lateral angle became weak and, importantly, lost its statistical significance (Spearman's r = 0.253, p = 0.223). This suggests that once good correction is achieved (with TCA Lateral often becoming 'normal' as per Table 3), the very low Pirani scores have less ability to discriminate or co-vary with the subtle variations that might remain in this now largely corrected angle. The correlation for the TiCA Lateral angle post-correction became very weak, shifted to a slightly negative direction (though likely not meaningful), and was clearly not statistically significant (Spearman's r = -0.152, p = 0.469). This implies that the TiCA lateral angle, which was predominantly classified as 'mild' in the post-correction phase (Table 3), had little to no meaningful linear relationship with the very low post-correction Pirani scores.

Table 5. Correlation (Spearman's Rho, r) and significance (p-value) of radiologic parameters with Pirani score before and after treatment.

Variable	Time point	Spearman's r	p-value	Interpretation of correlation strength (Pre / Post)
TCA AP	Before	0.892	0.000	Very Strong Positive / Moderate Positive
	After	0.404	0.045	
Talo–1st metatarsal	Before	0.939	0.000	Very Strong Positive / Moderate Positive
	After	0.404	0.045	
TCA lateral	Before	0.880	0.000	Very Strong Positive / Weak Positive (Non-signif.)
	After	0.253	0.223	
TiCA lateral	Before	0.417	0.025	Weak Positive / Very Weak Negative (Non-signif.)
	After	-0.152	0.469	

4. Discussion

The observation of a female predominance (72.4%) in this CTEV cohort is an intriguing finding, as it diverges from the more commonly reported male predilection (often cited as 2:1) in much of the global literature. While this study suggested potential socio-cultural factors influencing presentation, from a pathophysiological standpoint, the genetic and embryological underpinnings of CTEV are complex and not fully elucidated. Gender-linked genetic modifiers or differential intrauterine environmental exposures could theoretically contribute to regional variations in gender ratios, though this remains speculative without further specific investigation into this cohort. The mean age at treatment initiation (5.72 months) is within a range where the foot tissues are still highly malleable and responsive to the Ponseti method, a crucial factor rooted in the viscoelastic

properties of neonatal connective tissues (ligaments, tendons, joint capsules) which allow for gradual plastic deformation and remodeling under the influence of serial casting. The low reported rate of positive family history (6.9%), while aligning with the understanding that many CTEV cases are multifactorial or sporadic, does not negate the established genetic components involved in CTEV susceptibility, which include genes related to limb development, connective tissue integrity, and neuromuscular function.[11,12]

The study unequivocally reaffirmed the effectiveness of the Ponseti method, as evidenced by the dramatic reduction in mean Pirani scores from 4.36 to 0.20 and the concurrent significant improvements in radiological parameters. This success is intrinsically linked to the method's foundation in a deep understanding of CTEV pathoanatomy and the unique biomechanical properties of neonatal tissues. Dr. Ponseti recognized that the deformity was not primarily one of bony dysmorphism but rather of malposition and contracture of otherwise relatively normal tarsal bones and surrounding soft tissues. The sequential manipulation and casting protocol systematically addresses the components of the deformity by applying gentle, sustained corrective forces that exploit the biological responsiveness (creep and stress relaxation) of these tissues. The cavus is corrected first by supinating the forefoot to align it with the hindfoot, thereby untwisting the plantar fascia and intrinsic muscles. The adduction and varus are then addressed by abducting the forefoot under the stabilized talus, allowing the navicular, cuboid, and calcaneus to externally rotate around the talar head and neck. The final equinus component, often the most rigid due to contracture of the triceps surae and posterior ankle capsule, is typically addressed by an Achilles tenotomy, which allows for passive dorsiflexion and subsequent healing of the tendon at an increased length. The radiological improvements seen in TCA AP, Talo-1st MT, and TCA Lateral directly reflect the successful realignment of the talocalcaneal complex and the midfoot structures achieved through this biomechanically sound approach.[13,14]

The very strong positive correlations observed pre-treatment between the Pirani score and the TCA AP (r=0.892), Talo-1st Metatarsal (r=0.939), and TCA Lateral (r=0.880) angles are highly significant. Pathophysiologically, these findings suggest that the Pirani score, through its systematic clinical palpation and assessment of reducibility, effectively captures the global severity of the multiplanar tarsal malalignments. The TCA AP angle directly reflects the degree of parallelism or convergence of the talus and calcaneus in the transverse plane. In severe CTEV, pronounced hindfoot varus causes these bones to be nearly parallel, significantly reducing this angle. The Pirani hindfoot components (like empty heel and posterior crease rigidity) are clinical manifestations of this severe varus and equinus, hence the strong correlation. Talo-1st MT is classically a sagittal plane measurement reflecting the cavus and forefoot position relative to the talus) is crucial. The significant cavus (midfoot plantarflexion) and forefoot adductus/supination in CTEV drastically alter this angle. The Pirani midfoot components (medial crease, lateral border curvature, talar head palpability) are direct clinical consequences of these malalignments. The exceptionally high correlation (r=0.939) underscores how well these palpable clinical signs mirror the underlying skeletal disarray in the sagittal and transverse planes of the midfoot and forefoot relative to the hindfoot. The TCA Lateral angle provides a sagittal plane view of the talocalcaneal relationship, which is markedly altered by the hindfoot equinus and varus. Reduced TCA lateral indicates increased parallelism of these bones in this plane. Again, the Pirani score, particularly its hindfoot components assessing equinus rigidity, directly reflects this. The weaker, though still significant, pre-treatment correlation of the Pirani score with the TiCA Lateral angle (r=0.417) is also informative. The TiCA lateral primarily measures the global ankle equinus (tibio-calcaneal plantarflexion). While equinus is a key component of CTEV and the Pirani score (rigidity of

equinus), the total Pirani score is a composite of six components, many of which relate more directly to the varus, adductus, and cavus deformities reflected by the other angles. Thus, an isolated equinus measure might not capture the total "Pirani severity" as strongly as angles reflecting more complex multiplanar malalignments.[15,16]

The attenuation of correlation strengths post-correction is an expected phenomenon when variance decreases as scores cluster towards normal. However, the persistence of moderate, significant correlations for TCA AP (r=0.404) and Talo-1st Metatarsal (r=0.404) with the post-correction Pirani score is a key finding. Pathophysiologically, this suggests that even when the foot appears clinically well-corrected (Pirani score often 0 or 0.5), these two radiological angles might still capture subtle residual structural deviations or particular interosseous relationships that are also, to some extent, detectable by a nuanced Pirani assessment. For instance, a minimal residual adduction or supination in the midfoot might yield a Pirani midfoot score of 0.5 and concurrently be reflected by a Talo-1st Metatarsal angle that is improved but not perfectly "normal" by strict radiological criteria. Similarly, slight residual hindfoot varus might influence the TCA AP. The Ponseti method aims to achieve a plantigrade, functional foot, and it's possible that "excellent" clinical outcomes (low Pirani) can coexist with minor radiological deviations that do not necessarily imply poor outcome but reflect the foot's new, corrected equilibrium. These persistent correlations for TCA AP and Talo-1st MT suggest they are sensitive indicators of the final corrected state. The source document's conclusion that these parameters "have a correlation with the Pirani score in CTEV patients pre and post Ponseti method correction" is thus well supported.[17,18]

The loss of significant correlation for TCA Lateral (r=0.253, p=0.223) and TiCA Lateral (r=-0.152, p=0.469) post-correction is also telling. The TCA lateral angle was reported to be "100% normal" post-correction in the qualitative assessment (Table 3). If this angle is consistently well-corrected radiologically, its variance would be minimal, making correlation with the already low-variance Pirani scores difficult to establish statistically. For the TiCA Lateral, it was "100% mild" post-correction. This uniform "mild" radiological finding, possibly reflecting a very slight residual equinus radiologically despite clinical resolution (or a stringent radiological definition of normal), would also show little covariation with the near-perfect Pirani scores. The Achilles tenotomy, a crucial part of Ponseti for most, directly addresses the equinus. It's possible that the tenotomy effectively "resets" the tibiocalcaneal relationship to a point where its residual radiological appearance (often a well-corrected but not "hyper-dorsiflexed" state) no longer strongly drives the very low overall Pirani score. The negative (though non-significant) 'r' value for TiCA lateral post-correction is likely statistical noise with no clinical meaning. The source's discussion point that the TiCA lateral angle is not suitable for assessing clinical deformity or monitoring treatment outcomes seems particularly relevant in the post-correction phase.[19,20]

The Ponseti method works by inducing biological remodeling of the soft tissues. The sustained gentle stretch leads to increased collagen synthesis and fiber reorientation in ligaments, tendons, and joint capsules, allowing them to elongate and adapt to the new, corrected position of the bones. The tarsal bones themselves, being largely cartilaginous in infancy, also possess some capacity for plastic deformation and adaptive growth in response to altered mechanical forces. The radiological angles serve as proxies for these anatomical changes. The TCA AP and Talo-1st Metatarsal angles, reflecting complex multi-planar relationships in the hindfoot-midfoot complex, appear to be robust indicators of the success of this remodeling process, both initially and in the finely-tuned post-correction state. Their continued correlation with the Pirani score suggests that successful Ponseti treatment achieves not just a superficial clinical correction but a genuine, measurable realignment of these core skeletal structures. This supports the idea that achieving good

radiological parameters, particularly for TCA AP and Talo-1st MT, in conjunction with an excellent Pirani score, is desirable for long-term stability. The study's findings reinforce the idea that while clinical assessment (Pirani score) is paramount for its ease of use and dynamic assessment of reducibility, radiological assessment focusing on specific angles like TCA AP and Talo-1st Metatarsal can provide valuable objective confirmation and potentially detect subtle residual issues. This is particularly important because incomplete correction is a known risk factor for recurrence.

While this study provides significant insights, its single-center nature and the lack of reported inter-observer reliability for measurements are limitations to consider. Future research should logically extend to long-term follow-up of such cohorts to correlate these early post-correction clinical and radiological parameters with eventual functional outcomes and recurrence rates. Incorporating functional assessments like gait analysis or patient-reported outcomes would provide a more holistic view of success. Further investigation into the specific biomechanical implications of the "mild" TiCA lateral findings post-correction is also warranted. Multi-center studies could help validate these findings more broadly and explore demographic variations.

5. Conclusion

This study, conducted at Dr. Mohammad Hoesin General Hospital Palembang, systematically evaluated the relationship between clinical Pirani scores and specific radiological parameters in infants with congenital talipes equinovarus (CTEV) managed by the Ponseti method. The demographic analysis of the 29 participants revealed a majority of females and a mean age of approximately five to six months at the start of treatment, with most cases being sporadic. The Ponseti method demonstrated high efficacy, achieving a statistically significant and clinically substantial reduction in Pirani scores, indicative of marked improvement in the foot deformity. This clinical enhancement was consistently paralleled by significant amelioration in radiological angles, with most measurements for TCA AP, Talo-1st metatarsal, and TCA lateral angles approaching or reaching normal ranges post-correction. Crucially, the research established strong, positive correlations between pre-treatment Pirani scores and the radiological angles of TCA AP, Talo-1st metatarsal, and TCA Lateral. This affirms the Pirani score's utility in accurately reflecting the initial anatomical severity of CTEV. Following Ponseti correction, moderate yet statistically significant positive correlations persisted between the Pirani score and both the TCA AP and Talo-1st Metatarsal angles. This suggests these two radiological parameters remain sensitive indicators of the foot's corrected structural status, aligning with subtle clinical variations even after substantial improvement. The TCA Lateral and TiCA Lateral angles, however, showed weaker and non-significant correlations with the Pirani score post-correction. In essence, this study underscores the synergistic value of integrating clinical Pirani scoring with targeted radiological assessment, particularly focusing on the TCA AP and Talo-1st Metatarsal angles, for a comprehensive evaluation of CTEV throughout Ponseti treatment. While the Pirani score is central to clinical monitoring, these specific radiological measures offer objective confirmation of anatomical realignment, reflecting the successful structural remodeling essential to the Ponseti philosophy. Future long-term follow-up is recommended to ascertain the prognostic significance of these early clinical-radiological findings for functional outcomes and recurrence.

6. References

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