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Original Research Article

Distal tibia physeal fractures and premature growth arrest

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ABSTRACT

Background: Distal tibia children's physeal fractures can cause growth complications, as premature physeal closure (PPC), which is radiographic growth plate closure compared to unaffected side.
Methods: Retrospective analysis of 243 patients, conducted to assess occurrence of physeal growth arrest. The study aims to identify factors associated with risk of PPC, investigate how common these complications are and to identify factors might predict their occurrence. Data of 243 children with distal tibial physeal fractures were reviewed in multiple military hospitals in Jordan between January 2018 and October 2023.
Results: Average follow-up was 37 weeks. PPC occurred in 29 cases (12.1%). Majority of PPC cases (64%) associated with Salter-Harris II fractures (19 cases), 14% in Salter-Harris III (4), 14% in Salter-Harris IV (4 cases), 8% in triplane fractures (2 cases). No cases of physeal arrest found in Salter-Harris I or Tillaux fractures. Cox multivariate regression analysis revealed statistically significant associations between mechanism of injury and PPC, and between degree of initial displacement and PPC. Each millimeter of initial displacement increased relative risk of PPC by 1.15 ($P < 0.01$). Although trends suggested possible link between residual displacement after reduction or number of reduction attempts and PPC risk, these correlations were not significant.
Conclusions: Recent studies reported higher PPC following distal tibial physeal fractures compared to this cohort. Significant predictors of PPC included extent of initial fracture displacement and mechanism of injury. While trends noted regarding residual displacement and number of reduction attempts, found not significant in predicting PPC.

Keywords: Salter Harris fractures, Premature physeal closure, Closed reduction percuatous pinning, Cast, Open reduction internal fixation

INTRODUCTION

Physeal fractures in children's distal tibia can sometimes lead to growth complications, such as premature physeal closure (PPC).[1-3,5,12,15] Those fractures are classified according to Salter Harris Classification (Figure 1).[14,15] PPC was defined as radiographic evidence of growth plate closure compared to the unaffected side.[8,10,11]

The study aims to measure the frequency of PPC and determine how variables like fracture type, displacement, and treatment methods influence outcomes. Patient charts were reviewed for cases between 2018 and October 2023. Follow-up continued until growth was observed to be symmetrical or the growth plates naturally closed. The study also used advanced statistical methods, such as Cox regression analysis, to evaluate the data.

METHODS

This is a retrospective study of 243 pediatric patients was conducted to assess the occurrence of physeal growth arrest, also referred to as premature physeal closure (PPC), following fractures of the distal tibial physis. The study also aimed to identify clinical factors associated with the risk of PPC and to investigate how common these complications are and to identify factors that might predict their occurrence. Medical records of 243 children with distal tibial physeal fractures were reviewed in multiple military hospitals, whose this study took place in the following military hospitals including Royal Jordanian Rehabilitation Center, Prince Ali Military hospital, Prince Hashem Bin Al Hussien Military hospital and Princess Haya military hospital during the period between January 2018 and October 2023.

Follow-up was maintained until either symmetric growth (confirmed via Harris growth lines) was observed for at least one year or physiologic growth plate closure was confirmed radiographically. The selection criteria included having isolated distal tibia physeal fracture (no association with other fractures), closed fractures, direct trauma related injuries (pathological fractures were excluded), no metabolic origin fractures were accepted in the study and no missing of following more than 6 months (follow up was conducted over 1 year). According to this selection criteria, and after fully reviewing for 347 patients, 104 patients were excluded from this retrospective study, ending in conducting this study over 243 patients. The overall incidence of PPC, as well as the rate of occurrence by fracture type, was calculated.

The management for distal tibia physeal injuries varied from: Closed reduction and casting, Closed reduction and percutaneous pinning (CRPP) with either screw or wires, and open reduction and internal fixation (ORIF) with either screw or wires. Regarding the procedure of ORIF, we start with addressing the suitable surgical approach regarding the character of the fracture we have. After opening layer by layer through the determined approach, we reach the fracture site, removal of the interposed periosteum inside the fracture then we obtain anatomical reduction for the fracture. Provisional fixation is obtained using k wires and or bone reduction C clamp, then we apply screws perpendicular to fracture site as needed. Closure is done layer by layer, and cast is applied 2 to 6 weeks. Then range of motion and rehabilitation exercises are initiated then.

Ethical approval was obtained by the ethical committee of directorate of professional training and planning in Royal Medical Services under the IRB number 31/1/2025. Finally, a Cox multivariate regression analysis was performed to evaluate various clinical factors which will be detailed in the discussion section below.

RESULTS

The average follow-up period was 37 weeks. PPC occurred in 29 cases (12.1%). The majority of PPC cases (64%) were linked to Salter-Harris II fractures, followed by 14% in Salter-Harris III, 14% in Salter-Harris IV, and 8% in triplane fractures. No cases of physeal arrest were observed in Salter-Harris I or Tillaux fractures. Regarding injury mechanisms: High-energy injuries (e.g., motor vehicle accidents) significantly increased the risk of PPC compared to lower-energy causes like sports injuries or falls. And if we spot light on displacement impact: For every millimeter of initial fracture displacement, the risk of PPC increased by 15%. Residual displacement and repeated reduction attempt also trended toward higher PPC risk but were not statistically conclusive which was carried through Cox multivariate regression Tabel 2.

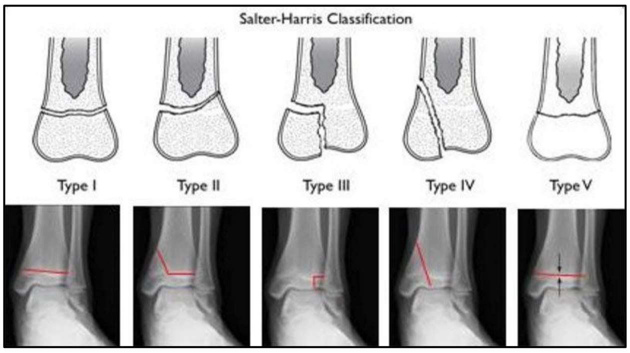

Figure 1: Salter Harris classification of growth plate injury.

Figure 2: (A) SH type I. (B) SH type II. (C) SH type III. (D) SH type IV.

Figure 3: (A) Tillaux fracture of distal tibia. (B) Triplane fracture of distal tibia.

Clinical implications

The study highlighted that fracture displacement and high-energy injuries are significant predictors of PPC. Minimizing the number of reduction attempts (ideally no more than one) may help reduce trauma to the growth plate Table 3.

Table 1: Summary of data distribution.

	No. Fx	% of patients	Sex, M/F	Mean Age, year	No. with surg Tx	No. PPC/% of PPC	Mean F/U, Wk	Physis closed at F/U
SH I	10	4	8/2	9.6	2	0/0	62.5	3/10
SH II	88	36	48/40	13.1	50	19/64	75.5	60/88
SH III	49	15	29/20	13.5	32	414	40.7	30/49
SH IV	24	10	11/13	12.7	11	4/14	111	20/24
Triplane	41	17	11/30	10.2	20	2/8	37.8	40/41
Tillaux	31	18	14/17	11.8	13	0/0	34.4	30/31

M/F indicates Male/Female; Surg Tx, Surgical treatment; F/U, Follow up.

Table 2: Cox multivariate regression analysis of PPC risk with risk factors, number of reductions, residual gap, and initial displacement.

Factors	Risk ratio	95% CI
No. reductions	1.15	0.556-2.27
Residual gap (mm)	1.23	0.935-1.94
Initial displacement (mm)	1.18	1.031-1.274

Table 3: Summary of patient data for patients with PPC.

	Gender		SH class				Mech of trauma			Initial displacement (mm)			Management			PPC age years		
	Male	**Female**	**2**	**3**	**4**	**5**	**Fall**	**Sports**	**MVA**	**<4**	**4-10**	**>10**	**Cast**	**CRPP**	**ORIF**	**<6**	**6-10**	**>10**
%	59	41	79	10	6	5	14	42	44	34	24	42	55	20	25	41	37	22
No.	17	12	23	3	2	1	4	12	13	10	7	12	16	6	7	12	11	6
	Mean age in Months						111.82											
	Mean of Number of reduction trials						1.58											
	Average Follow up time in months						74.37											
	Average of residual gap in mm						1.68											

Table 4: Frequency and proportion of PPC incidences according to number of reductions.

No. reductions					
PPC	**0**	**1**	**2**	**3**	**Total**
Yes, %	3 (3.5)	10 (10.0)	10 (19.0)	6 (75.0)	29 (12.1)
No, %	81 (96.5)	90 (90)	42 (81.0)	2 (25.0)	214 (87.9)
Total	83	100	52	8	243

Proper alignment through precise reductions, even surgical interventions, if necessary, might lower the likelihood of growth disturbances.

DISCUSSION

While looking through the literature, it was mentioned that Salter-Harris type I fractures represent approximately 15% of distal tibia physeal fracture Figure 2.[1,2,4,5] The literature reported a growth arrest rate of less than 4%. However, recent study by Barmada et al indicated that 66.7% of patients (4 out of 6) with Salter-Harris type I fractures experienced partial plate closure (PPC).[5] Despite this finding, the small sample size limits the ability to generalize these results. In this article, Salter-Harris type I fractures accounted for 5% of cases, and no instances of growth arrest were identified. Salter-Harris type II fractures constitute around 40% of distal tibia physeal fractures in the literature, closely aligning with the 35.71% observed in our cohort. Growth arrest following these fractures has historically been reported to occur at rates as low as 2% to 5%.[7-9] Initially considered minor injuries, type II fractures have since been associated with a higher risk of growth disturbances. Spiegel et al, documented a 16.7% growth disturbance rate, while Barmada et al reported a 36% incidence of partial plate closure when combining types I and II fractures, though they did not specify rates for type II alone.[5,11]

In our statistical analysis, the PPC rate for type II fractures was 25%, which decreased to 22% when types I and II were combined. This finding aligns with other research suggesting these injuries are more serious than previously assumed. Historically, it was well known that Salter-Harris types III and IV fractures have been estimated to account for roughly 25% of distal tibia physeal injuries.[10,14,15] These fractures are associated with higher risks of growth arrest and joint incongruity. Reported rates of growth arrest for these injuries range from 32% to 50%.[9,10] While in our study, the PPC rate was 14% for both type III and type IV fractures, with an overall combined rate of 14%, significantly lower than previously reported rates. Juvenile Tillaux and triplane fractures are known for their low risk of growth disturbances due to their occurrence in children nearing skeletal maturity Figure 3.[12,16] These injuries account for 3% to 5% of pediatric ankle fractures. The low risk is attributed to the closing state of the distal tibia physis at this stage.[12,16] In our cohort, we observed no cases of PPC in Tillaux fractures. Treatment for these fractures should prioritize accurate restoration of the joint surface to prevent ankle arthrosis.

Triplane fractures, which are classified as Salter-Harris type IV physeal fractures, involve the coronal, axial, and sagittal planes and represent 5% to 7% of pediatric ankle fractures.[12] Growth disturbance rates for these fractures vary widely in the literature. Barmada et al and Cooperman et al reported a 21% PPC rate, while Kay and Matthys noted a 10% rate.[5] In our cohort, the PPC rate for triplane fractures was 8%. Children with more than two years of growth remaining should be closely monitored for growth arrest. Long-term studies by Rapariz et al and Ertl et al suggest that growth arrest is not a major concern in patients nearing skeletal maturity.[12]

Treatment should focus on ensuring joint congruity to prevent ankle arthritis.[4,6,8] When analyzing our data, we categorized injuries based on their mechanism falls, sports-related activities, and motor vehicle accidents (MVA). Kaplan-Meier analysis revealed a statistically significant difference in PPC rates between high-energy (MVA) and low-energy mechanisms (sports or falls). Specifically, PPC occurred in 86% of fractures caused by MVAs, compared to 8% for sports injuries and 6% for falls ($p<0.001$). This highlights the increased risk of growth arrest associated with high-energy trauma, emphasizing the need for prolonged follow-up in such cases Tabel 3.[1,3,5,12] The influence of initial fracture displacement on the likelihood of PPC has been widely debated but not conclusively proven. Barmada et al reported PPC rates of 36% and 38% for combined types I/II and III/IV fractures, respectively, without finding a direct link to initial displacement.[5,12] Spiegel et al categorized fractures into low-risk, high-risk, and unpredictable groups, noting a correlation between displacement severity and complications but failing to quantify the risk.[11]

Our analysis found that for every millimetre of initial displacement, there was a 15% increase in PPC risk ($p<0.01$), suggesting a measurable relationship between displacement and complications. The role of residual fracture displacement in PPC remains uncertain. Some studies suggest that exact reduction may not be necessary, with Spiegel proposing that less than 2 mm of displacement is acceptable for types III and IV fractures.[1] Conversely, others have reported higher PPC rates with residual displacement, supported by animal studies showing that physeal cartilage injury combined with periosteal interposition disrupts growth plate organization.[13,14] While our findings did not show a statistically significant relationship between residual displacement and PPC, a trend was observed, supporting open reduction and internal fixation when anatomical reduction cannot be achieved. Another critical factor is the number of reduction attempts. Repeated manipulations can traumatize the physis, increasing the risk of PPC. Although Barmada et al found no significant correlation between reduction attempts and PPC, they recommended limiting attempts to two.[5]

Similarly, Kay et al and Matthys et al advised minimizing reductions to a single attempt.[9] In our cohort, PPC rates increased with the number of attempts, from 11% for one reduction to 24% for two and 50% for three attempts. Overall, our study reported a PPC rate of 12%, consistent with previous literature. While our cohort showed some variability in fracture type distribution, we identified statistically significant associations between PPC and certain risk factors. These findings can guide clinical decisions and help predict which patients are at greater risk of complications following distal tibia physeal fractures. Cox multivariate regression analysis was performed to evaluate various clinical factors Tabel 2.

The limitations we faced in our study were sample size which was affected by covid crises since that the study analysis were held over January 2018 and October 2023, during which covid crises has an effect over the sample size. Also, being a retrospective study is another limitation in analysis.

CONCLUSION

Recent studies have reported higher PPC rates following distal tibial physeal fractures compared to this study. Significant predictors of PPC included the extent of initial fracture displacement and the mechanism of injury. While trends were noted regarding residual displacement and the number of reduction attempts, these were not significant in predicting PPC.

This study found a PPC rate of 12%, consistent with earlier research, but identified specific risk factors that could inform clinical decisions. Monitoring patients with high-energy injuries, significant displacement, or multiple reduction attempts may help prevent or manage complications effectively.

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