Concomitant Injury and Complications Following Pediatric Tibial Spine Fractures

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Introduction

Tibial spine fractures are avulsion fractures of the tibial intercondylar eminence at the insertion of the anterior cruciate ligament. These injuries were once considered the childhood equivalent of the ACL injury, and though rare, occur most commonly in 8 to 14-year-old patients.[1]

Tibial spine fractures were originally classified as Type I, II, or III by Meyers and McKeever in 1959, and later modified to include type IV factures.[2, 3] Type I fractures are non-displaced, type II are displaced with an intact posterior hinge, type III are completely displaced, and type IV fractures are displaced and comminuted fractures.[2, 3]

Management of these injuries is controversial, especially for type II injuries since there is no consensus on optimal management in the literature.[4-6] Type I fractures may be managed with closed reduction, while types III and IV are best managed with surgical fixation.[1, 5, 6] For type II fractures, debate remains about whether they should first be managed with closed reduction rather than directly proceeding to internal fixation.[5-7]

These injuries are frequently associated with additional pathology. The most commonly seen concomitant pathology include meniscal tears, chondral injuries, and soft tissue entrapment in the fracture site.[8-10] Importantly, many of these injuries may prevent adequate reduction and can be treated at the time of surgical fixation. Early treatment may prevent further morbidity in the long term.

Methods and Materials

We retrospectively reviewed all patients treated surgically for tibial spine fractures between January 1, 2009 and December 31, 2015 at our institution. Pediatric patients 18 years or younger who presented and were initially treated surgically for a tibial spine fracture were included if followed for at least 3 months after surgery. Patients were excluded if they did not meet inclusion criteria, were initially treated at an outside institution, or lacked adequate follow-up or clinical data. Multi-trauma patients and those with additional lower extremity factures were also excluded.

82 patients with tibial spine fractures were identified between January 1, 2009 and December 31, 2015. After medical record review, 17 were excluded as they were managed non-operatively, 2 were excluded as they were initially treated at an outside hospital, 7 were excluded due to the presence of additional lower extremity fractures in the setting of severe trauma, and 7 were excluded for inadequate follow-up. An additional patient was excluded, as the fracture could not be classified since radiographs were not available and the operative note did not specify the degree of displacement. Thus, a total of 48 patients with tibial spine fractures were included in the analysis. All patients were treated surgically with arthroscopic assisted internal fixation. For the purpose of our analysis, arthrofibrosis was defined as a 10° extension deficit and/or 25° flexion loss 3 months after treatment that persisted despite physical therapy and was not caused by nonunion, malunion, a new injury, a ligamentous or meniscal injury, or a bony deformity.

Patient demographics, fracture classification, mechanism of injury, length of immobilization, concomitant injury patterns, and reoperation rates were collected. All fractures were classified as either Type I, II, or III according the Meyers & McKeever system and comminuted injuries were classified as Type IV as described by Zaricznyj.[2, 3]

Standard descriptive summaries (e.g. means and standard deviations for continuous variables such as age and percentage for categorical variables such as gender) were used to summarize demographic variables. Comparisons of categorical variables between groups were made using the Chi-Square or Fisher's exact test, depending on sample size. Statistical analysis was performed using the data analysis software SPSS® Version 24 (SPSS Inc., Chicago, IL) and Microsoft Excel 2011.

Results

There were 48 patients analyzed in the study, including 31 males and 17 females with an average age of 12.5 years (range, 7.4-17.5 years). There were no Type I, 14 Type II, 21 Type III, and 13 type IV fractures. The fractures most commonly resulted from twisting (20) or contact (18), but the injury also resulted from hyperextension in six patients. The mechanism of injury could not be determined from the patient record in four patients. Fifteen patients

Table 1. Patient Demographics

Average Age (years)	12.5 (7.4-17.5)
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Sex	
Male	31
Female	17
Height (cm)	157.8 (122-180)
Weight (kg)	53.3 (22.7-89.8)
BMI	21.0 (14.9–32.1)
Fracture Type Type II	14
Type III	21
Type IV	13
Mechanism Twisting	20
Contact	18
Hyperextension	6
Immobilized	31.4%
Days Immobilized	18.1 (6-43)
Follow-up (months)	11.1 (3.0-40.0)

Table 2. Concomitant Pathology

	Type II N=14	Type III N=21	Type IV N=13	Total N=48	P-Value
Meniscal injury	4 (28.6%)	7 (33.3%)	8 (61.5%)	19 (39.6%)	.160
Lateral Meniscus	3 (75%)	7 (100%)	7 (87.5%)	17 (89.5%)	
Medial Meniscus	1 (25%)	0 (0.0%)	1 (12.5%)	2 (10.5%)	
Soft Tissue Entrapment	6 (42.8%)	7 (33.3%)	6 (46.2%)	19 (39.6%)	.726
Meniscus	1 (16.7%)	3 (50%)	1 (16.7)	5 (27.8%)	
Intermeniscal Ligament	5 (83.3%)	3 (50%)	5 (83.5%)	13 (72.2%)	
Ligamentous Injury	1 (7.1%)	0 (0.0%)	2 (15.4%)	3 (6.3%)	.101
ACL	1 (100%)	0 (0.0%)	1 (50%)	2 (66.7%)	
MCL	0 (0.0%)	0 (0.0%)	1 (50%)	1 (33.3%)	
Loose body	1 (6.7%)	7 (33.3%)	5 (38.5%)	13 (27.1%)	.121
Chondral Injury	2 (14.3%)	3 (14.3%)	5 (38.5%)	9 (18.8%)	.259
None	3 (21.4%)	6 (28.6%)	0 (0.0%)	9 (18.8%)	.099
Number of Injuries (per Patient)	17 (1.1)	27 (1.3)	25 (1.9)	66 (1.7)	.116

(31.3%) were immobilized for an average of 18.1 days (range 6-43 days). The remaining patients were treated with continuous passive motion machines (CPM). (Table 1)

At the time of initial surgery, concomitant pathology was very common. Overall 81.2% of the patients suffered additional injuries, with an average of 1.7 injuries per patient. All of the type IV fractures suffered concomitant injuries, while only 78.6% of the type II fractures and 71.4% of the type III injuries were found to have suffered additional injuries, though a significant difference in the rate of concomitant pathology was not found (p = 0.099). The most common injuries were meniscal tears, soft tissue entrapment, chondral injuries, and loose bodies. Overall, there was a 39.6% incidence of meniscal pathology. Although meniscal injury was found in 61.5% of type IV fractures compared to only 28.6% of type II fractures and 33.3% of type III fractures, this difference was not significant (p = .160).

There was an overall 39.6% incidence of soft tissue entrapment. Soft tissue entrapment was found at similar rates across different fracture types with involvement in 42.8% of type II fractures, 33.3% of type III fractures, and 46.2% of type IV fractures (p = .726). The incidence of loose bodies was 6.7% in type II fractures, 33.3% in type III fractures, and 38.5% in type IV fractures for an overall incidence of 27.1%, and no statistical difference between fracture types (p = .121). 14.3% of type II fractures, 14.3% type III fractures, and 38.5% of type IV fractures were found to have chondral lesions for an overall incidence of 18.8%. There was no significant difference in the presence of associated chondral lesions between fracture types (p = .259). The most common finding was grade 1 chondromalacia of the patella, though three of the type IV fractures had more severe grade 2-3 chondromalacia or fissuring of the tibial plateau or femoral condyles. One patient required chondroplasty. 7.1% of type II fractures, no type III fractures, and 15.4% of type IV fractures were found to have ligamentous injuries for an overall incidence of 6.3% with no significant difference between fracture types (p = .101). Table 2 demonstrates the concomitant injury pattern for each fracture type.

Ten of forty-eight (20.8%) patients underwent reoperation during their treatment course, but half of the reoperation cases were for scheduled removal of hardware (10.4%). For the remaining patients, there were three cases of arthrofibrosis, two were in type IV fractures and one was in a type II fracture in the setting of a surgical infection. All were treated with lysis of adhesions and manipulation under anesthesia. There were two ACL reconstructions. One patient was treated for a newly ruptured ACL. A second patient had an ACLR for a rupture that occurred at the time of the initial injury, but reconstruction was delayed until after fixation of the tibial spine. This patient also underwent manipulation for knee stiffness at the time of the ACLR. (Table 3).

Discussion

Though tibial spine fractures are rare injuries, they can be significant due to the high risk for concomitant pathology and the potential for complications. Mitchell et al. conducted a review of 58 patients with tibial spine injuries and found no concomitant injuries in type I fractures, meniscal injury in 29% of type II fractures and 12% of type III fractures, entrapment in 33% of type II fractures and 48% of type III fractures, and chondral injury in 7% of type II fractures and 8% of type III fractures.[9] Overall, the authors found 59% of patients had concomitant pathology with 48 injuries occurring in 34 patients for an average of 1.4 injuries per patient. We found higher rates of concomitant pathology in our cohort (81.2%) with 66 injuries occurring in 39 patients for an average of 1.7 injuries per patient.

A wide range of incidence for associated meniscal and chondral injuries, ranging from 3.8% to 40%, has been reported in the literature.[9-14] Kocher et al. found only three meniscal injuries in a series of 80 skeletally immature patients treated for tibial spine fractures, which differs by over a factor of ten from the 39.6% that we report.[10] This wide range may owe to the differing definitions and methods of detection. Some studies use direct visualization under arthroscopy while others may rely on MRI, which has been found to be less reliable than direct visualization.[8, 9] Additionally, it is unclear how fracture classification affects injury rates as few studies distinguish between type III and type IV fractures. Our results are near the upper end of the reported spectrum, which may in part be due to selection bias of limiting our investigation to surgical patients as well as the relatively high proportion of type III and IV fractures in our sample. Classification of injury or method of detection may also play a role as we relied on arthroscopy in this cohort, however Shea et al. found 8 of 20 (40%) skeletally immature patients had associated meniscal injury based solely on MRI.[11]

Soft tissue entrapment, most commonly of either the anterior horn of the meniscus or the intermeniscal ligament, is known to block adequate reduction of type II and III fractures, though the incidence is less well characterized in type IV fractures.[10, 15] Kocher et al. also found soft tissue entrapment in 54% of cases with 26% occurring with type II and 65% occurring with type III fractures.[10] In most cases, the anterior horn of the meniscus was interposed. A prior study had also found interposition of the anterior horn of the meniscus in 90% of cases of type III fractures.[16] However, in our cohort, the intermeniscal ligament was interposed in the majority of cases of soft tissue entrapment (72.2%) with similar rates for type II, III, and IV fractures (42.8%, 33.3%, 46.2%, p=.726)

The incidence of chondral injury in tibial spine fractures is not well characterized. Mitchell et al reported a 7% rate of chondral injury in type II injuries and 8% in type III injuries.[9] We found an overall 18.8% rate, with 14.3% in both type II and type III and 38.5% in type IV fractures. While there were more chondral lesions in type IV fractures, this did not reach statistical significance. However, the group did have the most severe chondral injuries, with one requiring chondroplasty for grade 2-3 chondromalacia of the lateral femoral condyle.

The most debated fracture pattern is the type II fracture, as there is no consensus in the literature regarding optimal treatment.[1, 5, 6] However, some have recommended that first line treatment should be closed reduction, and advancing to surgery only if conservative management fails or if the fracture is not adequately reduced in extension.[10, 17] While similar outcomes have been found across open reduction, arthroscopic reduction, and closed reduction, one study did find a 16.7% reoperation for type II fractures that were managed conservatively due to loose bodies, continued instability, and soft tissue impingement.[4, 6, 18] Furthermore, a review of large series of consecutive tibial spine fractures found 47% of type II fractures would not reduce in extension, and of those, 26% had meniscal entrapment in the fracture site.[10]

In our series, we found a 20.8% reoperation rate (10 of 48 patients). The most common reason for reoperation was for removal of hardware, though this may be avoided with suture, suture anchor, or bioabsorable screw fixation methods. Other than removal of hardware, the most common reasons for reoperation were arthrofibrosis and ACLR. One patient had a ruptured ACL at the time of the tibial spine injury, and so delayed reconstruction was indicated. At the time of reconstruction, the patient also underwent manipulation for knee stiffness. There were three patients who developed arthrofibrosis and were treated with lysis of adhesions and manipulation under anesthesia. Overall, the rate of arthrofibrosis in this study was low (6.25%) compared to reported rates, which range from 2.7% to 38% and most commonly are reported between 10% and 15%.[4, 6, 7, 18-20] The lower rate in our series may be attributed to the early range of motion (ROM) treatment initiated in the majority of patients (68.6%). Patel et al. reviewed 40 tibial

Table 3. Reoperation and Complications

Patient	Fracture Type	Procedure	Indication	Associated Pathology
1	II	Lysis of Adhesions and Manipulation Under Anesthesia	Arthrofibrosis and Infection	
2	III	ACL Reconstruction	New ACL Rupture	
3	IV	ACL Reconstruction and Manipulation Under Anesthesia	Delayed ACL Reconstruction	Knee Stiffness
4	IV	Lysis of Adhesions and Manipulation Under Anesthesia	Arthrofibrosis	Meniscal Tear
5	IV	Lysis of Adhesions and Manipulation Under Anesthesia	Arthrofibrosis	
6	III	Removal of hardware	Retained Hardware	
7	II	Removal of hardware	Retained Hardware	
8	III	Removal of hardware	Retained Hardware	Chondral Injury and Meniscal Tear
9	II	Removal of hardware	Retained Hardware	
10	IV	Removal of hardware	Retained Hardware	Chondral Injury

spine fracture patients and found that there was a 12-fold increase in arthrofibrosis for patients who initiated ROM later than 4 weeks.[20]

Limitations of this study include its retrospective nature and small sample size. A convenience sample was used owing to the rare nature of the condition. Larger sample sizes may aid in detecting difference in injury patterns and injury rates between fracture types. Furthermore, only surgical patients were evaluated, which have introduced selection bias as less severe fractures, such as type I fractures or minimally displaced type II fractures, may have been more likely to be treated with closed reduction.

We noted a high rate of additional knee pathologies in this series of tibial spine fractures. The most common injuries are soft tissue interposed in the fracture site and meniscal injury. Chondral injuries are less common, except in type IV fractures, and ligamentous injury is rare. Types II, III, and IV fractures had similar rates of overall concomitant pathology. Other than hardware removal, the most common reason for reoperation were arthrofibrosis and ACL injuries. Given the high rate of additional injuries, MRI evaluation and a low threshold for surgical fixation should be considered, even for type II fractures. A high index of suspicion for additional injuries is required when treating tibial spine fractures as concomitant pathology is very common.

References

1. **Herman MJ, Martinek MA, Abzug JM.** Complications of tibial eminence and diaphyseal fractures in children: prevention and treatment. *Instr Course Lect.* 2015;64:471-82.

2. **Meyers MH, Mc KF.** Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg Am.* 1959;41-A(2):209-20; discussion 20-2.

3. **Zaricznyj B.** Avulsion fracture of the tibial eminence: treatment by open reduction and pinning. *J Bone Joint Surg Am.* 1977;59(8):1111-4.

4. **Gans I, Baldwin KD, Ganley TJ.** Treatment and management outcomes of tibial eminence fractures in pediatric patients a systematic review. *The American Journal of Sports Medicine.* 2013:0363546513508538.

5. **Beck NA, Patel NM, Ganley TJ.** The pediatric knee: current concepts in sports medicine. *Journal of Pediatric Orthopaedics B.* 2014;23(1):59-66.

6. **Coyle C, Jagernauth S, Ramachandran M.** Tibial eminence fractures in the paediatric population: a systematic review. *J Child Orthop.* 2014;8(2):149-59.

7. **Osti L, Buda M, Soldati F, Del Buono A, Osti R, Maffulli N.** Arthroscopic treatment of tibial eminence fracture: a systematic review of different fixation methods. *British Medical Bulletin.* 2016.

8. **Johnson AC, Wyatt JD, Treme G, Veitch AJ.** Incidence of associated knee injury in pediatric tibial eminence fractures. *J Knee Surg.* 2014;27(3):215-9.

9. **Mitchell JJ, Sjostrom R, Mansour AA, Irion B, Hotchkiss M, Terhune EB, *et al.*** Incidence of meniscal injury and chondral pathology in anterior tibial spine fractures of children. *Journal of Pediatric Orthopaedics.* 2015;35(2):130-5.

10. **Kocher MS, Micheli LJ, Gerbino P, Hresko MT.** Tibial eminence fractures in children: prevalence of meniscal entrapment. *The American Journal of Sports Medicine.* 2003;31(3):404-7.

11. **Shea KG, Grimm NL, Laor T, Wall E.** Bone bruises and meniscal tears on MRI in skeletally immature children with tibial eminence fractures. *J Pediatr Orthop.* 2011;31(2):150-2.

12. **Aderinto J, Walmsley P, Keating JF.** Fractures of the tibial spine: epidemiology and outcome. *Knee.* 2008;15(3):164-7.

13. **Casalonga A, Bourelle S, Chalencon F, De Oliviera L, Gautheron V, Cottalorda J.** Tibial intercondylar eminence fractures in children: The long-term perspective. *Orthop Traumatol Surg Res.* 2010;96(5):525-30.

14. **Reynders P, Reynders K, Broos P.** Pediatric and adolescent tibial eminence fractures: arthroscopic cannulated screw fixation. *J Trauma.* 2002;53(1):49-54.

15. **Archibald-Seiffer N, Jacobs J, Zbojniewicz A, Shea K.** Incarceration of the intermeniscal ligament in tibial eminence injury: a block to closed reduction identified using MRI. *Skeletal Radiol.* 2015;44(5):717-21.

16. **Mah JY, Adili A, Otsuka NY, Ogilvie R.** Follow-up study of arthroscopic reduction and fixation of type III tibial-eminence fractures. *J Pediatr Orthop.* 1998;18(4):475-7.

17. **Hunter RE, Willis JA.** Arthroscopic fixation of avulsion fractures of the tibial eminence: technique and outcome. *Arthroscopy.* 2004;20(2):113-21.

18. **Edmonds EW, Fornari ED, Dashe J, Roocroft JH, King MM, Pennock AT.** Results of Displaced Pediatric Tibial Spine Fractures: A Comparison Between Open, Arthroscopic, and Closed Management. *J Pediatr Orthop.* 2015;35(7):651-6.

19. **Vander Have KL, Ganley TJ, Kocher MS, Price CT, Herrera-Soto JA.** Arthrofibrosis after surgical fixation of tibial eminence fractures in children and adolescents. *The American Journal of Sports Medicine.* 2010;38(2):298-301.

20. **Patel NM, Park MJ, Sampson NR, Ganley TJ.** Tibial eminence fractures in children: earlier posttreatment mobilization results in improved outcomes. *Journal of Pediatric Orthopaedics.* 2012;32(2):139-44.