Original Article

Tibial Spine Repair in the Pediatric Population: Outcomes and Subsequent Injury Rates

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Purpose: To evaluate short- to mid-term outcomes after arthroscopic operative fixation of tibial spine fractures in pediatric patients, to determine the incidence of further ipsilateral and contralateral knee injuries, and to describe associated meniscal pathology and intraoperative findings at the time of tibial spine repair. **Methods:** All patients under age 18 with a tibial spine fracture treated arthroscopically at 1 institution by 2 surgeons from 2008 through 2019 were identified by Current Procedural Terminology codes. Patients at least 1 year from their date of surgery were contacted to complete a questionnaire, which included the International Knee Documentation Committee (IKDC) form. Questions pertained to knee function, pain, and further injury or surgery on either knee. Patient charts, preoperative imaging, and operative reports were reviewed to determine demographic information, tibial spine fracture type, concomitant injuries, and intraoperative details. **Results:** Sixty-six of 97 eligible patients (68%) completed questionnaires. Average age at initial surgery was 10.7 years (range, 4-17). Mean follow-up was 5.8 years (range, 1.0-11.9). Average IKDC score at follow-up was 91.4 (range, 62.1-100). Patients reported their knee as 92% of "normal" (range, 40-100). Thirty-five (53%) currently participate in sport; 6 (9%) remain limited because of instability and residual pain. Regarding pain on a visual analog scale, 94%, 95%, and 83% of patients reported less than a 3 at rest, with daily activity, and with sport, respectively. Seven patients (11%) had subsequent ACL rupture. Six patients (9%) underwent ACL reconstruction 3.1 years (range, 0.9-7) after initial repair. Fourteen patients (21%) required at least 1 additional procedure. Regarding the contralateral knee, there were no ACL or tibial spine injuries. Sixty-one (92%) patients were both satisfied and would definitely undergo the procedure again. **Conclusions:** Although many pediatric patients demonstrate excellent results after tibial spine repair at mean 5.8 years follow-up, 10.6% sustained an ipsilateral ACL rupture, and 21% required an additional procedure. No patient had a contralateral tibial spine or ACL injury. This is helpful when counseling patients regarding injury risk when returning to activity after tibial spine repair. **Level of Evidence:** Level IV, therapeutic case series.

Tibial spine avulsion has been described as an ACL injury equivalent in the pediatric population. Injury results from a similar mechanism because there is rotation on a planted leg with or without contact. In adults this causes rupture of the ACL; however, in the developing skeleton the ligament is stronger than the bone interface, often leading to an avulsion fracture.[1]

Treatment for tibial spine fracture ranges from nonoperative immobilization to operative fixation depending on continuity and displacement of the fragment. Operative treatment is typically recommended with any degree of displacement because failure to do so may lead to residual instability.[1] Even when fixed, objective residual instability may be noted

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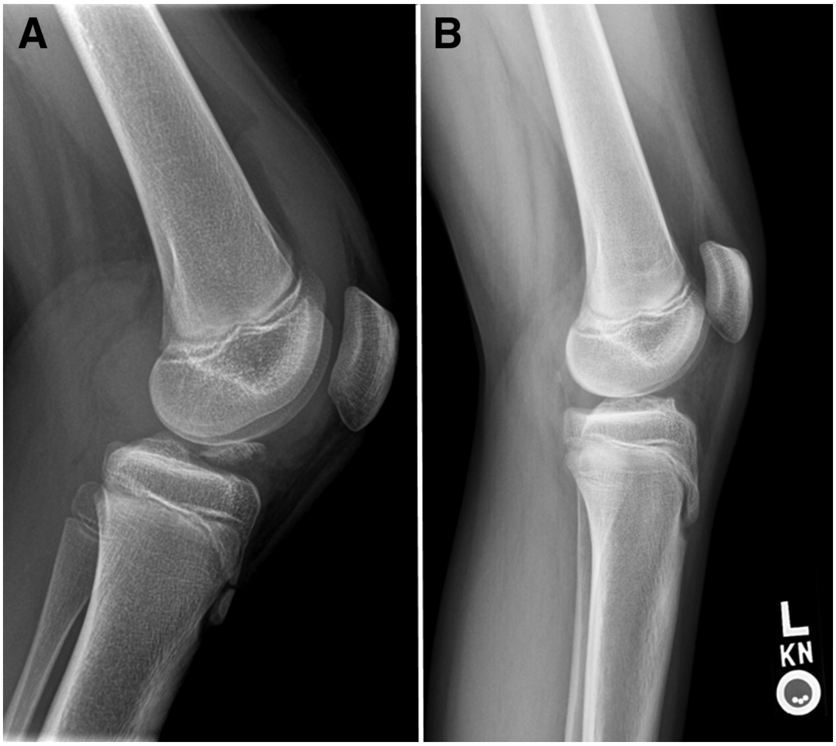

Fig 1. (A) Preoperative sagittal radiograph of a left knee demonstrating a type III tibial spine avulsion fracture. (B) Postoperative sagittal radiograph of the same left knee demonstrating complete healing after arthroscopic reduction and internal fixation of the fracture fragment.

on examination; however, this does not always correlate with outcome scores or subjective feelings of instability.[2-13] Although few studies report mid- to long- term results of tibial spine avulsions, most demonstrate good functional results with return to sport.[2,3,6-8,10,12-15]

However, residual instability, even if not perceived by the patient, raises concern for future injury. In particular, whether these patients are more susceptible to ipsilateral ACL rupture as they reach adulthood is unclear, with incidence ranging from 1% to 19% in a limited number of studies.[2,7,10,12-15] Additionally, in the adult population, athletes who sustain an ACL injury are prone to contralateral ACL rupture at an alarming rate of 20%.[16] Whether this is also true for tibial spine avulsions is unknown.

Given the young age at which this injury occurs and that it may alter knee stability, understanding outcomes is essential in guiding treatment decisions and advising patients. Failure to appropriately treat can lead to lifelong knee issues with increased risk for further injury. The purposes of this study were to evaluate short- to mid-term outcomes after arthroscopic operative fixation of tibial spine fractures in pediatric patients, to determine the incidence of further ipsilateral and contralateral knee injuries, and to describe associated meniscal pathology and intraoperative findings at the time of tibial spine repair. We hypothesized that pediatric patients undergoing tibial spine repair would have good mid-term outcomes yet, similar to patients undergoing ACL reconstruction, would have comparable rates of subsequent ACL events both ipsilateral and contralateral.

Methods

Study Cohort

With institutional review board approval, a hospital billing database was searched by Current Procedural Terminology code to identify patients who underwent operative fixation of a tibial spine injury by either of 2 surgeons (S.K.A., T.G.M.) at 1 institution between May 2008 and November 2019. Inclusion criteria were age younger than 18 at the time of surgery and patients coded with Current Procedural Terminology code 29851, which indicates “Arthroscopically aided treatment of intercondylar spine(s) and/or tuberosity fracture(s) of the knee, with or without manipulation; with internal or external fixation (includes arthroscopy).” Anyone who did not compete the survey was excluded. Chart review was performed to collect baseline cohort characteristics, including age, sex, body mass index, race, and ethnicity. Operative and clinic notes were reviewed to verify index procedure, the presence of meniscal pathology, other procedures at the time of tibial spine repair, and incarcerated structures preventing reduction at the time of surgery. When available, radiographs of the initial injury were evaluated for

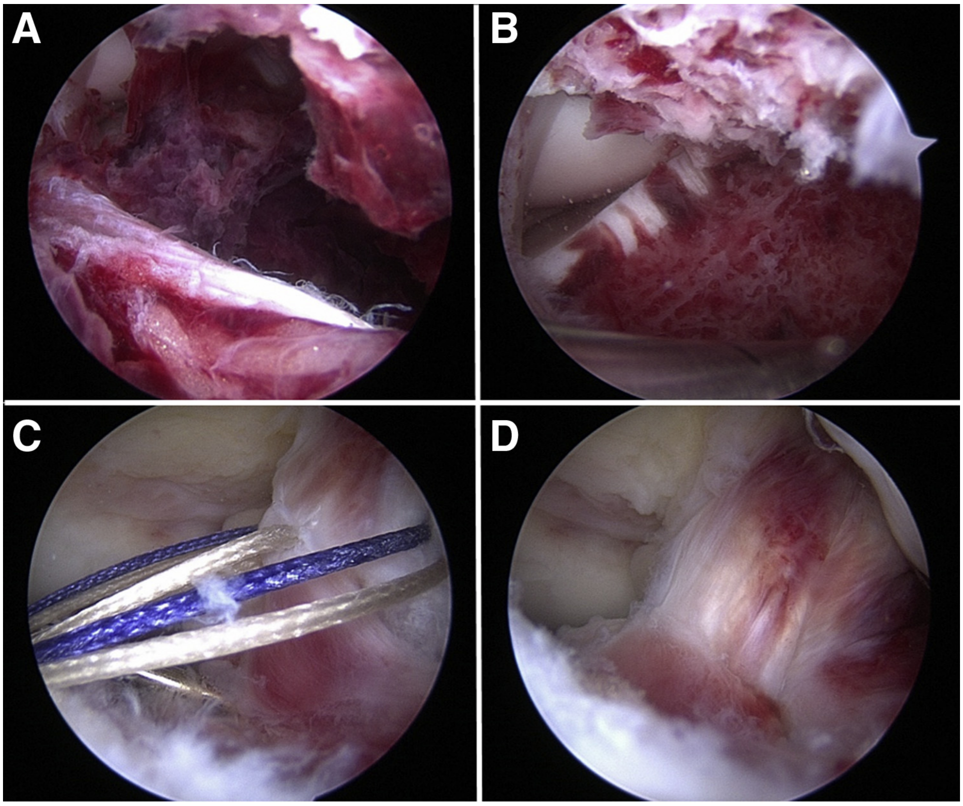

Fig 2. Arthroscopic images of the left knee shown in Figure 1 demonstrating (A) displaced tibial spine fracture, (B) fragment preparation, (C) suture placement, and (D) final reduction.

classification (Fig 1) by 2 fourth-year orthopaedic surgery residents (N.J.Q., T.E.H.); otherwise, this was obtained from documentation. Classification of tibial spine injuries was recorded according to the Meyers and McKeever classification[17] and later added to by Zaricznyj:[18] nondisplaced (type I), partially displaced with intact posterior hinge (type II), completely displaced (type III), and displaced with comminution (type IV).

Surgical Technique and Postoperative Protocol

Surgery included a diagnostic arthroscopy with evaluation of meniscus, cartilage, and ligaments. Meniscal pathology was treated with repair or debridement as indicated on the basis of the intraoperative evaluation. Repair was performed with suture tied over a bony bridge (Fig 2). After surgery, patients were placed in extension. Postoperative protocol consisted of toe-touch weightbearing for 4 to 6 weeks in an extension splint, cast, or immobilizer for 2 to 4 weeks. At 2 to 4 weeks after surgery, patients began range of motion exercises in the physical therapy setting. At 4 to 6 weeks after surgery, patients began weightbearing as tolerated. Early variation in motion varied by surgeon preference. At 8 weeks after surgery, patients were permitted progression as tolerated with limitations including no running, jumping, or pivoting. At 12 weeks, given adequate strength, patients were permitted to begin jogging. Pending progression, patients were cleared for full sport at 4 to 6 months after surgery.

Survey Methodology

Through review of the electronic medical records, contact information including mailing address, phone number, and email were obtained. Patients were first contacted by mail in February 2020 alerting them of the study and then contacted via phone for further participation between March 2020 and June 2020. If willing to participate, questionnaires were completed over the phone with responses directly recorded in the REDCap by a research coordinator or an e-mail link was sent to the patient to complete questionnaires online with responses automatically recorded in REDCap. Patients were called a minimum of 5 times to maximize the response rate.

Patients completed 1 all-encompassing questionnaire (Appendix 1) regarding function, pain, satisfaction, further injury or surgery to either knee, and current participation in sport. International Knee Documentation Committee Subjective Knee Form (IKDC) questions[19-22] were embedded within this.

Statistical Analyses

Data was exported to Microsoft Excel for further analysis. IKDC scores were calculated. For patients who indicated additional injury or surgery to either knee,

Table 1. Baseline Cohort Characteristics and Tibial Spine Fracture Classifications

Age at Time of Surgery, years, mean (Range)	10.7 (4-17)
Laterality, n (%)	
Right	35 (53%)
Left	31 (47%)
Sex, n (%)	
Male	33 (50%)
Female	33 (50%)
Body mass index, mean (range)	18.1 (12.1-28.5)
Race,* n (%)	
White	58 (88%)
Native Hawaiian or Pacific Islander	3 (5%)
American Indian or Alaskan Native	1 (2%)
Ethnicity,* n (%)	
Non-Hispanic/Latino	58 (88%)
Hispanic/Latino	6 (9%)
Tibial spine fracture type,† n (%)	
II	31 (47%)
III	17 (26%)
IV	8 (12%)

*Race was unavailable for 4 patients, and ethnicity was unavailable for 2 patients.

†Fracture type as defined by the Modified Meyers and McKeever Classification.[17,18] Radiographs were used for classification in 58 (88%), magnetic resonance imaging in 1 (2%), and computed tomography in 2 (3%) patients. Preoperative imaging was unavailable for review and classification of fracture type in 5 (8%) patients.

chart review was performed to review clinic and operative reports. Analysis included T-Test for continuous variables (Microsoft Excel), and Fisher Exact Test for categorical variables (IBM SPSS 27). Significance was set at $P < .05$.

Results

Ninety-seven patients met inclusion criteria, of whom 66 (68%) completed questionnaires. Thirty-one patients did not complete the survey and were excluded from the study analysis. Of those 31 patients, 25 did not respond after attempting to contact them at least 5 times via phone calls, voicemail, and e-mail, whereas 6 were unable to be reached because no working phone number, e-mail, or address was available after extensive chart review. In the 66 patients who completed the survey, average age at time of surgery was 10.7 years (range, 4-17) and there were 33 males (50%). Further demographic information is provided in Table 1. There were 35 (53%) right- compared to 31 (47%) left-sided injuries.

Fifty-six (84%) had preoperative imaging available for review in the form of radiograph, computed tomography, or magnetic resonance imaging (MRI). There were 34 (52%) type II, 19 (29%) type III, and 8 (12%) type IV tibial spine fractures (Table 1). At time of surgery, diagnostic arthroscopy was performed to evaluate for additional pathology. Thirteen (20%) had an associated meniscus injury. There were 8 (12%) isolated posterior horn lateral meniscus tears, 1 (2%) posterior horn lateral meniscus and intrasubstance medial meniscus tear, 1 (2%) radial medial meniscus tear, 1 (2%) radial lateral meniscus tear, 1 (2%) bucket handle lateral meniscus tear, and 1 (2%) superior surface lateral meniscus tear (Table 2). There were no full-thickness chondral injuries. Fifty-five (83%) patients underwent isolated repair of the tibial spine. Additional procedures included lateral meniscus repair (n = 7 [11%]), partial lateral meniscectomy (n = 3 [5%]), and MCL repair (n = 2 [3%]) (Table 3).

Regarding the tibial spine injury, incarcerated structures preventing reduction were noted. Twenty-three (35%) had incarceration of just the intermeniscal ligament, 19 (29%) of the intermeniscal ligament and anterior horn of the medial meniscus, 2 (3%) of the medial meniscus, 1 (2%) of the intermeniscal ligament and anterior horn of the lateral meniscus, 1 (2%) of the intermeniscal ligament and a radial tear of the medial meniscus interposed, and 1 (2%) of the ligamentum.

Table 2. Incidence of Meniscal Pathology at the Time of Surgery

Pathology	Number of patients, % (n = 66)
None	53 (80%)
Lateral meniscus, posterior horn tear	8 (12%)
Lateral meniscus, radial tear	1 (2%)
Lateral meniscus, bucket handle tear	1 (2%)
Lateral meniscus, superior surface tear	1 (2%)
Medial meniscus, radial tear	1 (2%)
Lateral meniscus, posterior horn and medial meniscus, intrasubstance tear	1 (2%)

Table 3. Procedures at the Time of Surgery

Procedure	Number of patients, % (n = 66)
Isolated tibial spine repair	55 (83%)
Lateral meniscus repair	7 (11%)
Partial lateral meniscectomy	3 (5%)
Medial collateral ligament repair	2 (3%)

All patients underwent tibial spine repair.

Table 4. Incarcerated Structures Preventing Reduction at Time of Surgery

Structure	Number of patients, % (n = 66)
Intermeniscal ligament	23 (35%)
Intermeniscal ligament and medial meniscus, anterior horn	19 (29%)
None	19 (29 %)
Medial meniscus	2 (3%)
Intermeniscal ligament and lateral meniscus, anterior horn	1 (2%)
Intermeniscal ligament and medial meniscus tear	1 (2%)
Ligamentum	1 (2%)

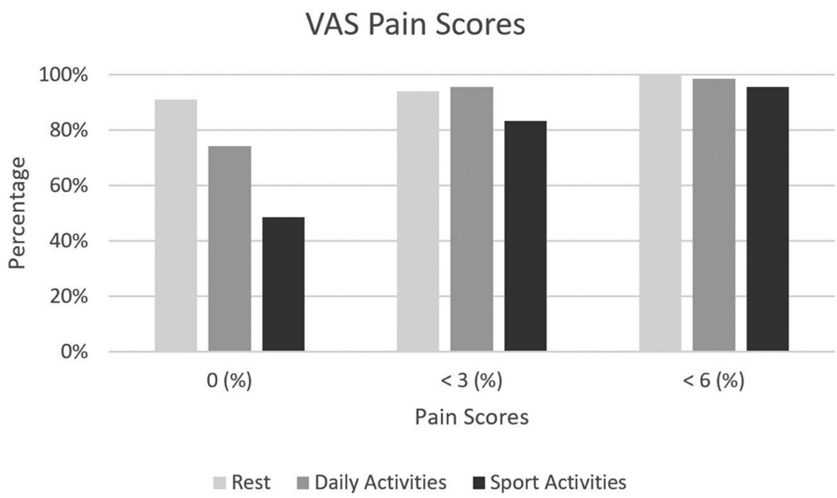

Fig 3. Percent of patients with visual analog scale visual analog scale scores of 0, <3, and <6 with rest, daily activities, and sport activities.

Nineteen patients (29%) had no incarcerated structures (Table 4).

Mean follow-up was 5.8 years (range, 1.0-11.9). Average IKDC score was 91.4 (range, 62.1-100), which exceeded the patient acceptable symptom state previously defined as 75.9.[23,24] Furthermore, 58 (87.9%) patients had IKDC scores greater than patient acceptable symptom state, and 38 patients (58%) reported an IKDC score >95. On average, patients reported their knee as 92% of normal (range, 40%-100%), with 23 patients (34%) reporting 100%. Thirty-five (53%) currently participate in sport whereas 6 (9%) refrain because of their knee. Fourteen (21%) report subjective stiffness; however, only 6 (9%) feel limited by this. Regarding pain on a visual analog scale, the number of patients reporting pain less than a 3 at rest, with daily activity, and with sport were 94%, 95%, and 83%, respectively (Fig 3). In response to the question, "How satisfied are you with the results of your surgery?," 52 (79%) were very satisfied, 9 (14%), were satisfied, 4 (6%) were neutral, none were unsatisfied, and 1 (2%) was highly unsatisfied (Table 5). Paralleling this, responses when asked if they would undergo the same care if needed were 61 (92%) definitely yes, 3 (5%) probably, 2 (3%) unsure, and no patient said no (Table 6).

Fourteen patients (21%) reported an additional ipsilateral procedure, of which 5 (8%) reported 2 procedures and 1 (2%) reported 3 procedures. Indications for additional surgery were ACL rupture (n = 6 [9%]), meniscal pathology (n = 6 [9%]), arthrofibrosis (n = 5 [8%]), revision tibial spine repair (n = 2 [3%]), MPFL injury (n = 2 [3%]), removal of prominent suture (n = 2 [3%]), and epiphysiodesis for leg length discrepancy caused by overgrowth with subsequent removal of hardware (n = 1 [2%]) (Table 7). Patient-reported procedures were confirmed via chart review, except one manipulation under anesthesia and arthroscopic debridement which was unable to be identified in available records. Four (6%) additional ipsilateral knee injuries were treated without surgery, including acute patella dislocation (1), "knee dislocation" (1 per patient report; could not be verified on the basis of notes), ACL rupture (n = 1 [2%]), and iliotibial band syndrome (n = 1 [2%]).

Overall, 7 patients (11%) had subsequent ipsilateral ACL rupture because of an acute injury. Six (9%) underwent ACL reconstruction at an average 3.1 years after initial repair (range, 0.9-7 years). The one (2%) ACL tear verified on MRI that was treated without surgery occurred 3.7 years after repair. There were no differences in patients who sustained subsequent ACL injuries and those who did not regarding age (10.4 vs 10.7 years old; $P = .772$), sex (male: 57% vs 49%; $P = 1.000$), fracture classification (type 2 vs 3/4: 57% vs 43%; $P = 1.000$), or follow-up time (5.2 vs 5.9 years;

Table 5. Patient Satisfaction Scores*

Rating	Number of patients, % (n = 66)
Very satisfied	52 (79%)
Satisfied	9 (14%)
Neutral	4 (6%)
Unsatisfied	0 (0%)
Highly unsatisfied	1 (2%)

*Assessed via Likert scales.

Table 6. Patient Responses to "If you had to do it all over again, would you have the surgery again?"

Response	Number of patients, % (n = 66)
Definitely yes	61 (92%)
Probably	3 (5%)
Unsure	2 (3%)
Probably not	0 (0%)
Definitely no	0 (0%)

Table 7. Indications for Additional Surgery on the Ipsilateral Knee*

Indication	Number, % (n = 24)
Anterior cruciate ligament rupture	6 (25%)
Meniscal pathology	6 (25%)
Arthrofibrosis	5 (21%)
Revision tibial spine repair	2 (8%)
Medial patellofemoral ligament injury	2 (8%)
Epiphysiodesis for leg length discrepancy	2 (8%)
Removal of prominent suture	1 (4%)

*Fourteen patients underwent 21 subsequent surgeries on the ipsilateral knee.

P = .5374). Regarding the contralateral knee, there were no ACL or tibial spine injuries.

Discussion

In this series, pediatric patients treated with operative fixation for tibial spine fractures had good outcomes at mean 5.8 years as supported by excellent IKDC scores, subjective normalcy of the knee, participation in sport, pain scores, and satisfaction. However, some continue to refrain from sport because of their knee or feel limited by stiffness. This is largely in agreement with the literature to date.

In tibial spine fractures treated with surgery or conservatively, Willis et al.[13] observed that 84% returned to sport, although on examination 64% had a positive anterior drawer or Lachman and 20% had a pivot shift. They noted increasing translation with KT1000 testing based on injury severity.[13] Similarly, in 14 patients treated with or without surgery, Tudisco et al.[12] found that all but 1 returned to activity. Two described their knee as normal, 11 nearly normal, and only 1 abnormal. Four had objective instability on examination; however, none reported instability.[12] Casalonga et al.[3] provided long-term follow-up on a series of tibial spine fractures. Eight described their knee as at least nearly normal, whereas 4 were abnormal, and 1 was very abnormal. All but 1 had returned to sport, although 70% reported pain. Operative treatment resulted in less clinical instability, but this was not correlated with subjective instability.[3]

There is a growing body of literature on patients treated surgically for tibial spine fractures. In their series, Reynders et al.[10] reported that 24 of 26 patients resumed full activity. Type 2 fractures seemed to fair better than type 3, because all of the type 3 fractures had a positive anterior drawer test result, 2 required later ACL reconstruction, and they had lower outcome scores.[10]

A common theme in postoperative tibial spine patients is objective instability with physical examination or KT1000 testing despite no impact on subjective function or feelings of instability. In 20 patients, Melugin et al.[7] reported an average IKDC score of 94, yet 26% had a positive Lachman. Shin et al.[11] reported excellent Lysholm scores in their series despite clinical instability with no correlation between the 2. In 10 patients treated by Perugia et al.,[9] 6 had an excellent result despite 3 with a positive Lachman result and 6 with a pivot shift.[9] The degree of laxity as measured by KT1000 is often within millimeters, which may explain why it is of little consequence. Louis et al.[5] observed excellent outcome scores in their series and all patients returned to pre-injury activity. On average there was 1 mm laxity with KT1000 testing, although none described instability.[5] Similarly, Shepley[25] reported on 5 patients who all returned to sport with good function and stability despite an average laxity of 1 mm. Among 12 tibial spine fractures, Owens et al.[8] noted 3 patients with a positive Lachman and an average 1.1 mm laxity, although again with no subjective pain, impaired function, or instability, and all returned to sport. Even with larger differences, there does not appear to be an impact on function. In 6 patients treated surgically, Kocher et al.[4] found a positive Lachman result in 5, pivot shift in 2, and at least 3 mm difference on KT1000 testing in 4, yet they still saw excellent functional scores. Mah et al.[6] had 1 to 4 mm of laxity, with an average 2.5 mm with excellent subjective function and no instability, and all returned to activity.[6] Finally, a review of 16 studies of displaced tibial spine fractures found no correlation between clinical and subjective instability. In the cohort treated without surgery, 70% had clinical instability, although only 54% reported instability. Patients treated with surgery had a 14% incidence of clinical instability, but only 1% reported instability. The authors also observed a higher rate of ACL reconstruction and extension deficit in patients treated without surgery, supporting the indications for surgical fixation of displaced tibial spine fractures.[2]

Based on arthroscopic evaluation, this study sheds light on the incidence of concomitant pathology in the setting of a tibial spine fracture. Fortunately, these tend to be isolated injuries. In this series, 80% of patients had no evidence of meniscal pathology and none had a significant cartilage defect. When meniscal injury did occur, it was most commonly in the posterior horn of the lateral meniscus. The rate of concomitant meniscal injury in the literature ranges from 0% to 43%.[7,9,11,14,25] The intermeniscal ligament with or without meniscus incarceration prevented fracture reduction in 67% of cases in this series. In the literature, these are the most often incarcerated structures ranging from 12% to 80% of cases.[4-6,11,14,25]

The ACL appeared normal in 91% of patients in this series. An observational study by Mayo et al.[26] demonstrated a 19% incidence of concomitant ACL injury with tibial spine fracture based on MRI or surgical evaluation. However, in patients who underwent both MRI and surgery, there was no agreement between these modalities. Older age and male sex were both associated with ACL injury.[26] In 12 cases, Mah et al.[6] found 1 tear of the posteromedial bundle of the ACL. Louis et al.[5] noted the ACL appeared distended in all 17 of their cases and Kocher et al saw hemorrhage within the ACL sheath in all six of their cases.[4]

Given this is an ACL equivalent injury, tibial spine fracture at a young age may predispose patients to a subsequent ACL injury. Although failure occurs at the bone, it has been postulated that the substance of the ACL sees significant force and is stretched before failure at the bone interface. This could lead to residual instability or a lower threshold for rupture.[15] In this series, a 10.6% ACL tear rate was seen after tibial spine fixation. In the literature, subsequent ACL rupture in patients with tibial spine fractures ranges widely from 1% to 19%.[2,7,10,12-15] Mitchell et al.[15] directly addressed this question and found a 19% incidence of later ACL reconstruction. Older age at time of injury was the only factor associated with increased likelihood with future reconstruction.[15] In our series, there were no identifiable factors associated with subsequent ACL injury. Additionally, it remains unclear whether tibial spine injury predisposes patients to subsequent ACL injury because they occur at a rate of 14 per 100,000 exposures, representing 19% of knee injuries, in high school athletes.[27] In contrast, tibial spine injuries occur at a rate of 3 per 100,000 children per year, representing 2% to 5% of pediatric knee injuries.[28]

Of primary interest in this study was the incidence of contralateral knee injury. In adult athletes, there has been a high reported rate of subsequent ACL injury in either knee following ACL reconstruction. Lindanger et al.[16] reported a 9% incidence of ipsilateral ACL revision, but more surprisingly a 20% incidence of contralateral ACL injury. The findings presented here suggest that this does not appear to be similar for tibial spine fractures as no patients had contralateral ACL or tibial spine injury. The incidence of future ipsilateral and contralateral ACL injuries provides useful information for patients and their families.

In this study, subsequent ipsilateral surgeries included 1 incidence of ipsilateral epiphysiodesis for leg length discrepancy secondary to overgrowth with subsequent removal of hardware for leg length discrepancy. We were unable to identify literature detailing limb overgrowth following tibial spine fracture. Several case reports describe growth arrest and resulting deformity or leg length discrepancy following tibial spine or ACL repair,[29-32] whereas operative techniques have been described to avoid physeal damage in these procedures.[33,34] Limb overgrowth after diaphyseal and metaphyseal tibial fractures is uncommon but well described, although noted to be most significant in children under age five.[35,36] The patient in question was 12 years old at the time of surgery. The mechanism of post-traumatic overgrowth is unclear, with theories including growth plate activation by callus formation, increased cell turnover, and hypervascularity of the growth plate, with experimental studies elucidating contributing biochemical mechanisms.[37-40] This patient's clinical course was therefore highly unusual.

Limitations

There are a few limitations to this study. First, the response rate was 68%. This loss to follow-up leads to attrition bias, which may affect the validity of the conclusions. Second, the patients included in this study were operated on by 2 surgeons at a single center, which may limit the generalizability of the outcomes. Third, 1 follow-up surgery, 1 ipsilateral knee injury, and 3 contralateral knee injuries were reported but unable to be verified via chart review as they presented to an outside hospital. Fourth, patients did not have preoperative outcome scores for comparison. However, these scores, even if available, are of limited value given the acute nature of tibial spine injuries. Additionally, there is no control population treated without surgery for comparison, although it is widely accepted that injuries with displacement of the tibial spine should be treated with surgery to restore function of the ACL. Fifth, the IKDC score is a validated patient-reported outcome measure; however, the remaining questions in our survey addressing function, satisfaction, and pain have not been validated. Sixth, at final follow-up there was no formal in-person clinical assessment of patients to evaluate objective outcomes, such as physical examination findings. Seventh, preoperative imaging was unavailable to assess for tibial spine fracture classification in 5 (8%) patients. However, we know the fracture classification for each of these patients is between II to IV because type I fractures are treated without surgery by the 2 surgeons in this study. Eighth, there were few subsequent ACL injuries, so comparisons between those who did and did not sustain a subsequent ACL injury should be interpreted with caution. Finally, this study is inherently limited through its design as a retrospective study.

Conclusions

Although many pediatric patients demonstrate excellent results following tibial spine repair at mean 5.8 years follow-up, 10.6% sustained an ipsilateral ACL rupture and 21% required an additional procedure. No patient had a contralateral tibial spine or ACL injury. This is helpful when counseling patients regarding injury risk when returning to activity after tibial spine repair.

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Appendix 1. Patient Survey

Demographics	
What is your name?	
Are you filling this questionnaire out for yourself or your child?	○ My self ○ My child
Was surgery performed on the affected knee?	○ Yes ○ No
On which knee did Dr. XXX or Dr. XXX perform surgery?	○ Left ○ Right ○ Both
2000 IKDC Subjective Knee Evaluation Form	
What is the highest level of activity that you can perform without significant knee pain?	○ Very strenuous activities like jumping or pivoting as in basketball or soccer ○ Strenuous activities like heavy physical work, skiing, or tennis ○ Moderate activities like moderate physical work, running, or jogging ○ Light activities like walking, housework, or yardwork ○ Unable to perform any of the above activities due to knee pain
During the past 4 weeks, or since your injury, how often have you had pain? (0 = Never and 10 = Constant)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
If you have pain, how severe is it? (0 = No pain and 10 = worst pain imaginable)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
During the past 4 weeks, or since your injury, how stiff or swollen was your knee?	○ Not at all ○ Mildly ○ Moderately ○ Very ○ Extremely
What is the highest level of activity you can perform without significant swelling in your knee?	○ Very strenuous activities like jumping or pivoting as in basketball or soccer ○ Strenuous activities like heavy physical work, skiing, or tennis ○ Moderate activities like moderate physical work, running, or jogging ○ Light activities like walking, housework, or yardwork ○ Unable to perform any of the above activities due to knee pain
During the past 4 weeks, or since your injury, did your knee lock or catch?	○ Yes ○ No
What is the highest level of activity you can perform without significant giving way in your knee?	○ Very strenuous activities like jumping or pivoting as in basketball or soccer ○ Strenuous activities like heavy physical work, skiing or tennis ○ Moderate activities like moderate physical work, running or jogging ○ Light activities like walking, housework or yardwork ○ Unable to perform any of the above activities due to knee pain
What is the highest level of activity you can participate in on a regular basis?	○ Very strenuous activities like jumping or pivoting as in basketball or soccer ○ Strenuous activities like heavy physical work, skiing, or tennis ○ Moderate activities like moderate physical work, running, or jogging ○ Light activities like walking, housework, or yardwork ○ Unable to perform any of the above activities because of knee pain

(continued)

Appendix 1. Continued

Demographics					
How does your knee affect your ability to:	Not difficult at all	Minimally difficult	Moderately difficult	Extremely difficult	Unable to
a. Go up stairs	○	○	○	○	○
b. Go down stairs	○	○	○	○	○
c. Kneel on the front of your knee	○	○	○	○	○
d. Squat	○	○	○	○	○
e. Sit with your knee bent	○	○	○	○	○
f. Rise from a chair	○	○	○	○	○
g. Run straight ahead	○	○	○	○	○
h. Jump and land on your involved leg	○	○	○	○	○
i. Stop and start quickly	○	○	○	○	○

Function: How would you rate the function of your knee on a scale of 0 to 10 with 10 being normal, excellent function and 0 being the inability to perform any of your usual daily activities which may include sports?

Function before your knee injury: (0 = Cannot perform daily activities and 10 = No limitation in daily activities)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
Current function of your knee: (0 = Cannot perform daily activities and 10 = No limitation in daily activities)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Marx Activity Scale

Please indicate how often you performed each activity in your healthiest and most active state, in the past year.

Running: running while playing a sport or jogging	○ Less than one time in a month ○ One time in a month ○ One time in a week ○ 2 or 3 times in a week ○ 4 or more times in a week
Cutting: changes directions while running	○ Less than one time in a month ○ One time in a month ○ One time in a week ○ 2 or 3 times in a week ○ 4 or more times in a week
Decelerating: coming to a quick stop while running	○ Less than one time in a month ○ One time in a month ○ One time in a week ○ 2 or 3 times in a week ○ 4 or more times in a week
Pivoting: turning your body with your foot planted while playing a sport; for example, skiing, skating, kicking, throwing, hitting a ball (golf, tennis, squash), etc.	○ Less than one time in a month ○ One time in a month ○ One time in a week ○ 2 or 3 times in a week ○ 4 or more times in a week

(continued)

Appendix 1. Continued

Demographics	
Survey	
How would you rate your affected knee today as a percentage of normal (0%-100% scale with 100% being "normal")?	0% 50% 100%
Please indicate how often you experienced knee instability events (i.e., the feeling of your knee giving way), in the past year?	○ Less than one time in a month ○ One time in a month ○ One time in a week ○ 2 or 3 times in a week ○ 4 or more times in a week
How satisfied are you with the results of your surgery?	○ Very satisfied ○ Satisfied ○ Neutral ○ Unsatisfied ○ Very unsatisfied
Looking back, if you "had to do it all over again," would you have the surgery again?	○ Definitely, yes ○ Probably, yes ○ Unsure ○ Probably, no ○ Definitely, no
Have you had any further surgeries on your knee since your initial knee surgery with Dr. XXX or Dr. XXX?*	○ Yes ○ No
Please explain what further surgeries you've had since your initial knee surgery with Dr. XXX or Dr. XXX. Include approximate date of surgery, if known.	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
Since your knee surgery, have you experienced any other injuries to your surgical knee?*	○ Yes ○ No
Since your knee surgeries, have you experienced any injuries to your other knee?*	○ Yes ○ No
Do you currently play any sports?	○ Yes ○ No
What sports do you currently play and at what level (competitive, recreational, etc.)?	(Example: recreational basketball, competitive soccer)

(continued)

Appendix 1. Continued

Demographics	
Are there any sports you would like to play but avoid because of your knee?	○ Yes ○ No
Why do you avoid the activity?	? Personal choice ? Outside influence (parent, friend, coach, therapist, physician, etc.) ? Knee does not tolerate sport ? Other (specify below)
Do you notice any stiffness or loss of motion in your knee?	○ Yes ○ No
How would you rate your pain on a scale of 0-10 at rest? (0 = No pain and 10 = worst pain imaginable)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
How would you rate your pain on a scale of 0-10 during daily activities? (0 = No pain and 10 = worst pain imaginable)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10
How would you rate your pain on a scale of 0-10 during sport activities? (0 = No pain and 10 = worst pain imaginable)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

*If affirmative, confirmed via chart review.