Title

Epidemiology and outcomes of tibial plateau fractures in adults aged 60 and over treated in the United

Kingdom

Declarations

Abstract

Background

Tibial plateau fractures are common in older adults, often resulting from low-energy falls. Although lower limb fragility fracture care has evolved, the management of tibial plateau fractures in older patients remains poorly researched. This study aimed to define the epidemiology, treatment and outcomes of tibial plateau fractures in patients aged over 60 years.

Methodology

Patients aged 60 years or older with a tibial plateau fracture who presented to a single trauma centre between January 2008 and December 2018 were identified. Incomplete records were excluded. Epidemiological data, fracture classification, injury management, radiological outcomes, complications, and mortality was assessed via retrospective case note and radiograph review. Local ethics approval was obtained.

Results

Two-hundred and twenty patients with a mean age of 74 years (range 60-100) were included. 73% were female and 71% of injuries were sustained following low-energy falls. Median follow up was three months. 50% of fractures involved the lateral plateau. 60% of injuries were treated non-operatively. 76% of patients had their weight-bearing restricted for the first six weeks, with little difference between operatively and non-operatively managed patients. 8% of all patients required subsequent knee replacement. All-cause mortality at 30-days and one-year were 2% and 5% respectively.

Conclusion

The majority of tibial plateau fractures in the over 60s are sustained from low-energy trauma. Management is relatively conservative when compared with younger cohorts. The data reported brings up questions of whether surgical treatment is beneficial to this patient group, or whether restricted weight bearing is either possible or beneficial. Prospective, multi-centre comparative trials are needed to determine whether increased operative intervention or different rehabilitation strategies purveys any patient benefit.

Keywords

Introduction

Fractures of the tibial plateau account for 8% of all fractures in older adults [1-4], where the most prevalent mechanism of injury is a low-energy fall from standing height [2]. However, the overall distribution of these fractures amongst the population is bimodal, with a younger cohort sustaining these fractures as a result of high-energy injuries [1]. In older adults, osteoporosis is a significant and dominant risk factor in sustaining these fractures from low-energy mechanisms. This is often further complicated by other factors including pre-existing comorbidities, pre-existing degenerative joint disease and a patient's premorbid functional status [5].

The lateral tibial condyle is most commonly affected (in all age groups) often owing to lateral impaction of the knee, and its natural slight valgus angle [4, 5]. Standards for radiological investigations include both plain radiographs and computed tomography (CT). The most commonly used classification systems in the literature and clinical practice is the Schatzker classification [7] However, a CT-based Three-Column Classification (TCC) is increasingly being used [8]. Consideration is given to condylar width, limb length discrepancy, and degree of (in)stability. Yet, these classification systems tend to be designed around and referenced upon younger cohorts of patients – for example, the mean ages were 57 years for Schatzker [7], and 47 years (range 22-62) for TCC [8].

The goal of treatment in older adult patients differs from that of younger patients: the goal is to an early return to full weight-bearing as soon as possible to prevent morbidity and mortality. It is well recognised that adherence to less-than-full weight-bearing recommendations can be a challenging goal among older comorbid adult patients. Data from the United Kingdom (UK) Best Practice Tariff (BPT) data for patients with neck of femur fractures have shown that timely appropriate treatment, early mobilisation and multidisciplinary care can transform outcomes in patients with fragility fractures of the hip [9].

At present, there is no clear guidance of the management of tibial plateau fractures in older adults, and there is an absence of any significant high-quality evidence regarding the long-term functional outcomes, the goals of treatment, and the challenges faced with respect to bone quality, co-morbidities and protected weight-bearing. One retrospective study of 327 patients has previously demonstrated the epidemiology and morphology of such injuries [10], and four smaller retrospective studies have demonstrated good outcomes following operative interventions for tibial plateau fractures in selected patients over 60 years [2, 4, 11, 12], however trauma care has significantly evolved since these studies were conducted. All patients in these small studies were treated operatively, and no comparisons to non-operatively outcomes were made.

This study aimed to determine the contemporary epidemiology, treatment and outcomes of tibial plateau fractures managed in an orthopaedic Major Trauma Centre over a ten-year period.

Materials and Methods

Study cohort

Patients were identified retrospectively from a database held at the study centre. An initial database search was generated for patients with fractures of the tibia or polytrauma patients sustained between January 2008 and December 2018. Due to local patient coding, polytrauma patients were searched for separately to capture polytrauma patients with fractures of the tibia. The database was then reduced by excluding all patients aged younger than 60 years. Other fractures of the tibia (distal, mid-shaft, proximal non-plateau); pathological fractures; fractures of the tibial spine, Segond fractures; avulsion fractures; replaced joints; and patients with incomplete records were also excluded (Figure 1). The study centre is a Level 1 Major Trauma Centre (MTC) in the UK, serving an adult population of over 2.3 million [13]. Patients undergoing both inpatient and outpatient treatments were included.

Figure 1: Identification of study cohort.

Patient demographics, injury characteristics, and treatment modalities

Electronic patient records were reviewed to determine the patients' age at the time of injury, gender and laterality of injury. Mechanism of injury were categorised for all patients into fall from standing, fall from height, road traffic accident (RTA), direct blows, and 'other.' A fall from height was defined as any height greater than two metres (six feet). 'Other' injuries included miscellaneous mechanisms such as being trampled by cows and hit by a dog. We also recorded whether injuries occurred indoors or outdoors. Open injuries were classified using the Gustilo and Anderson classification [14].

Standard anteroposterior (AP) and lateral radiographs of the tibia/fibula or knee, taken at the time of injury, were reviewed and verified by one of four authors (RLD, JRAS, DY and FB) using a picture

archiving and communication system (Synapse Radiology PACS, Fujifilm, USA). Fractures of the tibial plateau were classified according to the Schatzker classification [7]. For patients who had also undergone CT imaging, their fractures were also classified according to Three-Column Classification (TCC) [8] Any disputes were resolved through review by the senior author (TJSC).

Records were reviewed to determine whether patients were treated operatively with open reduction internal fixation, intramedullary nail, external fixation, other; or non-operatively using a cast or brace. The treatment modality was determined by the attending consultant or by specialist consensus in the local trauma meeting. The postoperative weight-bearing status for the initial six weeks was recorded as either full, partial, touch or non. Any postoperative complications and reasons for reoperation were noted. Radiological outcomes in terms of joint depression (millimetres) and the anatomical femorotibial angle (AFTA) (degrees) at the final follow-up were established. The length of stay (days); and mortality (all-cause) at 30-days and one-year were also recorded.

Statistical analysis

Statistical analysis was performed by an independent statistician (PW) using IBM SPSS, version 27.0, 2020. Continuous variables were presented as mean and standard deviation (SD) or by median and inter-quartile range for skewed continuous data. Categorical variables were presented as counts and percentages. Standard and well-established parametric tests (separate variances independent samples t-test, Pearson's correlation coefficient, Kaplan-Meier survival estimates) were used in the assessment of continuous data as appropriate, and the chi-square test of association, Mantel-Haenszel odds ratios were used to assess associations between categorical variables.

Multivariate analyses were performed using ordinary least squares regression or Cox proportional hazards regression as appropriate. In multivariate analysis, the dependent variables were the joint

depression at the final follow-up, the AFTA at final follow-up, and the length of stay. The independent variables were age (<75 versus ≥75), Schatzker classification grades (I-VI), TCC grades (grouped into 1- to 3-column injuries for each of analysis), treatment modality (operative versus non-operative), mechanism of injury (low-energy versus high-energy), joint depression at the time of final follow-up (<5mm versus >5mm), and initial weight-bearing status (fully, partial, touch, non) for the first six weeks. Statistically significant events were expressed with alpha values of 0.05 and two-sided tests used throughout, with 95% confidence intervals (CI).

Ethics approval

Local institutional ethics approval was obtained before data collection. This paper is reported per the STROBE checklist [15].

Results

Patient demographics, epidemiology and fracture classification

Two-hundred and twenty patients with fractures of the tibial plateau met the inclusion criteria. The mean age was 74 years (SD 9.6; range 60-100), and 160 patients (73%) were female. Figure 2 further highlights the breakdown of our study cohort by age and gender. 52% of patients sustained left-sided injuries, and 6% of patients sustained open fractures. Low-energy falls (height less than two metres) were the most common mechanism of injury (71%), followed by road traffic accidents (RTAs) (15%) and high-energy falls (height more than two metres) (7%). Alternative mechanisms accounted for a further 6%, and 1% had an unknown mechanism. One-hundred and seventeen injuries (53%) were sustained outdoors, and there was no significant seasonal variation in the presentation of patients with these injuries. 78% of patients underwent imaging with CT imaging. Nine patients were diagnosed with CT imaging alone. Median time-to-discharge from clinic was three months (interquartile range, IQR: 2-6 months). 35 patients (15%) had follow-up beyond six months.

Figure 2: Bar chart displaying the number of patients with tibial plateau fractures across the study period by age and gender.

The majority of injuries sustained affected the lateral plateau, according to both Schatzker and TCC classification models. According to the Schatzker classification, 61% of injuries affected the lateral plateau, and 55% according to the TCC system. Figures 3 and 4 provide a full breakdown of injuries for each Schatzker and TCC grade. There was a significant association between the Schatzker classification and the TCC when comparing one/two/three-column injuries against the six individual Schatzker classes

(p<0.001), and when comparing one/two/three-column injuries against grouped Schatzker classes of I-IV and V-VI (p<0.01).

Figure 3: Bar chart breakdown of the proportion of injuries by Schatzker grade.

Figure 4: Bar chart breakdown of the proportion of injuries by TCC grade.

Key: L=lateral; LP=posterolateral; M=medial; MP=posteromedial; ML=medial-lateral; P=posterior.

Treatment and length of hospital stay

One-hundred and thirty-one injuries (60%) were treated non-operatively, of which 70% were treated with a brace, and 30% were treated with a cast. 77% of patients treated non-operatively had their weight-bearing restricted for the first six weeks. Comparatively, 89 patients (40%) were treated operatively, of which 91% underwent ORIF with plate fixation, 3% total knee replacement (TKR), 2% external fixation, 1% intramedullary nailing, and 2% hybrid fixation. 90% of patients treated operatively who had their weight-bearing restricted for the first six weeks. Patients aged <75 were almost three times more likely to undergo operative treatments compared with those aged ≥75 (OR 2.79; 95% CI 1.62,5.08; p<0.001). Patients aged ≥75 were three times more likely to be permitted to fully weight bear on their injury in the initial six weeks than those aged <75 (OR 2.99; 95% CI 1.56,5.75; p=0.01).

The TCC (p<0.001) and Schatzker classification (p<0.001) were both associated with whether patients would undergo operative or non-operative treatment. In particular, Schatzker grade V-VI fractures were associated with operative treatment (p<0.001). Patients with these injuries were nearly six times more likely to undergo operative treatment than those with Schatzker grade I-IV fractures (OR 5.86; 95% CI 2.91,11.78; p<0.001). Table 1 outlines the number of patients who sustained injuries within each

grade of the Schatzker classification and the TCC, as well as illustrating how many were managed

operatively and non-operatively.

Table 1: Number of patients treated operatively and non-operatively, according to their Schatzker

and TCC grade.

Forty-six patients (21%) were managed as outpatients, the rest being admitted to hospital. The

median length of hospital stay for those admitted was 14 days (IQR 7-26). For patients managed

operatively, the median length of hospital stay was 14 days (IQR 8-25), and for those managed non-

operatively it was 12 days (IQR 5-28 days). Analysis of the reasons behind length of hospital stay was not

performed as it was beyond the remit of this study.

Univariate analysis demonstrated a significantly increased length of stay for patients aged ≥75

compared with those aged <75 (p=0.001), as illustrated in Figure 5.

Figure 5: Kaplan-Meier survival analysis plot of length of stay for patients by age group.

There were no significant associations between length of stay and Schatzker classifications

(p=0.554), TCC (p=0.104), gender (p=0.469), treatment modality (p=0.335) or weight-bearing status

(p=0.611).

In multivariate analysis, age ≥75, Schatzker grade V-VI, and operative treatment were all

predictive of increased length of stay (p=0.007). When controlling for the other two variables, age ≥75 was

associated with increased length of stay (p=0.005). However, operative treatment (p=0.847) and Schatzker

grade V-VI (p=0.068) were no longer significant after controlling for the other two variables.

Similarly, when replacing Schatzker grade V-VI with TCC one/two-column injuries, age ≥75 was associated with increased length of stay (p=0.008) when controlling for TCC grade and operative treatment. However, operative treatment (p=0.371) and TCC one/two-column injuries (p=0.059) were no longer significant after controlling for the other two variables.

Radiographic outcomes: joint depression and anatomical femorotibial angle (AFTA)

- *Joint depression*

The mean joint depression for all patients at the time of final follow-up was 4.0mm (SD 3.5). For patients treated operatively, the mean joint depression at final follow-up was 3.2mm (SD 3.7), compared to a mean of 4.5mm (SD 3.3) for patient treated non-operatively.

Univariate analysis of Schatzker (p=0.232) and TCC (p=0.168) grades did not demonstrate a significant association with the final joint depression when categorised as 0-5mm, 6-10mm, 11-15mm, 16-20mm of depression. For Schatzker grades, there was also an absence of significant association when the final joint depression was categorised as <5mm versus >5mm; however, they became significant when TCC grades of one/two-column injuries were compared with three-column injuries (p=0.020).

There were no associations between age (p=0.442), mechanism of injury (p=0.268) , treatment modality (operative versus non-operative) (p=0.378), weight-bearing status (p=0.856) or non-operative treatment modality (bracing versus casts) (p=0.418) and the final joint depression.

In multivariate analysis, there was a significant association between individual Schatzker grades and the final joint depression p=0.006), as well as between Schatzker grades I-IV versus V-VI and the final joint depression (p=0.031). Patients with Schatzker grade I-IV injuries were more than twice as likely to have a joint depression greater than 5mm at final follow-up than those with Schatzker grade V-VI injuries (OR 2.49; 95% CI 1.07,5.79; p=0.034).

There was an association between individual TCC grades and joint depression >5mm at final follow-up (p=0.058), but this was not significant. However, patients with TCC three-column injuries were more than three times as likely to have a joint depression >5mm at final follow-up than those with one/two-column injuries (OR 3.33; 95% CI 1.19,9.27; p=0.022).

In multivariate analysis, treatment modality (operative versus non-operative) was not significantly related to the final joint depression when controlling for mechanism of injury and Schatzker classification. Moreover, operative versus non-operative treatment showed no association with the final joint depression whether these factors were controlled for or not.

- *Anatomical femorotibial angle (AFTA)*

The mean anatomical femorotibial angle (AFTA) for all patients at the time of final follow-up was 173.0 degrees (SD 5.0). For patients treated operatively, the mean AFTA at final follow-up was 173.0mm (SD 5.3), compared to a mean of 173.1mm (SD 4.7) for patient treated non-operatively. These findings should be interpreted cautiously since there was a lack of standardisation of the weight-bearing status of patients when radiographs were performed. Although there were no associations between weight-bearing status (p=0.257) and the final AFTA, we have not provided further analysis on the AFTA due to this limitation.

Further surgery and complications

26 patients (12%) underwent further surgery. Of the patients treated operatively, ten patients required subsequent TKR surgery (at a mean ten months post-injury), four patients required debridement and removal of metalwork for infection, two required removal of metalwork for prominent metalwork, one required a revision ORIF, and one required amputation for limb ischaemia. Of the patients treated non-operatively, eight patients required subsequent TKR surgery (at a mean eight months post-injury). In total

8% of patients underwent delayed TKR. Three patients (1%) developed deep vein thrombosis (DVT), all of whom had been managed non-operatively.

The presence of postoperative complications (p=0.002), and joint depression >5mm (p=0.025) were independently associated with the need for further surgery. However, there was no association between Schatzker grade (p=0.214) or weight-bearing status (p=0.831) and the need for further surgery.

Mortality (all-cause)

Mortality was calculated to be 2% at 30 days, and 5% at 1 year. All of these patients had been managed non-operatively.

Discussion

This study is the largest consecutive cohort detailing the management and radiographical outcomes of tibial plateau fractures in older adults (over 60 years' old). Two-hundred and twenty patients were included in the analysis over ten years, of which 40% were managed operatively. The mean age at the time of injury was 74 years, and the majority (>70%) were sustained through means of low-energy trauma, in contrast to younger patients whose mechanism of injury is from high-energy [1].

The treatment goals for tibial plateau fractures are to re-establish the mechanical alignment of the limb, provide stability and restore articular congruity [1] – yet, in older patients, this must also be balanced with minimising deconditioning and mitigating the risks associated with reduced mobility. The treatment of tibial plateau fractures in older adults, both operative and non-operative, continues to be lacking in the contemporary literature, with only a couple of small retrospective observational studies.

Hsu *et al.* (2001) [11] retrospectively studied 22 older patients with displaced tibial plateau fractures, all of whom were treated operatively, demonstrating very good clinical and radiographical results after four years. Similarly, Su *et al.* (2004) [4], Frattini *et al.* (2009) [2], and Shimizu *et al.* (2016) [12] retrospectively studied 39, 49 and 33 older patients respectively who were treated operatively for displaced tibial plateau fractures, and also demonstrated relatively good clinical and radiographical outcomes.

In this study, both the Schatzker classification and the TCC were associated with whether patients would undergo operative or non-operative treatment. Patients with Schatzker grade V-VI fractures were almost six times more likely to undergo operative treatment than those with Schatzker grade I-IV fractures. Younger patients (60-75) were also three times more likely to undergo operative treatment, whereas older patients (≥75) tended to be treated non-operatively and were three times more likely to be instructed to fully weight bear on their injury in the first six weeks. This is interesting as it indicates the

difficulty of restricting weight bearing in the older population, and that a pragmatic approach should be taken, yet these patients would tend to have poorer bone stock.

Reoperation occurred in 11% of patients and was related to postoperative complications and high degrees of joint depression; however, no association were determined between reoperation and the Schatzker grade nor the weight-bearing instructions after treatment. 8% of patients required subsequent TKR surgery. We were unable to find any comparative incidence of subsequent revision to TKR for older adults in the literature.

Strengths of the study include that is the largest consecutive cohort detailing the management and radiographical outcomes of tibial plateau fractures older adults and utilised statistical analyses to mitigate confounding. Incomplete datasets were excluded to ensure that missing data did not introduce error. The limitations of this study include it being a retrospective observational study, which therefore increases the risk of confounding and selection bias. Second, there is the chance of interobserver variability when measuring degrees of joint depression by a single observer, as well as variability when classifying fractures; however, these remain universal issues. Third, there is no functional outcome reported and no patient-reported outcomes to assess function. Fourth, this data is from an MTC and may not reflect the presentations to District General Hospitals. Lastly, although this is the largest consecutive cohort in the literature to date, the numbers remain low, and the mean duration of follow-up is short.

Conclusion

The majority of tibial plateau fractures in the over 60s are sustained from low-energy trauma. Management is relatively conservative when compared with younger cohorts. The data reported raises questions of whether surgical treatment is beneficial to this patient group, of whether restricted weight bearing is either possible or beneficial. Prospective, multi-centre comparative trials are needed to

determine whether increased operative intervention or different rehabilitation strategies purveys any

patient benefit.

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Schatzker grade	Percentage of patients, n (%)		TCC grade	Percentage of patients, n (%)	
	Operative	Non-operative		Operative	Non-operative
I	9 (10)	28 (23)	L	17 (21)	25 (29)
II	30 (34)	37 (30)	LP	22 (27)	25 (29)
III	4 (5)	21 (17)	M	0 (0)	12 (14)
IV	6 (7)	23 (19)	MP	8 (10)	7 (8)
V	11 (13)	4 (3)	ML	1 (1)	3 (3)
VI	28 (32)	10 (8)	P	0 (0)	6 (7)
			3-column	35 (42)	9 (10)

Table 1: Number of patients treated operatively and non-operatively, according to their Schatzker

and TCC grade.