

Weight Bearing Protocols Following Subtrochanteric Fracture Fixation with Intramedullary Implants, a Retrospective Cohort Study

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ABSTRACT

AIM: Subtrochanteric femur fractures are commonly managed with operative fixation. However, they have a high complication rate due to cortical comminution and stress concentration during stance. This study evaluates the effects of immediate weight bearing in the recovery of subtrochanteric femur fractures treated with intramedullary fixation when compared to a traditional, limited weight bearing protocol.

MATERIALS AND METHODS: 69 consecutive subtrochanteric femur fractures were retrospectively reviewed at two level-I trauma centers, evaluating for postoperative hospital length of stay in relation to their respective weight bearing rehabilitation protocol. All femur

fractures were treated between August 2009 and November 2015.

RESULTS: Our study identifies a decreased length of stay in weight bearing as tolerated groups for both the overall sample (4.5 vs 5.9 days; $p < 0.01$) and those that experienced a high-energy injury (5.1 vs 7.0 days; $p < 0.001$), with no significant difference in postoperative complications (2 vs 3; $p = 0.43$).

CONCLUSIONS: This study provides preliminary evidence for the adoption of immediate weight bearing as tolerated as a viable postoperative rehabilitation protocol in the setting of subtrochanteric femur fractures treated with intramedullary fixation.

Key words: Subtrochanteric femur fracture; weight bearing protocol; Postoperative length of stay

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INTRODUCTION

Subtrochanteric femur fractures represent a challenging and unique problem to orthopaedic surgeons and rehabilitation teams, as these distinct fracture patterns historically have high complication rates due to the forces exerted on this region^[1,2]. The development of intramedullary implants with superior biomechanical profiles, as well as improvements in surgical technique, have reduced the morbidity and complication rate for these fracture patterns, and as a result intramedullary implants have surpassed angled blade plates as the gold standard of care^[3,4]. Although traditionally postoperative weight bearing has been limited to reduce the risk of implant failure, biomechanical studies indicate that modern load-sharing

intramedullary devices can withstand the forces of postoperative weight bearing, and numerous studies have reported encouraging results for patients with subtrochanteric femur fractures following a limited postoperative weight bearing protocol for 6 weeks, followed by progression to full weight bearing upon evidence of callus^[5-8]. This evidence suggests that patients with subtrochanteric fractures may be able to tolerate immediate postoperative weight bearing, reducing the overall time of recovery and rehabilitation.

The benefits of immediate weight bearing as tolerated (WBAT) and early mobilization in orthopaedic trauma have been previously described in the literature^[9-12]. Patients have been shown to be able to avoid complications associated with prolonged immobilization such as pneumonia, urinary tract infections, thromboembolic events, myocardial infarction, and stroke when following an immediate weight bearing protocol^[10]. Early ambulation may lead to improved function, faster return to work, and decreased economic impact^[11,13]. Immediate WBAT has become the standard of care in geriatric hip fractures^[14,15] and has been safely used to manage femoral shaft fractures, hip and knee arthroplasty, and acute spinal cord injury^[16].

Although immediate WBAT has shown excellent outcomes in other femur fractures^[17,18], it has not been examined for a cohort of subtrochanteric fractures. While locked intramedullary fixation has been shown to be safe in diaphyseal fractures^[17,19] and intertrochanteric hip fractures^[15], there has been reluctance to this adopt approach for subtrochanteric fractures. The purpose of this paper is to perform a preliminary evaluation on the effect of immediate WBAT on hospital length of stay (LOS) after

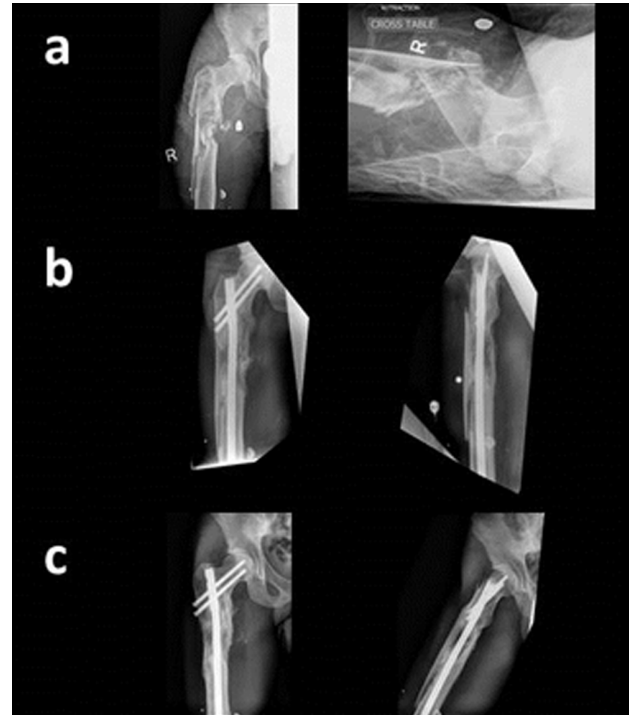


Figure 1 Images for 33-year-old male suffering a gunshot wound to his right femur who was allowed immediate postoperative weight bearing as tolerated after trochanteric start site reconstruction nail. Figure depicts radiographic images at time of injury (a), six-week post-op (b), and 10-months post-op (c). Patient was discharged home 2 days after surgery.



Figure 1 Radiographic progression of subtrochanteric femur fracture with an associated intertrochanteric fracture, treated with immediate weight bearing and resulted in a hypertrophic nonunion. This patient would require re-operation to remove broken hardware and repair non-union at 5.6 months (168 days) following original surgery date. Figure depicts radiographic images of injury AP radiograph (a), three-month post-op (b), coronal CT scan demonstrating hypertrophic nonunion of left femur after intramedullary fixation (c), and AP radiograph of left femur demonstrating broken distal interlock and hypertrophic nonunion. Patient was discharged home two days after surgery. Patient was discharged home 2 days after surgery.

intramedullary fixation of subtrochanteric fractures. We hypothesize that immediate WBAT after intramedullary stabilization of subtrochanteric fractures will be associated with decreased hospital LOS when compared to traditional postoperative limited weight bearing (LWB) protocol. The data provided by this preliminary evaluation will provide the foundation to pursue more rigorous studies in the future.

METHODS AND MATERIALS

Following IRB approval, a non-interventional retrospective therapeutic level III cohort study was conducted from August 2009 to November 2015 at two level-I trauma centers. Inclusion criteria were skeletally mature patients with subtrochanteric femur fractures involving the zone between the lesser trochanter and junction of the proximal and middle thirds of the femur, or intertrochanteric fracture with subtrochanteric extension. All study participants were treated with an intramedullary implant. These fracture patterns were classified with the Winquist and Hansen classification in regards to comminution^[20] and with the AO/OTA fracture classification system^[21]. Exclusion criteria were: skeletally immature patients, patients who presented with an initial Glasgow Coma Scale score below 8, other orthopaedic injuries affecting weight bearing, thoracic or abdominal injury requiring additional surgery, periprosthetic fractures, and bisphosphonate-related atypical subtrochanteric femur fractures. A final sample of 69 patients merited study inclusion, with intramedullary fixation device and assigned postoperative weight bearing protocol at the discretion of the operating surgeon.

Surgical stabilization was performed by one of four fellowship-trained orthopaedic trauma surgeons. When the collection period began there was a consensus among the treating surgeons to limit weight bearing out of concerns for implant failure and complications. During the course of the study the treating physicians initiated a WBAT protocol to improve physical therapy participation and increase mobilization, with all patients following an immediate WBAT protocol starting in 2010. Patients were evaluated regarding: age, sex, high vs low mechanism of injury (MOI), Winquist-Hansen degree of comminution (0-4)^[20], and fracture type according to the AO/OTA classification. Primary outcome in this study was total LOS for patients who were allowed immediate WBAT compared to patients that followed a LWB protocol (Table 1). LWB protocols included weight bearing restrictions, toe touch weight bearing, and partial weight bearing. All study participants were followed until full union could be achieved, determined by radiographic evidence, or until complication was diagnosed (Figure 1 & Figure 2), with an average follow-up period of 12.8 months. Patients requiring additional hospital stay outside the original admission, due to a diagnosed complication, were not considered in determining the LOS primary outcome. A secondary analysis was performed to observe the role of mechanism of injury (MOI) within the relationship between weight bearing protocol and LOS (Table 2). Additionally, a comparison was performed to observe total LOS outcomes for only study participants involved in a high MOI, Winquist-Hansen class III and IV (Figure 3). Lastly, a matched cohort assessment was performed between the two weight bearing groups to better isolate the weight bearing protocol to LOS relationship (Table 3). This involved individually selecting 15 WBAT participants that matched with the 15 original LWB participants on terms of identical MOI and an age within 5 years.

The length of stay primary outcome was compared between WBAT and LWB groups using Wilcox Rank Sum test, also known as Mann-

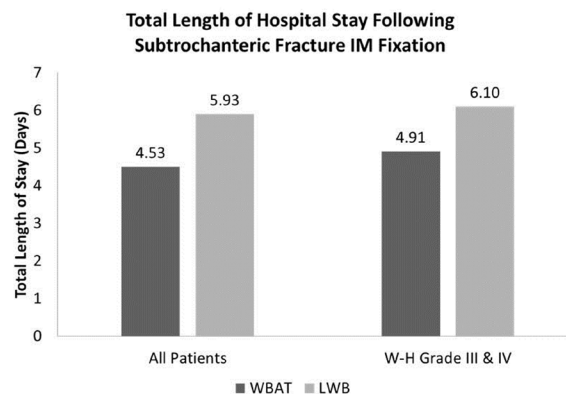


Figure 3 Total length of hospital stay (LOS) is reported for immediate weight bearing as tolerated (WBAT) and limited weight bearing (LWB) groups. LOS is reported for the full patient cohort as well as a high energy cohort of patients with Winquist-Hansen (W-H) Grade III & IV fractures.

Table 1 Study population characteristics by weight-bearing status from August 2009 to November 2015 (N=69).

	WBAT (n=54)	LWB (n=15)	p-value†
Age (in years)	59.5 (SD 24.5)	42.4 (SD 19.2)	0.02*
Gender			0.06
Male	29 (52.8%)	12 (80.0%)	
Female	25 (47.2%)	3 (20.0%)	
Side Fixed			0.25
Right	26 (47.2%)	10 (66.7%)	
Left	28 (52.8%)	5 (33.3%)	
Discharge Disposition			0.28‡
Home	13 (24.1%)	1 (6.6%)	
TCU	17 (31.5%)	7 (46.7%)	
Assisted Living Facility	24 (44.4%)	7 (46.7%)	
OTA			0.08‡
32A	23 (42.6%)	5 (33.3%)	
32B	8 (14.8%)	4 (26.7%)	
32C	8 (14.8%)	6 (40.0%)	
31-A3	15 (27.8%)	0 (0.0%)	
Comminution [0-4]	1.26 (SD 1.11)	2.13 (SD 1.36)	0.02*
Implant			0.51
Cephalomedullary	45 (83.3%)	11 (73.3%)	
Reconstructive	5 (9.3%)	4 (26.7%)	
Standard	4 (7.4%)	0 (0.0%)	
MOI			<0.01*
High	23 (42.6%)	12 (80.0%)	
Low	31 (57.4%)	3 (20.0%)	
Length of Stay	4.53 (SD 1.58)	6.20 (SD 3.10)	<0.01*
Complications	2 (3.70%)	3 (20.0%)	0.43

Abbreviations: Weight bearing as tolerated, WBAT; Limited weight bearing, LWB; standard deviation, SD; OTA, Orthopaedic Trauma Association. *Indicates statistical significance, $p < 0.05$. †Resulting Wilcoxon Rank Sum p-value in comparing distributions of populations across weight bearing status. ‡Resulting chi-squared p-value for multiple categorical analysis.

Whitney-U test, for statistical significance. Linear regression analysis was performed to observe the relationship between weight bearing status, independent variable, and LOS, dependent variable, adjusting for MOI. R-squared values were excluded within the reporting of results, due to uneven and small cohort sizes. All statistical analysis was performed using R software (R Core Team 2013; Boston, Massachusetts).

RESULTS

The mean patient age was 55.7 years [49.8, 61.2] with peaks at 36.5 years [31.1, 41.8] and 75.0 years [70.0, 80.0] for high and low energy MOIs, respectively. High energy injuries including motor vehicle collisions, gunshot wounds, and auto versus pedestrian trauma accounted for 51% (*n* = 35) while low energy ground level falls accounted for the remaining 49% (*n* = 34). A total of 77% (*n* = 53) of fracture patterns were classified as subtrochanteric fractures according to the AO/OTA classification: 32A (*n* = 28), 32B (*n* = 12), and 32C (*n* = 13), while 23% (*n* = 16) were classified as 31-A3 intertrochanteric fractures with subtrochanteric extension. Fractures were further classified in regards to comminution with the majority of fractures falling in the Winqvist type I (*n* = 35) and type II with over fifty percent of cortical contact (*n* = 18). The remaining fractures were highly comminuted type III (*n* = 9) or type IV (*n* = 6).

Implant choice was predominantly a cephalomedullary nail (83%, *n* = 56), followed by reconstruction (13%, *n* = 9) and standard piriformis entry (4%, *n* = 3) without cephalomedullary fixation. The nail diameter was predominantly 10mm (74%, *n* = 51) followed by 11.5 mm (12%, *n* = 9), and 12 mm (12%, *n* = 9).

Fifteen patients followed a LWB protocol, while the remaining 54 followed an immediate WBAT protocol. Overall the WBAT group had a decreased LOS compared to the LWB group (4.53 vs 6.20 days, *p* < 0.01). However, the WBAT group was significantly older than the LWB cohort (59.5 vs 42.4 years; *p* = 0.02). A subgroup analysis of high-energy MOI patients with highly comminuted fracture patterns, Winqvist-Hansen type III or IV, had a decreased LOS when following a WBAT protocol compared to LWB (4.91 vs 6.10 days, *p* < 0.01). Linear regression models identified negative coefficients for the weight bearing status to LOS relationship within a crude (-1.41, *p* = 0.02), MOI-adjusted (-1.17, *p* = 0.07), and MOI interaction model (-1.41, *p* = 0.26). However, only the crude model identified statistically significant results (*p* = 0.02). The matched cohort assessment also identified a significant reduction in LOS for the WBAT group (3.80 vs 6.20 days; *p* = 0.01) while controlling for variables of age (*p* = 0.91) and MOI (*p* = 1.00). There was no statistical difference in the complication rates between groups (*p* = 0.43).

DISCUSSION

Subtrochanteric femur fractures are challenging fractures that occur predominantly in young patients with high-energy MOI and in elderly patients with low-energy MOI^[1,2,22,23]. Internal fixation has gradually transitioned away from extramedullary implants towards cephalomedullary load sharing implants to capitalize on their improved biomechanical profile and biologically conscientious surgical technique^[23,24], with biomechanical data indicating that modern cephalomedullary implants are capable of withstanding the forces of immediate WBAT^[23,25]. In geriatric literature, immediate weight bearing has been used after intramedullary fixation of subtrochanteric femur fractures^[26,27], and it has been suggested that a high energy MOI population may also tolerate immediate WBAT^[28]. The purpose of this study was to evaluate the effect of immediate WBAT versus LWB postoperative protocols on hospital LOS for patients who were treated with cephalomedullary fixation of a subtrochanteric femur fracture.

Our study demonstrated that utilization of an immediate WBAT protocol was associated with a reduced postoperative LOS (4.5 vs 5.9 days, *p* = 0.01). In addition, a sub group analysis of highly comminuted high energy fracture patterns (WH III & IV) had a decreased LOS

Table 2 Linear regression analysis for the association between length of stay and weight bearing status, adjusting for mechanism of injury (N=69).

Model	Parameter	Beta (β)	95% CI	p-value
LOS = WB†	WB1	-1.41	[-2.01, -0.80]	0.02*
LOS = WB + MOI‡	WB1	-1.17	[-1.80, -0.54]	0.07
	MOI	0.6	[0.08, 1.12]	0.25
LOS = WB + MOI + (MOI*WB)	WB	-1.41	[-2.65, 0.17]	0.26
	MOI	0.33	[-1.00, 1.66]	0.8
	WB*MOI	0.32	[-1.13, 1.77]	0.83
LOS = WB + MOI‡ + OTA§	WB	-1.4	[-2.69, 0.21]	0.33
	MOI	0.29	[-1.22, 1.80]	0.82
	31A3§	0.31	[-0.94, 1.56]	0.77
	32A§	-2.23	[-3.62, -0.84]	0.11
	32B§	-1.19	[-2.75, 0.38]	0.49
	32C§	1.45	[-0.34, 3.24]	0.42

Abbreviations: LOS, Length of Stay; WB, Weight Bearing; MOI, Mechanism of Injury. *Indicates statistical significance, *p* < 0.05. †Weight-bearing status with limited weight bearing coded as the reference group and weight bearing as tolerated as the comparator. ‡Mechanism of injury (MOI) with low energy coded as the reference group. §Orthopaedic Trauma Association (OTA) fracture pattern was evaluated as four separate binary terms with the remainder of the population acting as the control.

Table 3 Comparison of length of stay outcomes between weight-bearing status cohorts when matched for mechanism of injury (MOI) and age (within five years).

	WBAT (n=15 of 54)	LWB (n=15)	p-value ^a
Age	41.7 (SD 18.3)	42.4 (SD 19.2)	0.91
Gender			0.25
Male	9 (60.0%)	12 (80.0%)	
Female	6 (40.0%)	3 (20.0%)	
Side Fixed			0.16
Right	6 (40.0%)	10 (66.7%)	
Left	9 (60.0%)	5 (33.3%)	
Discharge Disposition			
Home	2 (13.3%)	1 (6.6%)	0.69
TCU	5 (33.3%)	7 (46.7%)	
Assisted Living Facility	8 (53.3%)	7 (46.7%)	
Comminution [0-4]	1.80 (SD 1.01)	2.13 (SD 1.36)	0.45
MOI			
High	12 (80.0%)	12 (80.0%)	1
Low	3 (20.0%)	3 (20.0%)	
Length of Stay	3.80 (SD 1.52)	6.20 (SD 3.10)	0.01*

Abbreviations: Weight bearing as tolerated, WBAT; Limited weight bearing, LWB; standard deviation, SD. *Indicates statistical significance, *p* < 0.05 ^aResulting Wilcoxon Rank Sum p-value in comparing distributions of populations across Weight-Bearing status. ^bResulting chi-squared p-value for multiple categorical analysis.

when allowed for immediate WBAT after surgery (4.9 vs 6.1 days, *p* = 0.01). The linear regression analysis also supports a decreasing trend in LOS with the use of immediate WBAT after surgery (β = -1.41, *p* = 0.02). Although this study was not powered for analysis of union rates or implant failures, there was no statistical difference (WBAT: 2 vs LWB: 3; *p* = 0.43) for this preliminary assessment. Regardless, immediate postoperative WBAT presents preliminary evidence as an effective strategy to reduce LOS in subtrochanteric fractures and potentially reduce overall rehabilitation time.

Literature on subtrochanteric fractures consists primarily of small case series^[5-8,28-30], and nearly every study has limited postoperative weight bearing to reduce the risk of implant failure in this high stress

region. The most common protocol was LWB for 6 weeks, followed by progressive weight bearing until radiographic union^[5-8]. A 99% union rate was reported in 95 patients with subtrochanteric fractures treated with interlocked intramedullary nails using protected weight bearing with crutches for 6 weeks, followed by progressive weight bearing.⁵ In another study, reconstruction nails were used to treat 45 patients with subtrochanteric fractures who utilized a LWB protocol that was transitioned to full weight bearing after radiographic evidence of callus bridging; this yielded 100% union at 2 years with an average time to union of 13.5 weeks^[29]. A retrospective study of 56 patients with subtrochanteric fractures treated with an open, clamp assisted technique followed by intramedullary nailing resulted in 98% union rate following toe touch weight bearing for 6 weeks^[6]. Similarly, a clamp assisted reduction technique followed by fixation with a statically locked intramedullary nail and supplemental cerclage cables resulted in 98% union rate with protected weight bearing for 6-weeks^[7]. In a study examining outcomes of lateral entry intramedullary nailing, patients were treated with a limited weight bearing protocol for 8-12 weeks, and 75 of 76 patients healed uneventfully^[30]. To date, the only study reporting immediate weight bearing in high energy injuries is a small case series examining the effect of malreduction on time to union^[28]. While limited evidence for immediate WBAT after subtrochanteric fractures exists in the geriatric population^[27,28,31], a growing body of literature has demonstrated the advantages of this protocol for other injuries.

The clinical benefits and safety of immediate WBAT have been demonstrated by a number of previous studies examining geriatric hip fractures, ankle fractures, femoral shaft fractures, humeral shaft fractures and geriatric subtrochanteric fractures^[14,15,32-35]. Immediate weight bearing after surgical stabilization of geriatric hip fractures has become the standard of care due to the decreased mortality and LOS^[14,15]. A systematic review and meta-analysis of weight bearing protocols for internal fixation of ankle fractures concluded that immediate WBAT accelerated patients' return to work and daily activities^[12]. Additionally, a retrospective study of humeral shaft fractures treated with plate osteosynthesis found that immediate crutch weight bearing in patients with non-weight bearing lower extremity injuries was safe and effective, without increasing complications or non-unions in the humeral shaft fractures^[32]. The treatment of comminuted femoral shaft fractures with statically locked intramedullary nails and immediate weight bearing has led to high union rates without an increase in hardware failure^[17,33]. Furthermore, it has been speculated that LWB "may slow rehabilitation, prolong hospitalization, and increase the cost of care in comminuted femoral shaft fractures."^[17] Our findings provide preliminary evidence that immediate WBAT can decrease a patient's LOS, and in the context of current literature provides support for immediate postoperative WBAT as a viable option to decrease LOS after subtrochanteric fractures treated with intramedullary fixation.

This study had a number of strengths and weaknesses. To our knowledge this is the first study to evaluate the effect of immediate postoperative WBAT on LOS for all patients with subtrochanteric fractures. One strength of this study is the relatively large cohort for this unique fracture pattern. Large uniform studies have been difficult to establish because subtrochanteric fractures are less prevalent than fractures of the diaphysis or intertrochanteric femur, and they occur in a heterogeneous population^[6]. Additionally, this retrospective cohort design provides level III evidence on a topic that has predominantly been covered only in small case series^[5-8,28-30]. Most importantly, this study was piloted to encourage future large-scale investigations, and the data collected by this preliminary investigation provides

foundational evidence to pursue larger and more rigorous studies.

There are also considerable limitations to the collected data. The immediate WBAT and LWB groups are not evenly matched because in 2010 an immediate WBAT protocol was initiated so that all subtrochanteric fractures were permitted early participation in physical therapy-this generated an uneven distribution between groups (54 vs 15). There is also imbalance in the fracture patterns between the two weight-bearing cohorts, as the LWB group presents without 31-A3 fractures. The implants used for fixation were heterogeneous, and the surgeons performing the procedures were allowed to use the intramedullary implants and nail sizes of their preference. Moreover, this study is unable to adjust for the quality of reduction that was achieved during surgery. Another potential weakness was that WBAT is patient-dependent, and no attempt was made to quantify the weight self-transmitted through the injured limb. We were also unable to account for other patient-dependent characteristics, such as BMI, medical comorbidities, smoking, and patient disposition. These are important considerations when evaluating the effectiveness of WBAT protocol for both LOS and overall complication rate but were not directly assessed due to concerns regarding overall sample size and uneven group sizes. These variables will be actively collected in future studies to ensure a reliable representation of the study population and statistical robustness. This study was underpowered to evaluate for overall complication rate and need for re-operation. Complication rates for this procedure are relatively rare and would require 163 patients in either cohort to detect an increased rate from 5 to 10%, via post-hoc power analysis. This sample size consideration could be accounted for within a multi-site study, which would appropriately evaluate complication rates in immediate postoperative weight bearing. Finally, due to the non-interventional nature of this study, there are concerns of surgeon or clinician bias influencing study results, including that clinicians might assign younger and healthier patients to the WBAT cohort. However, in the present study, the immediate WBAT cohort identifies with a significantly older mean age than the LWB cohort (59.5 vs 42.4 years; $p = 0.02$). Furthermore, the matched analysis identifies a significant difference in LOS between the two protocols even after controlling for age and MOI (Table 3).

While hindered by considerable limitations, this pilot-level study still provides a preliminary representation of the impact of postoperative WBAT protocols on LOS outcomes, and sets the foundation for large-scale studies to further evaluate these long-term outcomes. This study can act as a foundational source of data to encourage further large-scale studies to evaluate more rigorous clinical outcomes such as long-term complications or morbidity, time to radiographic union, and time to return-to-previous functionality. Future studies may involve controlled RCTs or large-scale multi-center retrospective reviews.

Our study demonstrates that a postoperative protocol utilizing immediate WBAT associates with a reduced LOS for patients with subtrochanteric femur fractures treated with locked intramedullary nails. While our study presents considerable limitations, the initial findings have contributed key foundational level data to encourage further large-scale studies which would allow for an adequately powered sample when evaluating the safety of immediate weight bearing protocol for subtrochanteric fractures and adjust for various patient-related characteristics. Immediate postoperative weight bearing presents preliminary evidence to effectively reduce postoperative LOS and has potential to improve patient satisfaction, decrease overall cost of care, and even reduce rehabilitation time for recovering patients.

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