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ORIGINAL ARTICLE • HIP - FRACTURES

The association between weight-bearing status and early complications in hip fractures

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Abstract

Background Early mobilization and weight-bearing have been proposed to improve hip fracture outcomes. This study aimed to compare early postoperative complications and outcomes of patients who underwent weight-bearing as tolerated (WBAT) on postoperative day one (POD1) with those that did not on: (1) 30-day mortality; (2) 30-day postoperative major and minor complications; (3) length of stay (LOS); and (4) discharge disposition after hip fracture management.

Methods The NSQIP database was used to identify 7947 hip fracture patients managed with a hemiarthroplasty and internal fixation, sliding hip screw, or cephalomedullary nail, for a total of 5845 patients were allowed to WBAT on POD1. They were compared to patients who were non-WBAT using adjusted multivariate regression models to evaluate the effect of WBAT status on the outcomes above.

Results Among the cephalomedullary nail patients, WBAT on POD1 was associated with a decreased likelihood of mortality. In the cephalomedullary nail and sliding hip screw treatment groups, patients were less likely to experience major and minor complications if they were WBAT on POD1. WBAT patients had shorter LOS in the sliding hip screw and cephalomedullary nail treatment groups. Patients were less likely to be discharged to a non-home facility when WBAT on POD1 regardless of treatment.

Conclusion Early weight-bearing after surgical care of hip fracture seems to decrease morbidity and mortality; however, this effect is treatment dependent. These findings further support the need for early mobilization and rapid recovery programs in the care of hip fracture patients.

Level of evidence Level III.

Keywords Weight-bearing · Sliding hip screw · Cephalomedullary nail · Hemiarthroplasty · Short-term mortality · Short-term complications

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Introduction

Hip fractures are a common injury with a lifetime incidence of approximately 10% in males and 20% in females [1–3]. Furthermore, patients who suffer a hip fracture face challenging repercussions, with half of them never walking independently again and 1-year mortality rates ranging between 14 and 25% [4–6]. Interestingly, while 1-year mortality rates for intertrochanteric fractures decreased substantially between the 1980s and late 2000s (34% to 23%), 1-year mortality rates for femoral neck fractures have stayed relatively constant at 20% [7]. Furthermore, healthcare costs associated with the management of hip fractures place a substantial financial burden, with national estimates between \$10.3 billion and \$15.2 billion a year for the USA in 2015 [8].

Various patient factors have been found to affect postoperative morbidity and mortality following hip fractures. Older age has been shown to increase mortality between 5 and 8 times in the first 3 months following hip fracture [9]. Other factors known to increase hip fracture mortality include, but are not limited to, functional status, male sex, high risk for anesthesia, abnormal EKG, cognitive impairment, pre-fracture mobility, time to surgery, fracture type, and transfer of patient [10, 11]. Additionally, several added risk factors have been associated with prolonged LOS after hip fractures such as congestive heart failure (CHF), neurological disorders, complicated diabetes, and older age [12]. In an effort **to** mitigate these factors and decrease morbidity and mortality, early mobilization and rapid recovery programs have been implemented [13–16].

The effects of weight-bearing in major orthopedic procedures have found to potentially attenuate morbidity and mortality. A meta-analysis on early weight-bearing in hip fracture patients after uncemented total hip arthroplasty (THA) found no differences in subsidence ($p=0.84$), spot welds ($p=0.24$), bone growth fixation ($p=1.00$), radiolucent lines ($p=0.96$), and prosthetic loosening ($p=0.74$) between full weight-bearing patients and partial weight-bearing controls at 2-year follow-up [17]. A prospective cohort study of 194 patients treated with sliding hip screw, hemiarthroplasty, or intramedullary hip screw found that non-weight-bearing status was associated with increased mortality (odds ratio [OR], 1.99; 95% confidence interval [CI] 1.16–3.43) [18]. Moreover, a recent retrospective study including 3668 patients treated with sliding hip screw, cephalomedullary nail, or hemiarthroplasty reported that overall those with weight-bearing restrictions had an increased risk of any adverse event(OR 1.44; 95% CI 1.21–1.70; $p<0.001$) [19]. While these studies found that weight-bearing status had substantial effects on postoperative complications, both arthroplasty- and osteosynthesis-based treatments were grouped together and subanalyses of specific procedures have not been performed.

While the potential benefits of early weight-bearing after hip fracture management have been presented, its effect on reducing postoperative complications and mortality within specific surgical procedures has not been determined. Therefore, the aim of the current study was to assess the effect of WBAT on: (1) 30-day mortality; (2) 30-day postoperative major and minor complications; (3) discharge disposition; and (4) LOS in hip fracture patients treated with cephalomedullary nail, sliding hip screw, and hemiarthroplasty and internal fixation,

Methods

Data source

The American College of Surgeons (ACS) National Surgical Improvement Quality Improvement Program (NSQIP) database as well as the hip fracture subsection was utilized in this study. The database includes postoperative mortality and morbidity outcomes, intraoperative variables, and preoperative risk factors, for a variety of major surgeries [20, 21]. The specialized hip fracture subsection provides additional information not available for other conditions such as pathologic fracture status, use of an osteoporotic medication, and dementia status. Certified Surgical Clinical Reviewers maintain and audit the database regularly to ensure accuracy.

Study population

The hip fracture subsection of the NSQIP database was queried for all patients who underwent cephalomedullary nail, sliding hip screw, and hip hemiarthroplasty and internal fixation using the Current Procedural Terminology (CPT) codes 27245, 27244, and 27236, respectively, between January 1, 2016, and December 31, 2016, which yielded a total of 9390 patients. The principal treatment variable was reviewed to ensure the CPT code matched one of the three surgical procedures, and no discrepancies were found. Patients were then cross-referenced with the NSQIP database for additional data on existing comorbidities and incidence of 30-day complications; those without data in both databases were excluded leaving a total of 9360 (99.7%). Patients were also excluded if their case contained any other procedure, such as concurrent humeral shaft or acetabular fracture open reduction and internal fixation leaving 8785 (93.6%) cases. Additionally, patients whose weight-bearing status was designated "N/A (Bedridden or Medical Issue)" were excluded to remove patients where WBAT was not possible, thus leaving a total of 7947 eligible cases (84.6%) for the final analysis. Not including patients that were under the designation of "N/A bedridden or Medical Issue" would further strengthen the findings of the study if an effect were to be found, by removing the potential confounder of patient that were not able to weight bear or ambulate due to other no modifiable factors. Of the final 7947 patients included in the analysis 4040 underwent a cephalomedullary nail procedure, 1138 patients underwent a sliding hip screw procedure, and 2769 patients underwent hip hemiarthroplasty or internal fixation procedures.

Study variables

The WBAT on POD1 variable is reported in NSQIP as "Yes" or "No" (cases reported as "N/A" were excluded as noted above) [22]. Patients who did not weight bear as tolerated are recorded as "No," but were not further stratified into non-weight-bearing, partial weight-bearing, or touch-down weight-bearing in the database. The cephalomedullary nail treatment group had 2858 (70.7%) patients who were WBAT on POD1, the sliding hip screw treatment group had 823 (72.3%), and the hemiarthroplasty and internal fixation treatment group had 2164 (78.2%). Preoperative variables on patient demographics and comorbidities were also collected and are presented in Table 1. Overall, patients who were WBAT on POD1 were less likely to have preoperative dementia (23.9% vs. 33.5% for cephalomedullary nail $p < 0.001$, 22.0% vs. 35.9% for sliding hip screw $p < 0.001$, and 26.9% vs. 38.7% for hemiarthroplasty and internal fixation $p < 0.001$), delirium (8.7% vs. 15.1% for cephalomedullary nail $p < 0.001$, 7.0% vs. 16.8% for sliding hip screw $p < 0.001$, and 11.0% vs. 15.0% for hemiarthroplasty and internal fixation $p = 0.006$), and CHF (3.9% vs. 4.6% for cephalomedullary nail $p = 0.344$, 1.8% vs. 2.9% for sliding hip screw $p = 0.277$, and 3.0% vs. 3.6% for hemiarthroplasty and internal fixation n $p = 0.467$).

Perioperative and postoperative outcomes

The outcomes of interest included 30-day mortality, 30-day complications (major and minor), LOS, and non-home discharge disposition. Importantly, patients whose home was a facility prior to admission were included in the home discharge cohort. The 30-day postoperative complications were assessed as the following pooled groups, any complication, any major complication and any minor complications separately. Major complications included deep incisional surgical site infection (SSI), organ/space SSI, dehiscence, unplanned intubation, pulmonary embolism, on a ventilator greater than 48 h, acute renal failure, stroke or cerebrovascular accident, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, deep vein thrombosis (DVT) requiring therapy, sepsis, septic shock, 30-day reoperation, 30-day readmission, 30-day unplanned readmission, and 30-day mortality, as defined by the ACS NSQIP [20]. Minor complications included superficial incisional (SSI), pneumonia, progressive renal insufficiency, urinary tract infection (UTI), transfusions within 72 h of surgery, Clostridium difficile (C. Diff) infection, pressure sore, and delirium.

Data analysis

To compare baseline characteristics between the WBAT and non-WBAT cohorts, Pearson's Chi-squared tests and Fisher's exact tests were performed for categorical preoperative variables, while two-sided independent t tests were performed for scale variables. Mortality rates, complications rates, and non-home discharge dispositions between the WBAT and non-WBAT cohorts were compared with Pearson's Chi-squared tests and Fisher's exact tests, whereas LOS was examined using two-sided independent t tests (Table 2).

In order to identify WBAT on POD1 as an independent risk factor for mortality, complications, or non-home discharge, potential confounding variables were controlled for with bimodal multivariate logistic regression models. The models were adjusted for preoperative variables that were significantly different on bivariate analysis. Additionally, a multivariate linear regression model adjusted for significantly different baseline variables was constructed to evaluate whether non-WBAT was statistically significant risk factor for an increased LOS. Statistical significance was maintained at a p value of < 0.05 for all tests. All analyses were performed using SPSS Statistics 23 for Mac (IBM Corporation, Armonk, NY).

Results

30-Day mortality

Overall, 30-day mortality rates were lower in the WBAT on POD1 cohorts for cephalomedullary nail and sliding hip screw patient, but not hemiarthroplasty and internal fixation. After controlling for potentially confounding variables, multivariate analysis revealed that WBAT on POD1 status was associated with a significantly reduced risk of 30-day mortality (OR 0.532; 95% CI 0.383–0.738; $p < 0.001$) for the cephalomedullary nail cohort. For patients managed with sliding hip screw, although a trend of lower 30-day mortality was observed with the WBAT cohort, this was not statistically significant (OR 0.589; 95% CI 0.298–1.163; $p = 0.127$). WBAT on POD1 for patients treated with hemiarthroplasty and internal fixation was not found to have an effect on 30-day mortality (OR 1.072; 95% CI 0.670–1.715;

Table 1 Demographics in CMN, SHS, and hemiarthroplasty for WBAT on POD1 and non-WBAT on POD1

Demographic	Cephalomedullary nail ($n=4040$)					Sliding hip screw ($n=1138$)					Hemiarthroplasty and internal fixation ($n=2769$)				
	WBAT on POD1 ($N=2858$)		Non-WBAT on POD1 ($n=1182$)		*p* value	WBAT on POD1 ($n=823$)		Non-WBAT on POD1 ($n=315$)		*p* value	WBAT on POD1 ($n=2164$)		Non-WBAT on POD1 ($n=605$)		*p* value
	N	%	*N*	%		*N*	%	*N*	%		*N*	%	*N*	%	
Age mean ± SD	76.1 ± 20.1		77.8 ± 18.8		**0.017****	75.5 ± 20.8		77.0 ± 18.7		0.261**	76.8 ± 18.9		76.7 ± 18.5		0.126**
BMI	25.21 ± 6.11		25.48 ± 6.57		0.248**	24.88 ± 5.50		24.65 ± 6.13		0.584**	24.94 ± 5.28		24.60 ± 4.93		0.188**
Sex—female	2403	71.5	857	72.5	0.512	586	71.2	201	63.8	**0.016**	1466	67.7	429	70.9	0.139
Anesthesia					**0.012***					**0.026***					0.213*
Epidural	2	0.1	0	0		0	0.0	0	0.0		0	0.0	1	0.2	
General	2025	70.9	839	71.0		508	61.7	217	68.9		1506	69.6	445	73.6	
Local	0	0.0	1	0.1		0	0.0	0	0		0	0.0	0	0.0	
Monitored anesthesia care	221	7.7	64	5.4		65	7.9	11	3.5		162	7.5	35	5.8	
None	0	0.0	0	0.0		0	0.0	0	0.0		1	< 0.1	0	0.0	
Other	2	0.1	1	0.1		1	0.1	0	0.0		1	< 0.1	0	0.0	
Regional	22	0.8	4	0.3		10	1.2	2	0.6		10	0.5	3	0.5	
Spinal	586	20.5	273	23.1		239	29.0	85	27.0		484	22.4	121	20.0	
Hip fracture type					**< 0.001**					0.583					**0.016**
Femoral neck—nondisplaced	76	2.7	16	1.4		71	8.6	27	8.6		426	19.7	136	22.5	
Femoral neck—displaced	74	2.6	44	3.7		52	6.3	19	6.0		1573	72.7	405	66.9	
Intertrochanteric	2376	83.1	941	79.6		639	77.6	236	74.9		102	4.7	32	5.3	
Subtrochanteric	258	9.0	149	12.6		45	5.5	24	7.6		14	0.6	7	1.2	
Other	74	2.6	32	2.7		16	1.9	9	2.9		49	2.3	25	4.1	
Diabetes					0.514					0.249					0.140
Insulin dependent	225	7.9	104	8.8		56	6.8	23	7.3		133	6.1	50	8.3	
Non-insulin dependent	306	10.7	133	11.3		105	12.8	29	9.2		199	9.2	60	9.0	
Non-diabetic	2327	81.4	945	79.9		662	80.4	263	83.5		1832	84.7	495	81.8	
Smoker	334	11.7	131	11.1	0.584	94	11.4	39	12.4	0.652	224	10.4	66	10.9	0.692
Functional status					**< 0.001**					**< 0.001**					**< 0.001**
Independent	2374	83.1	860	72.8		682	82.9	216	68.6		1754	81.1	408	67.4	
Partially dependent	418	14.6	265	22.4		112	14.8	81	25.7		360	16.6	153	25.3	
Totally dependent	55	1.9	39	3.3		16	1.9	13	4.1		36	1.7	37	6.1	
Unknown	11	0.4	18	1.5		3	0.4	5	1.6		14	0.6	7	1.2	
Hx of COPD	284	9.9	143	12.1	**0.042**	74	9.0	38	12.1	0.120	216	10.0	58	9.6	0.774
Hx of CHF	112	3.9	54	4.6	0.344	15	1.8	9	2.9	0.277	66	3.0	22	3.6	0.467
Dialysis	42	1.5	29	2.5	**0.030**	7	0.9	14	4.4	**< 0.001**	29	1.3	16	2.6	**0.025**
Disseminated cancer	85	3.0	30	2.5	0.448	17	2.1	4	1.3	0.372	56	2.6	12	2.0	0.396

Table 1 (continued)

Demographic	Cephalomedullary nail ($n=4040$)					Sliding hip screw ($n=1138$)					Hemiarthroplasty and internal fixation ($n=2769$)				
	WBAT on POD1 ($N=2858$)		Non-WBAT on POD1 ($n=1182$)		*p* value	WBAT on POD1 ($n=823$)		Non-WBAT on POD1 ($n=315$)		*p* value	WBAT on POD1 ($n=2164$)		Non-WBAT on POD1 ($n=605$)		*p* value
	N	%	*N*	%		*N*	%	*N*	%		*N*	%	*N*	%	
Wound infection	94	3.3	56	4.7	**0.027**	24	2.9	20	6.3	**0.007**	72	3.3	31	5.1	**0.039**
Use of corticosteroids	160	5.6	63	5.3	0.734	38	4.6	15	4.8	0.917	140	6.5	29	4.8	0.128
Weight loss	42	1.5	18	1.5	0.899	4	0.5	5	1.6	0.126	29	1.3	11	1.8	0.384
ASA classification					**<0.001***					**0.002***					**0.047***
1—No disturb	24	0.8	6	0.5		9	1.1	1	0.3		16	0.7	2	0.3	
2—Mild disturb	508	17.8	148	12.5		167	20.3	40	12.7		373	17.2	84	13.9	
3—Severe disturb	1798	62.9	716	60.6		480	58.3	184	58.4		1360	62.8	385	63.6	
4—Life threatening	519	18.2	305	25.8		159	19.3	89	28.3		415	19.2	133	22.0	
5—Moribund	5	0.2	2	0.2		2	0.2	0	0.0		0	0.0	1	0.2	
None assigned	4	0.1	5	0.4		6	0.7	1	0.3		0	0.0	0	0.0	

Statistical significance was maintained at a *p* value of < 0.05 (in bold)

* = Fisher's exact test, ** = two-sided t test

$p=0.771$). Odds ratios on outcomes of interest can be found in Table 3.

30-Day postoperative major and minor complications

Risk of 30-day complications was found to be lower in the patients who were WBAT in the cephalomedullary nail and sliding hip screw groups mainly, but not hemiarthroplasty and internal fixation. Among patients treated with cephalomedullary nail, those who were WBAT on POD1 had a lower risk of suffering any complication (OR 0.631; 95% CI 0.541–0.736; $p<0.001$). The cephalomedullary nail WBAT cohort was also significantly less likely to have major (OR 0.750; 95% CI 0.632–0.902; $p=0.002$) and minor (OR 0.618; 95% CI 0.532–0.719; $p<0.001$) complications. Reductions in specific major complications included deep incisional SSI ($p=0.020$), unplanned reintubation ($p=0.034$), and cardiac arrest requiring CPR ($p=0.013$). Specifically, the minor complications that saw reductions were: postoperative pressure sore ($p=0.019$), postoperative delirium ($p<0.001$), transfusion ($p<0.001$), and C. Diff infection ($p=0.027$). Moreover, among patients treated with sliding hip screw, WBAT on POD1 status was associated with a significantly reduced risk of major complications (OR 0.594; 95% CI 0.407–0.867; $p=0.007$). There was also a reduction in minor complications associated with WBAT on POD 1 after sliding hip screw ($p=0.023$). Following hemiarthroplasty and internal fixation, although a decrease in blood transfusion risk ($p=0.003$) was observed with WBAT on POD1, there were no relationships between WBAT status and overall major (OR 0.965; 95% CI 0.749–1.244; $p=0.783$) or minor complications (OR 0.832; 95% CI 0.680–1.018; $p=0.074$).

Discharge disposition

Patients that were in the WBAT cohorts were more likely to be discharged home. On multivariate analyses, WBAT on POD1 was associated with a significantly lower risk of non-home discharge disposition after cephalomedullary nail (OR 0.661; 95% CI 0.564–0.774; $p<0.001$), sliding hip screw (OR 0.621; 95% CI 0.458–0.842; $p=0.002$), and hip hemiarthroplasty and internal fixation (OR 0.720; 95% CI 0.584–0.889; $p=0.002$).

Lengths of stay

Early weight-bearing was found to be associated with reduced in-hospital LOS. WBAT on POD1 was associated with significantly decreased LOS among patients managed with cephalomedullary nail ($B=-1.071$; 95% CI -1.513 to

Table 2 Complications in CMN, SHS, and hemiarthroplasty for WBAT on POD1 and non-WBAT on POD1

Demographic	Cephalomedullary nail ($n=4040$)					Sliding hip screw ($n=1138$)					Hemiarthroplasty and internal fixation ($n=2769$)				
	WBAT on POD1 ($n=2858$)		Non-WBAT on POD1 ($n=1182$)		*p* value	WBAT on POD1 ($n=823$)		Non-WBAT on POD1 ($n=315$)		*p* value	WBAT on POD1 ($n=2164$)		Non-WBAT on POD1 ($n=605$)		*p* value
	N	%	*N*	%		*N*	%	*N*	%		*N*	%	*N*	%	
Any complication	1552	54.3	827	70.0	< **0.001**	396	48.1	199	63.2	< **0.001**	989	45.7	332	54.9	< **0.001**
Major complication	394	13.8	235	19.9	< **0.001**	90	10.9	65	20.6	< **0.001**	320	14.8	102	16.9	0.210
Minor complication	1437	50.3	788	66.7	< **0.001**	361	43.9	189	60.0	< **0.001**	874	40.4	301	49.8	< **0.001**
Postoperative pressure sore	106	37.0	71	60.0	**0.001**	52	6.3	23	7.3	0.550	76	3.5	33	5.5	**0.030**
Postoperative delirium	671	23.5	427	36.1	< **0.001**	177	21.5	102	32.4	< **0.001**	561	25.9	199	32.9	**0.001**
Postoperative mobility aid	1445	52.2	679	60.8	< **0.001**	380	47.9	169	56.7	**0.010**	1161	53.1	35	60.4	**0.002**
Postoperative osteoporosis medication	1314	46.0	521	44.1	0.270	368	44.7	142	45.1	0.912	1051	48.6	296	48.9	0.876
Superficial SSI	14	0.5	6	0.5	0.942	4	0.5	2	0.6	0.671*	9	0.4	2	0.3	1.000*
Deep SSI	1	< 0.1	6	0.5	**0.003***	1	0.1	1	0.3	0.477*	2	0.1	1	0.2	0.523*
Organ/space SSI	4	0.1	0	0.0	0.328*	1	0.1	0	0.0	1.000*	11	0.5	2	0.3	0.746*
Dehiscence	0	0.0	1	0.1	0.293*	1	0.1	0	0.0	1.000*	3	0.1	0	0.0	1.000*
Pneumonia	98	3.4	55	4.7	**0.064**	23	2.8	22	7.0	**0.001**	65	3.0	23	3.8	0.323
Reintubation	13	0.5	13	1.1	**0.020**	4	0.5	7	2.2	**0.013***	10	0.5	6	1.0	0.134*
Pulmonary embolism	15	0.5	4	0.3	0.431	5	0.6	2	0.6	1.000*	11	0.5	5	0.8	0.365*
Ventilator > 48 h	8	0.3	10	0.8	**0.014**	2	0.2	4	1.3	0.053*	11	0.5	3	0.5	1.000*
Progressive renal insufficiency	8	0.3	6	0.5	0.254*	2	0.2	1	0.3	1.000*	4	0.2	3	0.5	0.181*
Acute renal failure	6	0.2	5	0.4	0.310	1	0.1	2	0.6	0.187*	5	0.2	0	0.0	0.592*
Urinary tract infection	127	4.4	57	4.8	0.599	31	3.8	23	7.3	**0.012**	89	4.1	19	3.1	0.275
Cerebrovascular accident	18	0.6	12	1.0	0.194	3	0.4	1	0.3	1.000*	13	0.6	5	0.8	0.567*
Cardiac arrest requiring CPR	7	0.2	10	0.8	**0.013***	2	0.2	2	0.6	0.308*	6	0.3	1	0.2	1.000*
Myocardial infarction	74	2.6	34	2.9	0.607	8	1.0	8	2.5	0.052*	36	1.7	13	2.1	0.424
Transfusion	863	30.2	487	41.2	< **0.001***	206	25.0	99	31.4	**0.029**	275	12.7	114	18.8	< **0.001**
Deep vein thrombosis	41	1.4	19	1.6	0.679	7	0.9	3	1.0	1.000*	18	0.8	6	1.0	0.708
Sepsis	22	0.8	19	1.6	**0.016**	4	0.5	2	0.6	0.671*	21	1.0	5	0.8	< **0.001**
Septic shock	14	0.5	5	0.4	0.778	4	0.5	3	1.0	0.403*	9	0.4	3	0.5	0.732*
C. difficile	25	0.9	22	1.9	**0.008**	4	0.5	4	1.3	0.228*	17	0.8	6	1.0	0.621
Mortality	84	2.9	81	6.9	< **0.001**	23	2.8	19	6.0	**0.010**	83	3.8	27	4.5	0.485
Return to OR	51	1.8	23	1.9	0.728	14	1.7	13	4.1	**0.016**	56	2.6	13	2.1	0.540
Non-home discharge	1029	43.0	551	56.6	< **0.001**	273	38.6	146	52.3	< **0.001**	665	36.1	247	47.0	< **0.001**
Still in hospital	28	1.0	20	1.7	0.057	18	2.2	6	1.9	0.767	17	0.8	9	1.5	0.113
Reoperation	51	1.8	23	1.9	0.728	14	1.7	13	4.1	**0.016**	56	2.6	13	2.1	0.540
Readmission	195	6.8	98	8.3	0.102	51	6.2	34	10.8	**0.008**	19	8.8	54	8.9	0.911
Unplanned readmission	194	6.8	97	8.2	0.113	51	6.2	32	10.2	**0.021**	54	8.9	189	8.7	0.883

Statistical significance was maintained at a p value of < 0.05 (in bold)

** = Fisher's exact test

-0.630; $p<0.001$) and sliding hip screw ($B=-1.486$; 95% CI -2.412 to -0.561; $p=0.002$) when WBAT on POD1. For hemiarthroplasty and internal fixation patients, no statistically significant relationship between LOS and WBAT on POD1 ($B=-0.476$; 95% CI -1.006 to 0.055; $p=0.079$) was found.

Discussion

The prevalence of hip fractures is only expected to increase further due to our aging population with some estimates predicting 500,000 to 1 million cases occurring in the USA per year by 2050 [23]. A hip fracture doubles the risk of

Table 3 Adjusted multivariate regression analysis of perioperative outcomes and complications

Outcome	Cephalomedullary nail			Sliding hip screw			Hemiarthroplasty and internal fixation		
	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value	Odds Ratio	95% CI	*p* value
Any complication	0.631	(0.541–0.736)	< **0.001**	0.756	(0.599–1.021)	**0.068**	0.843	(0.690–1.030)	0.095
Major complication	0.750	(0.623–0.902)	**0.002**	0.594	(0.407–0.867)	**0.007**	0.965	(0.749–1.244)	0.783
Minor complication	0.618	(0.532–0.719)	< **0.001**	0.706	(0.523–0.954)	**0.023**	0.832	(0.680–1.018)	0.074
Postoperative pressure sore	0.684	(0.498–0.940)	**0.019**	1.151	(0.651–2.032)	0.629	0.807	(0.520–1.252)	0.339
Postoperative delirium	0.651	(0.550–0.770)	< **0.001**	0.804	(0.566–1.142)	0.223	0.895	(0.710–1.129)	0.351
Superficial SSI	1.129	(0.426–2.993)	0.807	1.269	(0.163–9.863)	0.820	1.672	(0.344–8.134)	0.524
Deep SSI	0.078	(0.009–0.673)	**0.020**	0.817	(0.037–17.916)	0.898	0.726	(0.055–9.512)	0.807
Organ/space SSI	2.14E + 06	(.000–)	0.989	6.93E + 05	(.000–)	0.993	1.593	(0.339–7.473)	0.555
Dehiscence	0.000	(.000–)	0.948	6.44E + 08	(.000–)	0.994	1.07E + 06	(.000–)	0.991
Pneumonia	0.854	(0.602–1.210)	0.375	0.454	(0.240–0.858)	**0.015**	0.971	(0.585–1.613)	0.909
Reintubation	0.425	(0.192–0.937)	**0.034**	0.289	(0.074–1.120)	0.072	0.581	(0.201–1.684)	0.317
Pulmonary embolism	1.765	(0.570–5.465)	0.324	0.784	(0.143–4.347)	0.784	0.632	(0.213–1.879)	0.409
Ventilator > 48 h	0.386	(0.148–1.002)	0.050	0.304	(0.046–2.006)	0.216	1.117	(0.296–4.218)	0.870
Progressive renal insufficiency	0.567	(0.193–1.666)	0.302	1.452	(0.094–22.382)	0.789	0.421	(0.090–1.971)	0.272
Acute renal failure	0.626	(0.171–2.296)	0.480	0.168	(0.013–2.213)	0.175	1.98E + 06	(.000–)	0.991
Urinary tract infection	0.924	(0.665–1.284)	0.638	0.480	(0.267–0.865)	**0.015**	1.365	(0.817–2.283)	0.235
Cerebrovascular accident	0.639	(0.302–1.352)	0.241	9.335	(0.076–1147.539)	0.363	0.735	(0.255–2.118)	0.569
Cardiac arrest requiring CPR	0.287	(0.107–0.773)	**0.013**	0.820	(0.086–7.824)	0.863	2.532	(0.251–25.594)	0.431
Myocardial infarction	0.960	(0.630–1.462)	0.849	0.673	(0.221–2.052)	0.487	0.867	(0.449–1.673)	0.670
Transfusion	0.699	(0.604–0.810)	< **0.001**	0.878	(0.643–1.200)	0.414	0.684	(0.532–0.879)	**0.003**
Deep vein thrombosis	0.845	(0.482–1.481)	0.556	0.866	(0.193–4.081)	0.877	0.920	(0.351–2.409)	0.865
Sepsis	0.561	(0.297–1.059)	0.075	0.715	(0.121–4.239)	0.712	1.475	(0.535–4.072)	0.453
Septic shock	1.064	(0.374–3.024)	0.908	0.561	(0.133–2.782)	0.479	0.962	(0.249–3.716)	0.955
C. difficile	0.511	(0.282–0.927)	**0.027**	0.686	(0.143–3.295)	0.638	0.829	(0.318–2.163)	0.702
Mortality	0.532	(0.383–0.738)	< **0.001**	0.589	(0.298–1.163)	0.127	1.072	(0.670–1.715)	0.771
Return to OR	1.078	(0.645–1.801)	0.774	0.453	(0.201–1.023)	0.057	1.306	(0.699–2.440)	0.402
Non-home discharge	0.661	(0.564–0.774)	< **0.001**	0.621	(0.458–0.842)	**0.002**	0.720	(0.584–0.889)	**0.002**
Still in hospital	0.633	(0.348–1.154)	0.138	1.780	(0.639–4.955)	0.270	0.679	(0.292–1.578)	0.368
Reoperation	1.078	(0.645–1.801)	0.774	0.453	(0.201–1.023)	0.057	1.306	(0.699–2.440)	0.402
Readmission	0.920	(0.709–1.194)	0.529	0.677	(0.412–1.110)	0.112	1.070	(0.772–1.482)	0.685
Unplanned readmission	0.928	(0.714–1.206)	0.576	0.741	(0.448–1.225)	0.242	1.062	(.069–2.372)	0.315

death within 1 year which highlights the importance of interventions that decrease morbidity and mortality among hip fracture patients [23, 24]. Our study demonstrated that WBAT on POD1 is associated with both decreased mortality in patients treated with a cephalomedullary nail, but not with sliding hip screw or hemiarthroplasty and internal fixation. Additionally, in the cephalomedullary nail and sliding hip screw treatments groups, patients that were WBAT on POD1 were found to have a lower risk of major and minor complications and decreased LOS, but not in those treated with hemiarthroplasty and internal fixation. Across all treatment groups, patients were less likely to be discharged to a non-home destination if they were WBAT on POD1; and after cephalomedullary nail and sliding hip screw, patients that were WBAT on POD1 had significantly shorter in-hospital LOS.

Despite the relatively large sample size and numerous variables included in the analyses for this study, it is not without limitations. The reasons surrounding physician's treatment decision for cephalomedullary nail, sliding hip screw or hemiarthroplasty and internal fixation were unknown. The clinical decision to make a patient non-WBAT on POD1 whether that be due to the severity of the fracture, the difficulty of the surgery, or the perceived lack of reliability of the patient was not able to be investigated. Furthermore, weight-bearing may not be a modifiable risk factor in all patients, and baseline physical status has a crucial role. However, to account for this we controlled for baseline physical status with multivariate analyses and excluded constitutionally bedridden patients or those who may have been unable to weight bear for medical reasons. Since previous studies have called into question weight-bearing restriction compliance [25, 26], this might further limit our findings due to unknown crossover, which is an unavoidable limitation of this aspect of hip fracture care research. Finally, NSQIP only tracks 30-day complications, and while many complications arising for surgery occur within this time frame, long-term follow-up data to capture outcomes outside of the 30-day window could shed more light on the role of WBAT on POD1 in hip fractures. Despite these limitations, this study is the first of its kind in describing the importance of early weighing bearing in specific hip fracture surgical treatments.

Our findings are consistent with existing evidence. The use of a hip fracture bundle care, which includes early mobilization, has previously shown to reduce in-hospital mortality by 10.5% ($p < 0.001$) in 198 patients with subcapital, subtrochanteric, and intertrochanteric hip fractures regardless of procedure with a 12-month follow-up [27]. Similarly, a randomized controlled trial with 60 hip fracture patients (managed with cephalomedullary nail, sliding hip screw, or hemiarthroplasty and internal fixation) found that those who walked on postoperative day 1 or 2 had a higher incidence of home discharge compared to patients who walked on POD 3 or 4 (26.3% vs. 2.4%) [14]. Additionally, Ottesen et al. a retrospective study using the same NSQIP hip fracture database with 3668 patients treated with sliding hip screw, cephalomedullary nail, and hemiarthroplasty and internal fixation found that weight-bearing restrictions increased any adverse events (OR 1.44; 95% CI 1.21–1.70; $p < 0.001$) [19]. The study also discovered weight-bearing restrictions were a risk factor for severe adverse events (OR 1.42; 95% CI 1.17–1.73; $p < 0.001$), minor adverse events (OR 1.30; 95% CI 1.02–1.65; $p = 0.034$), a LOS > 7 days (OR 1.69; 95% CI 1.47–1.95; $p < 0.001$), and mortality within 30 days (OR 1.77; 95% CI 1.31–2.41; $p < 0.001$). An important distinction to be made is that these prior studies have grouped two osteosynthesis procedures (cephalomedullary nail and sliding hip screw) with hemiarthroplasty; however, when these different surgical procedures were assessed through a more granular analysis, the mortality benefit only extended to the cephalomedullary nail treatment group, whereas the benefits in LOS, major and minor complications extend to the cephalomedullary nail and sliding hip screw groups, but not those managed with hemiarthroplasty and internal fixation. Additionally, our study benefits from having larger sample sizes, with double the amount of total patients and 500 more patients in the cephalomedullary treatment group alone when compared to their pooled treatment group of sliding hip screw, cephalomedullary nail, and hemiarthroplasty and internal fixation.

Some findings from this study are in contrast to previously published literature. Early ambulation is recommended as a measure to prevent venous thromboembolism in elective THA cases [28–30]; however, our study found no reduction in venous thromboembolism with WBAT on POD1 in non-elective hip fracture surgery. Wu et al. reported on 331 hip fracture patients treated with intramedullary nail, sliding hip screw, and hemiarthroplasty and internal fixation and found decreased LOS for those patients allowed to WBAT when compared to touch-down weight-bearing and non-weight-bearing (40 days v 26 days; $p < 0.001$). However, in contrast to our findings, this study showed no differences in weight-bearing status between those discharged to inpatient rehabilitation and those discharged home ($p = 0.89$). Of note the Wu et al. study did not control for the type of surgery performed and had an unequal distribution of weight-bearing restriction 6% (7/114) of arthroplasty patients compared to 100% (15/15) of intramedullary nail patients.

While this study provides insight into the role of early weight-bearing in hip fracture surgical care, it was limited to the procedures contained with in the NSQIP hip fracture database, namely cephalomedullary nail, sliding hip screw, and hemiarthroplasties. Therefore, other treatment modalities, such as cannulated screw fixation and THA, warrant further exploration as to the effects weight-bearing status has on their outcomes. Additionally, longitudinal trials may reveal whether the effects of initial weight-bearing status remain beyond the 30-day postoperative window. Also a detailed risk–benefit analysis of the potential surgical complications associated with early weight-bearing and the potential benefits early weight-bearing has on medical complications.

Conclusion

Overall early weight-bearing after surgical care of hip fracture seems to decrease morbidity and mortality; however, this effect is highly dependent on the treatment. For hip fracture patients treated with a cephalomedullary nail patients, those that were WBAT on POD1 had a significantly lower risk of mortality. Additionally, for hip fracture patients managed with cephalomedullary nail and sliding hip screw, WBAT on POD1 was associated with lower complication rates, shorter LOS, and a greater likelihood for home discharge. Future studies need to determine the size effect of weight-bearing status on postoperative complications such as periprosthetic fractures, subsidence, and implant failures which are essential to establish the optimal risk–benefit analysis on weight-bearing status after hip fracture surgery.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. Board and committee member of the Orthopaedic Trauma Association, American Association of Hip and Knee Surgeons, Mid-American Orthopaedic Association, and Musculoskeletal Infection Society. Editorial or governing board member of American Journal of Orthopedics, Journal of Hip Surgery, Journal of Knee Surgery. Research support from CD Diagnostics, Cymedica, KCI, OREF, Ferring Pharmaceuticals, OrthoFix, Inc, Stryker, Zimmer. Paid Consultant for Zimmer and KCI. Paid presenter for KCI. Stock or stock options in PSI.

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