



Total Hip Arthroplasty Outperforms Hemiarthroplasty in Patients Aged 65 Years and Older: A Propensity-Matched Study of Short-Term Outcomes

Jared A. Warren, DO¹ , Kavin Sundaram, MD, MSc¹,
Hiba K. Anis, MD¹, Nicolas S. Piuze, MD¹,
Carlos A. Higuera, MD¹, and Atul F. Kamath, MD¹ 

Abstract

Introduction: Displaced femoral neck fractures in the elderly individuals may be treated with total hip arthroplasty (THA) or hip hemiarthroplasty (HHA). However, it is unclear what the short-term medical outcomes are related to these surgical options. The purpose of this study was to compare early postoperative outcomes in THA patients to those of HHA patients. **Methods:** In this study, we compared 30-day mortality, likelihood of still being in the hospital at 30 days, postoperative major and minor complications, discharge disposition, reoperation and readmission, length of stay, days from admission to surgery, and operative time between THA and HHA. Using the American College of Surgeons National Surgical Quality Improvement Project database, hip fracture patients ≥ 65 years old from 2008 to 2016 were identified. After propensity score matching, there were 2795 THAs and 2795 HHAs. To assess the effect of THA on the above-mentioned outcomes, bivariate regression models were created. **Results:** The THA patients ≥ 65 years old were at reduced risk for mortality ($P = .029$) and still being in the hospital at 30 days ($P = .017$). The THA patients were at an increased risk for minor complications ($P = .011$) and longer operative times ($P < .001$). However, THA patients were more likely to have a home discharge ($P < .001$). **Discussion:** Patients ≥ 65 years who underwent THA for hip fractures had reduced short-term mortality risk, were more likely to be discharged home, and had less likelihood of being in the hospital at 30 days. This is the first study to explore short-term outcomes in patients ≥ 65 and has direct implications for alternate payment and merit-based payment models. **Conclusion:** As hip fracture treatment has come under scrutiny with respect to alternate payment models and merit-based incentive payments, this analysis of short-term outcomes warrants consideration when evaluating treatment pathways.

Keywords

THA, hemiarthroplasty, short-term complication, mortality, discharge disposition, hip fracture

Submitted May 17, 2019. Revised July 22, 2019. Accepted August 15, 2019.

Introduction

Hip fractures occur relatively frequently, with a lifetime incidence of 20% in females and 10% in males.¹ This injury can have devastating consequences, as 1-year mortality rates associated range between 14% and 25%.²⁻⁵ Not only are hip fractures associated with dramatically increased mortality, but they also bear substantial health-care costs, with the estimated cost of hip fracture admissions in the United States in 2015 ranging between US\$10.3 and US\$15.2 billion.⁶

Displaced femoral neck hip fractures are currently treated with either total hip arthroplasty (THA) or hip hemiarthroplasty (HHA); however, treatment selection is controversial.⁷⁻¹²

Guidelines in the United Kingdom recommend THA for patients who can ambulate outside the home, have no cognitive impairment, and are medically fit for the procedure.¹³ Formal guidelines in other countries, such as the United States, are yet

¹ Department of Orthopaedic Surgery, Orthopaedic and Rheumatology Institute, Cleveland Clinic, Cleveland, OH, USA

Corresponding Author:

Atul F. Kamath, Department of Orthopaedic Surgery, Orthopaedic and Rheumatology Institute, Cleveland Clinic, 9500 Euclid Ave, A41, Cleveland, OH 44195, USA.

Email: kamatha@ccf.org



to be formulated. Several articles have reported a mortality benefit of up to 10 years for those treated with THA when compared with HHA, while other studies have found no mortality benefit.¹⁴⁻¹⁷ When performed for the treatment of hip fractures, HHAs have shown inferior functional scores but have lower rates of dislocation compared to THA.¹⁸⁻²⁰ Additionally, it remains unclear whether either surgical modality is associated with inferior postoperative complication rates.²⁰⁻²⁴ A recent study from Canada also found that the health-care costs in the first year after injury was Can\$2700 lower for THAs than HHAs.²⁰

Although previous studies have examined long-term morbidity and mortality, as well as rates of surgical complications, there is a lack of research on short-term morbidity, mortality, and medical complications. As hip fracture treatment has come under scrutiny with respect to alternate payment models and merit-based incentive payments, an analysis of short-term outcomes is warranted. Therefore, the aim of the current study is to assess the effect of THA compared to bipolar HHA for the management of hip fractures in patients ≥ 65 years old. Specifically, the following outcomes were assessed: (1) 30-day mortality, (2) still hospitalized at 30 days, (3) 30-day postoperative major and minor complications, (4) discharge disposition, (5) reoperation and readmission, (6) length of hospital stay (LOS), (7) days from admission to surgery, and (8) operative time.

Methods

Data Source

The American College of Surgeons (ACS) National Surgical Improvement Quality Improvement Program (NSQIP) database was utilized. The database contains numerous comorbidity and perioperative care variables as well as postoperative mortality and morbidity outcomes for surgeries in a variety of specialties.^{25,26} The 2016 version draws data from 680 hospitals across the United States. The ACS NSQIP database has been used to evaluate short-term outcomes in hip fracture patients.²⁷⁻²⁹

Study Population

Using any iteration of the *International Classification of Diseases, Ninth Revision (ICD-9)* codes 820 and 821 and *ICD-10* code S72, we identified 89 075 hip fracture cases. Patients were then excluded if they did not have a procedure corresponding to Current Procedural Terminology codes 27130 (THA) and 27125 (bipolar HHA). This resulted in 16 582 (18.6%) patients. Patients were then selected if there were ≥ 65 years old ($n = 11 831$) for subgroup analysis. There were 9033 HHA and 2798 THAs in the ≥ 65 subgroup.

Study Variables

The following preoperative variables on patient demographics and comorbidities were also collected: age, sex, race, body mass index (BMI), functional status, American Society of

Table 1. Demographics in THA and HHA.

Demographic	HHA, N = 2795		THA, N = 2795		P Value
	n	%	n	%	
Age, mean \pm SD	76.78 \pm 6.84		76.31 \pm 7.01		.011^a
BMI, mean \pm SD	25.13 \pm 5.28		25.68 \pm 5.57		<.001^a
Comorbidity count, mean \pm SD	1.41 \pm 1.20		1.35 \pm 1.17		.038^a
Sex—Female	1997	71.4%	1998	71.1%	.790
Smoker	324	11.6%	321	11.5%	.910
Race					.957
American Indian or Alaska Native	14	0.5%	13	0.5%	
Asian	52	1.9%	56	2.0%	
Black or African American	95	3.4%	93	3.3%	
Native Hawaiian or Pacific Islander	1	<0.1%	1	<0.1%	
Unknown	281	10.1%	302	10.8%	
White	2352	84.2%	2330	83.4%	
Anesthesia					.030
Spinal	476	17.0%	529	18.9%	
General	2173	77.7%	2091	74.8%	
Other	146	5.2%	175	6.3%	
Functional status					.894
Independent	2496	89.3%	2482	88.8%	
Partially dependent	251	9.0%	260	9.3%	
Totally dependent	37	1.3%	39	1.4%	
Unknown	11	0.4%	14	0.5%	
Year					.940
2008	20	0.7%	21	0.8%	
2009	55	2.0%	51	1.8%	
2010	65	2.3%	52	1.9%	
2011	135	4.8%	147	5.3%	
2012	234	8.4%	226	8.1%	
2013	311	11.1%	25	11.7%	
2014	490	17.5%	483	17.3%	
2015	682	24.4%	671	24.0%	
2016	803	28.7%	818	29.3%	
ASA classification					.020^b
1	27	1.0%	43	1.5%	
2	741	26.5%	833	29.8%	
3	1697	60.7%	1611	57.6%	
4	32	11.7%	303	10.8%	
5	1	<0.1%	2	0.1%	
Not reported	3	0.1%	3	0.1%	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; HHA, hip hemiarthroplasty; SD, standard deviation; THA, total hip arthroplasty.

^aStudent *t* test.

^bFishers exact test.

Bold values are < 0.05 .

Anesthesiologists (ASA) classification, year in which surgery was performed, anesthesia type, and comorbidity count (Table 1). Functional status was used a surrogate for ambulatory status, specifically the variable options at entry are “independent,” “partially dependent,” “totally dependent,” and “unknown.”³⁰ The comorbidity count assigned 1 point for the presence of available comorbidity variables: diabetes mellitus, dyspnea, use of a ventilator, history of chronic obstructive pulmonary

disease, ascites, history of congestive heart failure, use of hypertension medication, renal failure, use of dialysis, disseminated cancer, wound infection, corticosteroid usage, weight loss, bleeding disorder, prior transfusion, and previous sepsis. The comorbidity count was isolated to all comorbidity variables without missing values in the database.

Perioperative and Postoperative Outcomes

The perioperative and postoperative outcomes of interest were as follows: 30-day mortality, still in the hospital at 30 days, 30-day complications, nonhome discharge, operative time, and LOS. Thirty-day complications were grouped into major complications and minor complications using the proposed classification of Pulido et al, which identifies complications as major “if they required complex surgical or medical intervention if they were deemed to pose a threat to patient’s life or result in functional impairment.”³¹ As defined by the ACS NSQIP, the following complications were classified as major: deep incisional surgical site infection (SSI), organ/space SSI, dehiscence, unplanned intubation, pulmonary embolism, on a ventilator greater than 48 hours, acute renal failure, stroke or cerebrovascular accident, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, deep vein thrombosis (DVT) requiring therapy, sepsis, and septic shock.²⁵ The following were considered minor complications: superficial incisional SSI, pneumonia, progressive renal insufficiency, urinary tract infection (UTI), and transfusions within 72 hours of surgery.

Propensity Score Matching

Logistic regression was utilized to generate propensity scores for patients in the THA and HHA cohorts. Patients were matched at a ratio of 1:1 using the following covariates: age, sex, race, ASA classification, functional status, anesthesia type, year in which the surgery was performed, and a comorbidity count as previously defined using the “MatchIt” package provided with R software.³² Due to a large number of missing values, BMI ($n = 374$, 6.7%) was excluded from the propensity score matching. After propensity score matching, there were 5590 cases, including 2795 THAs and 2795 HHAs.

Data Analysis

Patient demographic characteristics in addition to postoperative outcomes were assessed using χ^2 tests for categorical variables and independent sample t tests for continuous variables (Table 2). Bimodal bivariate logistic regression models were used to identify THA as an independent risk factor for the outcomes of interest. To assess for increased LOS, days from admission to surgery, and operative time, bivariate linear regression model were constructed to evaluate THA as an independent risk factor. An α value of $<.05$ was used as statistical significance for all tests. SPSS Statistics 23 for Mac (IBM Corporation, Armonk, New York) was used to perform all tests.

Table 2. Outcomes and Complications in THA and HHA.

Outcome	HHA, N = 2795		THA, N = 2795		P Value
	n	%	n	%	
Mortality	112	4.0%	82	2.9%	.028
Still in hospital	23	0.9%	9	0.4%	.013
Major complication	175	6.6%	183	6.5%	.662
Minor complication	661	23.6%	744	26.6%	.01
Superficial SSI	22	0.8%	16	0.6%	.329
Deep SSI	14	0.5%	16	0.6%	.714
Organ/space SSI	8	0.3%	10	0.4%	.637
Dehiscence	3	0.1%	3	0.1%	1.000 ^a
Pneumonia	92	3.3%	73	2.6%	.133
Reintubation	42	1.5%	41	1.5%	.912
Pulmonary embolism	25	0.9%	29	1.0%	.584
Ventilator > 48 hours	15	0.5%	22	0.8%	.248
Progressive renal insufficiency	14	0.5%	11	0.4%	.548
Acute renal failure	7	0.3%	10	0.4%	.466
Urinary tract infection	137	4.9%	97	3.5%	.008
Cerebrovascular accident	15	0.5%	11	0.4%	.432
Cardiac arrest requiring CPR	21	0.8%	24	0.9%	.653
Myocardial infarction	21	0.8%	29	1.0%	.256
Transfusion	458	16.4%	633	22.6%	<.001
Deep vein thrombosis	26	0.9%	25	0.9%	.888
Sepsis	25	0.9%	25	0.9%	1.000
Septic shock	16	0.6%	17	0.6%	.861
Home discharge	590	22.2%	847	31.8%	<.001
Reoperation	88	3.3%	115	4.3%	.058
Readmission	217	8.3%	201	7.6%	.355

Abbreviations: CPR, cardiopulmonary resuscitation; HHA, hip hemiarthroplasty; THA, total hip arthroplasty; SSI, surgical site infection.

^aFisher exact test.

Bold values are < 0.05 .

Results

Thirty-Day Mortality

Using multivariate regression analyses, THA (odds ratio [OR], 0.724; 95% confidence interval [CI], 0.524-0.967; $P = .029$) was associated with a decreased risk of mortality when compared with HHA.

Still in the Hospital at 30 Days

There was decreased risk for still being in the hospital when treated with a THA (OR, 0.389; 95% CI, 0.180-0.842; $P = .017$).

Thirty-Day Postoperative Major and Minor Complications

There was no association between major complications (OR, 1.049; 95% CI, 0.847-1.299; $P = .662$). The THA patients were at an increased risk of minor complications (OR, 1.171; 95% CI, 1.038-1.322; $P = .011$). The only complication that was associated with a decreased risk of occurring in THA patients was UTI (OR, 0.698; 95% CI, 0.535-0.910; $P = .008$). There was an increased risk of transfusion (OR, 1.494; 95% CI,

Table 3. Multivariate Regression Analysis of Perioperative Outcomes and Complications.

Outcome	Odds Ratio (95% CI)	P Value
Mortality	0.724 (0.542-0.967)	.029
Still in hospital	0.389 (0.180-0.842)	.017
Major complication	1.049 (0.847-1.299)	.662
Minor complication	1.171 (1.038-1.322)	.011
Superficial SSI	0.726 (0.380-1.385)	.331
Deep SSI	1.144 (0.557-2.348)	.714
Organ/space SSI	1.251 (0.493-3.174)	.638
Dehiscence	1.000 (0.202-4.959)	1.000
Pneumonia	0.788 (0.577-1.076)	.134
Reintubation	0.976 (0.633-1.505)	.912
Pulmonary embolism	1.162 (0.679-1.988)	.585
Ventilator > 48 hours	1.470 (0.761-2.8440)	.251
Progressive renal insufficiency	0.785 (0.356-1.732)	.549
Acute renal failure	1.430 (0.544-3.762)	.469
Urinary tract infection	0.698 (0.535-0.910)	.008
Cerebrovascular accident	0.732 (0.336-1.597)	.434
Cardiac arrest requiring CPR	1.144 (0.635-2.060)	.654
Myocardial infarction	1.385 (0.788-2.434)	.258
Transfusion	1.494 (1.307-1.708)	<.001
Deep vein thrombosis	0.961 (0.554-1.669)	.888
Sepsis	1.000 (0.573-1.745)	1.000
Septic shock	1.063 (0.536-2.108)	.861
Home discharge	1.627 (1.440-1.840)	<.001
Reoperation	1.314 (0.990-1.744)	.059
Readmission	0.910 (0.745-1.111)	.355

Abbreviations: CI, confidence interval; CPR, cardiopulmonary resuscitation; SSI, surgical site infection.

Bold values are < 0.05.

1.307-1.708; $P < .001$) when being treated with THA. Table 3 contains a full list of ORs for each complication.

Discharge Disposition

Total hip arthroplasty was associated with an increased likelihood of home discharge (OR, 1.627; 95% CI, 1.440-1.840; $P < .001$).

Reoperation and Readmission

There was no statistically significant relationship for treatment choice between THA and HHA for reoperation (OR, 1.314; 95% CI, 0.990-1.744; $P = .059$) and readmission (OR, 0.910; 95% CI, 0.745-1.111; $P = .355$).

Length of Stay, Days From Admission to Surgery, and Operative Time

Using linear multivariate regression models, THA was not associated with a decreased LOS ($B = -0.381$ days; 95% CI, -0.766 to 0.005 ; $P = .053$). There was no difference in days from admission to surgery ($B = 0.232$ days; 95% CI, -0.212 to 0.676 ; $P = .306$). Total hip arthroplasty was associated with increased operative time ($B = 17.372$ minutes; 95% CI, 15.002 - 19.743 ; $P < .001$).

Discussion

Hip fractures place a large burden on our health-care system.^{3,4,6} There is substantial controversy regarding the indications for THA and HHA as well as what should be the preferred treatment in different circumstances,^{3,7,12,13} including in different age subgroups. Our study found that patients aged 65 years and older who were treated with a THA had decreased mortality when compared with propensity score-matched patients after HHA. These patients were also at a decreased risk of being in the hospital past 30 days postoperatively and were more likely to be discharged home. They were, however, at an increased risk of minor complications and transfusions.

Although this study benefits from propensity score matching, is it not without limitations. Data on patient and surgeon preference for THA versus HHA were not available; however, in an effort to mimic ambulatory status, patients were matched based on their functional status. Moreover, the vast majority of patients were independent prior to their injury indicating these patients may have been appropriate candidates for THA. Additionally, patients were unable to be matched based on Charlson or Elixhauser comorbidity indices; however, in an attempt to as closely replicate these assessments of global health and medical fragility metrics, patients were matched by a comorbidity count as well as ASA classification. Despite this, it is likely that more medically fragile patients received an HHA. Although there were statistically significant differences in BMI, age, and comorbidity count, these differences were clinically irrelevant. Similarly, there were statistically significant differences in ASA classification and anesthesia modality; however, these were as a result of the robust cohort sizes, making even small differences statistically significant. Previous place of residence was not controlled for which may bias the results of the discharge disposition outcome. Preoperative nutrition status was not controlled for using albumin values as 38.8% of the pre-matched cohort did not have this laboratory value available. It should also be pointed out that there may be an outsized effect of transfusions on the minor complications variables, as there was substantially more transfusion than any other complication. The ACS NSQIP database only contains 30-day complication rates, which will capture many complications directly attributable to the surgical episode. Long-term follow-up data to capture outcomes outside the 30-day window could shed more light on the role of THA versus HHA with respect to complications, including those experienced in the first several years after surgery. Despite these limitations, this study is the first of its kind to describe the role of THA and HHA with respect to short-term medical complications and key health-care-associated metrics.

The findings of this study are supported in prior literature. In a retrospective analysis of 2902 femoral neck fractures treated with THA matched with 2902 fractures treated with HHA, those receiving THA had a decreased risk of mortality at 5 years (risk ratio [RR], 0.51; 95% CI, 0.46-0.570).¹⁴ Similarly, a study of 70 242 femoral neck fractures found that the 2-year survival of patients receiving THA was superior to

those receiving HHA (adjusted hazard ratio, 1.67; 95% CI, 1.59-1.92).¹⁵ In one randomized trial, after 100 months of follow-up with 81 displaced femoral neck fracture patients, more HHA patients perished than those in the THA treatment arm ($P = .026$).³³

Several findings on the topic of complications surrounding the treatment decision of THA versus HHA support our findings. A meta-analysis of 12 randomized control trials, with 624 THA patients and 696 HHA patients treated for displaced femoral neck fractures, found no difference in general complication rate (RR, 1.15; 95% CI, 0.91-1.45) at a minimum of 24 months,²¹ similar to our findings on major complications. In Liodakis et al, a study of 3192 HHA versus 866 THAs found that THA was not an independent risk factor for major complications (OR, 0.8; $P = .18$) but was a risk factor for transfusion (OR, 0.168; $P < .001$).²² Similarly, in Burgers et al, a meta-analysis of 472 THA patients and 514 HHA patients with minimum 1-year follow-up found equal rates of major complications (25% in THA vs 24% in HHA).²³ A retrospective review of 2437 THAs and 38 328 HHA treating intracapsular hip fractures patients found no difference in short-term complications at 90 days (OR, 0.89; $P = .06$).²⁴ Ravi et al,²⁰ a retrospective review of 2689 THAs matched to 2689 HHAs, found no differences in myocardial infarction, DVT, pulmonary embolism, nor pneumonia at 90 days.

Our finding that THA patients are more likely to be discharged to home after a femoral neck fracture when compared with HHA patients is supported by prior investigations. A case-control study by Jonas et al of 110 intracapsular hip fractures patients, matched 1:1 THA to HHA, found less HHA patients (33/55) were discharged home when compared with THA patients (35/55).³⁴ In a survey of US trends in the treatment of femoral neck fractures by Woon et al, THA patients were more likely to be discharged home than their HHA counterparts (23.2% vs 11.6%; $P < .01$).³⁵

In Wang et al, a meta-analysis of 8 randomized trials found no difference LOS. Ravi et al also concluded that there was no difference in LOS between THA and HHA patients in addition to findings that THAs had 10 minutes more of operative time. In van den Bekerom et al, a randomized trial with 137 HHAs and 115 THAs found that operative time was longer in THA cases (28% >1.5 hours vs 12% >1.5 hours; $P < .001$).³⁶ A comparable randomized trial of 21 THAs and HHAs treating displaced femoral neck fractures found that THA had increased operative time as well (51.80 ± 8.70 minutes HHA vs 119.10 ± 16.75 minutes THR group; $P < .0001$).¹²

An investigation of the treatment decision between HHA and THA in hip fractures found that there may be no difference in revision rates in the elderly individuals. Specifically, a study of 40 THAs versus 72 HHAs in unstable intertrochanteric fractures found no difference in revision rates at a minimum of 2 years follow-up, which may support reoperation.¹¹

Our article has found several differences in outcomes from what can be found in the literature. In Voskuijl et al, a retrospective study treating femoral neck fractures with 74 088 HHA patients and 8503 THA patients found no difference in

in-hospital mortality; however, this was a cross-sectional study of patients treated during 1 year, and no matching occurred despite the large difference in cohort size.¹⁶ A meta-analysis of 7 randomized trials with 828 patients found that reoperation at 1 year was less likely to occur in THA cases (RR, 0.40; 95% CI, 0.24-0.67; $P = .0004$).¹⁸ However, the minimum follow-up was 1 year, and there was a smaller sample size. Additionally, a retrospective study of 22 675 hip fractures treated with HHA and 8155 treated with THA found increased 1-year revision rates for THA patients (cumulative incidence function 2.4% [95% CI, 2.0-2.7] vs 1.6% [95% CI, 1.4-1.8])³⁷; however, no match was attempted and the outcome was evaluated at 1 year.

Conclusion

In summary, THA patients ≥ 65 years old are at a decreased risk of 30-day mortality when compared with HHA patients. Additionally, THA patients were more likely to go home and less likely to be in the hospital after 30 days when compared with HHA patients. However, they were more likely to have minor complications. As hip fracture treatment has come under scrutiny with respect to alternate payment models and merit-based incentive payments, this analysis of short-term outcomes warrants consideration when evaluating treatment pathways.



Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Jared A. Warren  <https://orcid.org/0000-0001-7605-074X>
Atul F. Kamath  <https://orcid.org/0000-0002-9214-2756>

References

- Landefeld C. Goals of care for hip fracture: promoting independence and reducing mortality Title. *Arch Intern Med*. 2011; 171(20):1837-1838.
- Chow SK-H, Qin J, Wong RM-Y, et al. One-year mortality in displaced intracapsular hip fractures and associated risk: a report of Chinese-based fragility fracture registry. *J Orthop Surg Res*. 2018;13(1):235. doi:10.1186/s13018-018-0936-5.
- Hu F, Jiang C, Shen J, Tang P, Wang Y. Preoperative predictors for mortality following hip fracture surgery: a systematic review and meta-analysis. *Injury*. 2012;43(6):676-685. doi:10.1016/j.injury.2011.05.017.
- Moyet J, Deschasse G, Marquant B, Mertl P, Bloch F. Which is the optimal orthogeriatric care model to prevent mortality of elderly subjects post hip fractures? A systematic review and meta-analysis based on current clinical practice. *Int Orthop*. 2018;1-6. doi:10.1007/s00264-018-3928-5.
- Oñativia I, PAI S, Diaz Dileria F, et al. Outcomes of nondisplaced intracapsular femoral neck fractures with internal screw

- fixation in elderly patients: a systematic review. *Hip Int.* 2018;28(1):18-28.
6. Judd KT, Christianson E. Expedited operative care of hip fractures results in significantly lower cost of treatment. *Iowa Orthop J.* 2015;35:62-64.
 7. Carroll C, Stevenson M, Scope A, Evans P, Buckley S. Hemiarthroplasty and total hip arthroplasty for treating primary intracapsular. *Tidsskr Nor Laegeforen.* 2011;131(19):1893-1896. doi:10.3310/hta15360.
 8. Mariconda M, Costa G, Misasi M, Recano P, Balato G, Rizzo M. Ambulatory ability and personal independence after hemiarthroplasty and total arthroplasty for intracapsular hip fracture: a prospective comparative study. *J Arthroplasty.* 2017;32(2):447-452. doi:10.1016/j.arth.2016.07.017.
 9. Ossendorf C, Scheyerer MJ, Wanner GA, Simmen HP, Werner CML. Treatment of femoral neck fractures in elderly patients over 60 years of age—which is the ideal modality of primary joint replacement? *Patient Saf Surg.* 2010;4(1):1-8. doi:10.1186/1754-9493-4-16.
 10. Nichols CI, Vose JG, Nunley RM. Clinical outcomes and 90-day costs following hemiarthroplasty or total hip arthroplasty for hip fracture. *J Arthroplasty.* 2017;32(9): S128-S134. doi:10.1016/j.arth.2017.01.023.
 11. Fan L, Dang X, Wang K. Comparison between bipolar hemiarthroplasty and total hip arthroplasty for unstable intertrochanteric fractures in elderly osteoporotic patients. *PLoS One.* 2012;7(6): 1-6. doi:10.1371/journal.pone.0039531.
 12. Sonaje JC, Meena PK, Bansawal RC, Bobade SS. Comparison of functional outcome of bipolar hip arthroplasty and total hip replacement in displaced femoral neck fractures in elderly in a developing country: a 2-year prospective study. *Eur J Orthop Surg Traumatol.* 2018;28(3):493-498. doi:10.1007/s00590-017-2057-y.
 13. National Institute for Health and Care Excellence. Hip Fracture: management (NICE Guideline CG124). 2011. <https://www.nice.org.uk/guidance/cg124>. Accessed March 3, 2019.
 14. Hansson S, Nemes S, Kärrholm J, Rogmark C. Reduced risk of reoperation after treatment of femoral neck fractures with total hip arthroplasty: a matched pair analysis. *Acta Orthop.* 2017;88(5): 500-504. doi:10.1080/17453674.2017.1348095.
 15. Wang Z, Bhattacharyya T. Outcomes of Hemiarthroplasty and total hip arthroplasty for femoral neck fracture: a medicare cohort study. *J Orthop Trauma.* 2017;31(5):260-263. doi:10.1097/BOT.0000000000000814.
 16. Voskuijl T, Neuhaus V, Kinaci A, Vrahas M, Ring D. In-hospital outcomes after hemiarthroplasty versus total hip arthroplasty for isolated femoral neck fractures. *Arch Bone Jt Surg.* 2014;2(3): 151-156. <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4225018&tool=pmcentrez&rendertype=abstract>.
 17. Wang F, Zhang H, Zhang Z, Ma C, Feng X. Comparison of bipolar hemiarthroplasty and total hip arthroplasty for displaced femoral neck fractures in the healthy elderly: a meta-analysis. *BMC Musculoskelet Disord.* 2015;16(1):1-13. doi:10.1186/s12891-015-0696-x.
 18. Liao L, Zhao JM, Su W, Ding XF, Chen LJ, Luo SX. A meta-analysis of total hip arthroplasty and hemiarthroplasty outcomes for displaced femoral neck fractures. *Arch Orthop Trauma Surg.* 2012;132(7):1021-1029. doi:10.1007/s00402-012-1485-8.
 19. Guyen O. Hemiarthroplasty or total hip arthroplasty in recent femoral neck fractures? *Orthop Traumatol Surg Res.* 2018:1-7. doi:10.1016/j.otsr.2018.04.034.
 20. Ravi B, Pincus D, Khan H, Wasserstein D, Jenkinson R, Kreder HJ. Comparing complications and costs of total hip arthroplasty and hemiarthroplasty for femoral neck fractures. *J Bone Jt Surg.* 2019;101(7):572-579.
 21. Yu L, Wang Y, Chen J. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fractures: Meta-analysis of randomized trials hip. *Clin Orthop Relat Res.* 2012;470(8): 2235-2243. doi:10.1007/s11999-012-2293-8.
 22. Liidakis E, Antoniou J, Zukor DJ, Huk OL, Epure LM, Bergeron SG. Major complications and transfusion rates after hemiarthroplasty and total hip arthroplasty for femoral neck fractures. *J Arthroplasty.* 2016;31(9):2008-2012. doi:10.1016/j.arth.2016.02.019.
 23. Burgers PTPW, Van Geene AR, Van Den Bekerom MPJ, et al. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fractures in the healthy elderly: a meta-analysis and systematic review of randomized trials. *Int Orthop.* 2012;36(8): 1549-1560. doi:10.1007/s00264-012-1569-7.
 24. SooHoo NF, Farng E, Chambers L, Zmigmond DS, Lieberman JR. Comparison of complication rates between hemiarthroplasty and total hip arthroplasty for intracapsular hip fractures. *Orthopedics.* 2013;36(4):e384-e389. doi:10.3928/01477447-20130327-09.
 25. NSQIP. American College of Surgeons National Surgical Quality Improvement Program. n.d. <https://www.facs.org/quality-programs/acs-nsqip/>. Accessed March 3, 2019.
 26. Cohen ME, Ko CY, Bilimoria KY, et al. Optimizing ACS NSQIP modeling for evaluation of surgical quality and risk: patient risk adjustment, procedure mix adjustment, shrinkage adjustment, and surgical focus. *J Am Coll Surg.* 2013;217(2):336-346.e1. doi:10.1016/j.jamcollsurg.2013.02.027.
 27. Durand WM, Goodman AD, Johnson JP, Daniels AH. Assessment of 30-day mortality and complication rates associated with extended deep vein thrombosis prophylaxis following hip fracture surgery. *Injury.* 2018;49(6):1141-1148. doi:10.1016/j.injury.2018.03.019.
 28. Haughom BD, Basques BA, Hellman MD, Brown NM, Della Valle CJ, Levine BR. Do mortality and complication rates differ between periprosthetic and native hip fractures? *J Arthroplasty.* 2018;33(6):1914-1918. doi:10.1016/j.arth.2018.01.046.
 29. Neufeld ME, O'Hara NN, Zhan M, et al. Timing of Hip Fracture Surgery and 30-Day Outcomes. *Orthopedics.* 2016;39(6): 361-368. doi: 10.3928/01477447-20160719-07.
 30. NSQIP. American College of Surgeons National Surgical Quality Improvement Program - Procedure Targeted. n.d. <https://www.facs.org/quality-programs/acs-nsqip/>. Accessed August 11, 2016.
 31. Pulido L, Parvizi J, Macgibeny M, et al. In hospital complications after total joint arthroplasty. *J Arthroplasty.* 2008;23(6):139-145. doi:10.1016/j.arth.2008.05.011.
 32. Harrell FEJ. rms: regression modeling strategies. R package version 4.4-0.

33. Avery PP, Baker RP, Walton MJ, et al. Total hip replacement and hemiarthroplasty in mobile, independent patients with a displaced intracapsular fracture of the femoral neck: a seven- to ten-year follow-up report of a prospective randomised controlled trial. *Bone Joint J.* 2011;93-B(8):1045-1048. doi:10.1302/0301-620X.93B8.27132.
34. Jonas SC, Shah R, Al-Hadithy N, Norton MR, Sexton SA, Middleton RG. Displaced intracapsular neck of femur fractures in the elderly: bipolar hemiarthroplasty may be the treatment of choice; a case control study. *Injury.* 2015;46(10):1988-1991. doi:10.1016/j.injury.2015.06.047.
35. Woon CYL, Moretti VM, Schwartz BE, Goldberg BA. Total hip arthroplasty and hemiarthroplasty: us national trends in the treatment of femoral neck fractures. *Am J Orthop (Belle Mead NJ).* 2018;46(6):E474-E478. <http://www.ncbi.nlm.nih.gov/pubmed/29309466>.
36. van den Bekerom MPJ, Hilverdink EF, Sierevelt IN, et al. A comparison of hemiarthroplasty with total hip replacement for displaced intracapsular fracture of the femoral neck: a randomised controlled multicentre trial in patients aged 70 years and over. *J Bone Jt Surg Br Vol.* 2010;92-B(10):1422-1428. doi:10.1302/0301-620X.92B10.24899.
37. Moerman S, Mathijssen NMC, Tuinebreijer WE, Vochteloo AJH, Nelissen RGHH. Hemiarthroplasty and total hip arthroplasty in 30,830 patients with hip fractures: data from the Dutch Arthroplasty Register on revision and risk factors for revision. *Acta Orthop.* 2018;89(5):509-514. doi:10.1080/17453674.2018.1499069.