What Factors Increase Revision Surgery Risk When Treating Displaced Femoral Neck Fractures With Arthroplasty: A Secondary Analysis of the HEALTH Trial

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Objectives: HEALTH was a randomized controlled trial comparing total hip arthroplasty with hemiarthroplasty in low-energy displaced femoral neck fracture patients aged ≥50 years with unplanned revision surgery within 24 months of the initial procedure being the primary outcome. No significant short-term differences between treatment arms were observed. The primary objective of this secondary HEALTH trial analysis was to determine if any patient and surgical factors were associated with increased risk of revision surgery within 24 months after hip fracture.

Methods: We analyzed 9 potential factors chosen a priori that could be associated with revision surgery. The factors included age, body mass index, major comorbidities, independent ambulation, type of surgical approach, length of operation, use of femoral cement, femoral head size, and degree of femoral stem offset. Our statistical analysis was a multivariable Cox regression using reoperation within 24 months of index surgery as the dependent variable.

Results: Of the 1441 patients included in this analysis, 8.1% (117/1441) experienced reoperation within 24 months. None of the studied factors were found to be predictors of revision surgery ($P > 0.05$).

Conclusion: Both total and partial hip replacements are successful procedures in low-energy displaced femoral neck fracture patients. We were unable to identify any patient or surgeon-controlled factors that significantly increased the need for revision surgery in our elderly and predominately female patient population. One should not generalize our findings to an active physiologically younger femoral neck fracture population.

Key Words: revision surgery, femoral neck fracture

Level of Evidence: Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Displaced femoral neck fractures are commonly treated with arthroplasty in the elderly population. Although arthroplasty procedures are associated with a high success rate, it is uncertain whether outcomes are better with total hip arthroplasty (THA) or hemiarthroplasty (HA). Several studies suggest that when treating active, physiologically younger, low-energy femoral neck fracture patients, a total hip replacement can provide a more durable solution with lower long-term revision rates.[1,2] A recent study, the hip fracture evaluation with alternatives of THA versus hemiarthroplasty (HEALTH) trial, attempted to more definitively answer this question. The results demonstrated no significant short-term differences between the 2 arthroplasty treatment groups in patients 50 years of age or older who sustained a low-energy displaced femoral neck fracture.[3] However, other aspects such as patient and surgical factors were not analyzed to determine risk for revision surgery, and their contributions to clinical outcomes remain an area of active interest.

The purpose of this study was to investigate what patient and surgical factors increase risk of the arthroplasty revision surgery after THA or HA in patients 50 years of age or older who sustained a low-energy displaced femoral neck fracture. This secondary HEALTH trial study was designed to perform a prognostic analysis of baseline patient characteristics and surgical factors associated with revision surgery within 24 months of the index arthroplasty procedure. Identifying factors that are associated with increased revision surgery can assist surgeons with treatment decisions when caring for low-energy femoral neck fracture patients.

METHODS

The HEALTH study randomized patients 50 years of age or older with a displaced femoral neck fracture into surgical treatment with either THA or HA. Surgeons were expected to meet a procedural experience threshold and were allowed to perform their preferred surgical approach to the hip. This included anterior, anterolateral, lateral, or posterolateral/posterior approaches. In addition, surgeons were allowed to choose at their own discretion either a cemented or uncemented femoral stem, the THA femoral head size, and standard or high offset femoral stem.

We performed 2 multivariable Cox regression analyses using the HEALTH primary outcome of reoperation within 24 months of initial surgery as the dependent variable. The number of independent variables and corresponding levels included in the 2 analyses were based on Peduzzi et al[4]'s recommendations, where having fewer than 10 events for each predictor variable can result in overfitted, unstable models. In our first model, 9 potential prognostic factors with 11 parameters were identified a priori that could be associated with revision surgery. Factors were selected based on biological rationale and expert opinion. The studied factors were age (continuous), body mass index (BMI) (continuous), patients limited by major comorbidities (yes vs. no), independent ambulation (yes vs. no), surgical approach (direct anterior vs. posterior/posterolateral vs. anterolateral/lateral), length of operation, use of femoral cement (yes vs. no), femoral head size (36 mm for THA vs. 28 mm for THA, 32 mm for THA vs. 28 mm for THA, and hemiarthroplasty vs. 28 mm for THA), and degree of femoral stem offset (high vs. standard/reduced). We performed a secondary post-hoc exploratory analysis where we performed the original Cox regression model but with the following changes: (1) the femoral head size variable was recategorized to 36 mm versus 32 mm versus 28 mm and (2) the degree of femoral stem offset variable was replaced with the implant type (THA vs. HA). Results were reported as hazard ratios (HRs) with 95% confidence intervals (CIs). All tests were 2-tailed with alpha = 0.05.

RESULTS

A total of 1441 patients were studied. THA and HA were performed in 718 and 723 patients, respectively. Table 1 displays patient demographic characteristics comparing the 1324 cases that did not require a revision versus the 117 that required a secondary procedure. The mean age was 79 (SD 8) years, and 70% (1009/1441) were female. Table 2 displays patients' different fracture characteristics. All fractures were displaced, and 95% of the fractures were either subcapital or midcervical. All of the injuries were the result of low-energy trauma.

Approximately two-thirds of the arthroplasty procedures were performed with a cemented femoral stem. The lateral approach was most commonly used in 65.5% of cases, followed by the posterolateral approach (32%). The anterior approach was only used 2.5% of the time. With THA, 32-mm heads were used in a majority of cases (54%), followed by 36-mm heads (29%) and 28-mm heads (17%). High offset femoral stems were only implanted 18% of the time.

After 24 months from the index arthroplasty procedure, 8.1% (117/1441) of patients required revision surgery. Table 3 displays the difference in surgical factors between the 1324 patients who did not require a revision surgery versus the 117 who required a secondary procedure. Tables 4 and 5 display our analysis of predictors for revision surgery. We were unable to identify any patient or surgical factors associated with increased risk of revision surgery at 24 months. Age, BMI, major comorbidities, independent ambulation status, surgical approach, operative time, use of cemented or uncemented femoral components, femoral head size, and femoral stem offset were not found to be predictors of revision surgery ($P > 0.05$).

DISCUSSION

The top 3 reasons for revision surgery in the HEALTH trial were dislocations, soft-tissue procedures, and implant exchanges (reason unspecified). The rate of a secondary procedure was relatively low at 8% in both the THA and HA groups. The results of our secondary analysis did not identify any patient-controlled or surgeon-controlled factors that significantly increased the need for revision surgery. All patient factors, surgical techniques, approaches, and implant types used did not affect these overall reproducible and successful arthroplasty outcomes.

TABLE 1. Patient Demographics

Variable	No Revision Surgery, N = 1324	Revision Surgery, N = 117
Age, mean (SD)	78.9 (8.5)	78.2 (8.2)
Sex, n (%)	N = 1323	
Male	400 (30.2)	31 (26.5)
Female	923 (69.8)	86 (73.5)
Ethnicity, n (%)		
Indigenous	3 (0.2)	0 (0.0)
South Asian	8 (0.6)	1 (0.9)
East Asian	13 (1.0)	1 (0.9
Hispanic/Latino	11 (0.8)	2 (1.7)
White	1255 (95.1)	112 (95.7)
Black	27 (2.0)	0 (0.0)
Middle Eastern	3 (0.2)	1 (0.9)
BMI (kg/m^2), n (%)	N = 1285	
Underweight (<18.5)	69 (5.4)	4 (3.4)
Normal weight (18.5–24.9)	641 (49.9)	52 (44.4)
Overweight (25–29.9)	413 (32.1)	47 (40.2)
Obese (30–39.9)	146 (11.4)	14 (12.0)
Morbidly Obese (≥40)	16 (1.2)	0 (0.0)
Prefracture living setting, n (%)		
Institutionalized	53 (4.0)	4 (3.4)
Not institutionalized	1271 (96.0)	113 (96.6)
Prefracture functional status, n (%)		
Use of Aid	337 (25.5)	32 (27.4)
Independent Ambulator	987 (74.5)	85 (72.6)
ASA classification, n (%)		
Class I/II	595 (44.9)	57 (48.7)
Class III/IV/V	729 (55.1)	60 (51.3)
Major comorbidities, n (%)	N = 1320	
Osteopenia	53 (4.0)	5 (4.3)
Osteoporosis	208 (15.8)	16 (13.7)
Lung disease	223 (16.9)	26 (22.2)
Diabetes	257 (19.5)	23 (19.7)
Ulcers or stomach disease	110 (8.3)	6 (5.1)
Kidney disease	126 (9.5)	12 (10.3)
Anemia or other blood diseases	97 (7.3)	6 (5.1)
Depression	137 (10.4)	17 (14.5)
Cancer	134 (10.2)	11 (9.4)
Osteoarthritis, degenerative	186 (14.1)	16 (13.7)
Arthritis		
Back pain	122 (9.2)	13 (11.1)
Rheumatoid arthritis	32 (2.4)	2 (1.7)
Heart disease	460 (34.8)	36 (30.8)
High blood pressure	801 (60.7)	76 (65.0)

ASA, American Society of Anesthesiologists; BMI, body mass index.

Our results revealed that age, BMI, major comorbidities, and independent ambulation were not predictive of revision surgery. As expected, the HEALTH patient population has significant comorbidities as noted in Table 1. The mean age was 79 years and 55% percent of the patients were American Society of Anesthesiologists (ASA) classification III-V. Furthermore, 99% of the HEALTH patients had a BMI <30. It is important to appreciate that this hip fracture population is different from many other studies that have evaluated predictors for primary THA revision, which are mostly performed for osteoarthritis and not a femoral neck fracture. In primary THA series in the literature, the patients are generally younger, healthier, and have a higher BMI. Peters et al studied an arthroplasty registry cohort of 218,214 primary THAs performed in patients with osteoarthritis in the Netherlands between 2007 and 2018.[5] In contrast to our results, the authors found higher revision rates at 1 year after primary THA in patients with BMI >40, ASA scores of III-V, patients older than 75 years of age, and men. At 3 years, high BMI, previous hip surgery, Charnley score C, men, and a high ASA score were independently associated with an increased risk for revision. Most common causes for revisions were infections, dislocations, and periprosthetic fractures. Importantly, only one-third of their patients were older than 75 years or had a BMI <30, and 13.4% of patients had ASA scores III-IV. This highlights the discrepancy in study participants from our investigation and those studying THA for osteoarthritis.

TABLE 2. Fracture Characteristics

Variable	No Revision Surgery	Revision Surgery
Fractured hip, n (%)	N = 1324	N = 117
Left	708 (53.6)	64 (54.7)
Right	612 (46.4)	53 (45.3)
Level of the fracture line, n (%)	N = 1320	
Subcapital	806 (61.1)	84 (71.8)
Midcervical	451 (34.2)	30 (25.6)
Basal	63 (4.8)	3 (2.6)
Garden classification, n (%)	N = 1320	
Garden III (displaced)	574 (43.5)	57 (48.7)
Garden IV (displaced)	746 (56.5)	60 (51.3)
Pauwels' classification, n (%)	N = 1318	
Type I	106 (8.0)	11 (9.4)
Type II	708 (53.7)	63 (53.8)
Type III	504 (38.2)	43 (36.8)
Mechanism of injury, n (%)	N = 1320	
Fall from standing	1283 (97.2)	113 (96.6)
Spontaneous fracture	27 (2.0)	3 (2.6)
Fall from small height	10 (0.8)	1 (0.9)

ASA, American Society of Anesthesiologists; BMI, body mass index.

A recent systematic review and meta-analysis concluded that THA is superior to HA for reoperation rates and quality of life and should be the recommended intervention for displaced femoral neck fractures in younger patients (<80) and in those whose life expectancy is greater than 4 years.[6] Nevertheless, dislocation rates were slightly higher in patients with THA. In the HEALTH study, THA outcomes were only marginally better for quality of life. Dislocation rates, however, were higher in the THA as compared with the HA group (4.7% as opposed to 2.4%). Previous published studies have found that dislocations after primary THA have been linked to extremes of age, BMI >30, lumbosacral pathology, surgeon experience, and femoral head size. There is conflicting evidence regarding

TABLE 3. Surgical Characteristics

Variable	No Revision Surgery, N = 1324	Revision Surgery, N = 117
Implant received, n (%)	N = 1310	N = 116
Total hip arthroplasty	621 (47.4)	57 (49.1)
Monopolar hemiarthroplasty	315 (24.0)	27 (23.3)
Bipolar hemiarthroplasty	374 (28.5)	32 (27.6)
Time from injury to surgery, mean (SD) (h)	52.3 (75.3)	68.6 (116.0)
Length of procedure, mean (SD) (minutes)	86.7 (40.3)	88.0 (37.5)
Preoperative traction, n (%)	N = 1319 100 (7.6)	9 (7.7)
Preoperative thromboprophylaxis, n (%)	N = 1317 930 (70.6)	83 (70.9)
Postoperative thromboprophylaxis, n (%)	N = 1311 1303 (99.4)	116 (99.1)
Type of Anaesthesia, n (%)	N = 1318	
General	496 (37.6)	39 (33.3)
Regional	872 (66.2)	81 (69.2)
Sedation	13 (1.0)	1 (0.9)
Neurolept	14 (1.1)	2 (1.7)
Intraoperative blood loss, mean (SD) (mL)	292.0 (183.7)	305.3 (211.9)
Use of femoral cement, n (%)	N = 1312	
Yes	839 (63.9)	79 (67.5)
No	473 (36.1)	38 (32.5)
Type of surgical approach, n (%)	N = 1311	N = 116
Direct anterior	33 (2.5)	3 (2.6)
Anterolateral/lateral	869 (66.3)	67 (57.8)
Posterior/posterolateral	409 (31.2)	46 (57.8)
Femoral head size, n (%)	N = 1290	N = 114
28 mm for total hip arthroplasty	104 (8.1)	11 (9.6)
32 mm for total hip arthroplasty	324 (25.1)	30 (26.3)
36 mm for total hip arthroplasty	175 (13.6)	14 (12.3)
Hemiarthroplasty	687 (53.3)	59 (51.8)
Offset of chosen stem, n (%)	N = 1087	N = 100
Standard/Reduced	890 (81.9)	88 (88.0)
High	197 (18.1)	12 (12.0)

SD, standard deviation.

TABLE 4. Prognostic Factors for Reoperation (n = 1,137, 98 Events)

Variable	Hazard Ratio (95% CI)	*P*
Age (10-y increase)	0.87 (0.68–1.11)	0.26
BMI (5-point increase)	0.98 (0.80–1.21)	0.87
Patient limited by comorbidities		
Yes vs. no	1.15 (0.75–1.75)	0.54
Independent ambulation		
Yes vs. no (any aid used)	1.21 (0.73–1.89)	0.42
Type of surgical approach		
Direct anterior vs. posterior/posterolateral	1.05 (0.32–3.51)	
Anterolateral/lateral vs. posterior/posterolateral	0.77 (0.51–1.17)	Overall: 0.24
Length of operation (minutes)	0.999 (0.995–1.01)	0.99
Use of femoral cement		
Yes vs. no	1.11 (0.70–1.74)	0.67
Femoral head size		Overall: 0.83
32 mm for total hip arthroplasty vs. 28 mm for total hip arthroplasty	0.93 (0.44–2.01)	
36 mm for total hip arthroplasty vs. 28 mm for Total hip arthroplasty	0.78 (0.31–1.93)	
Hemiarthroplasty vs. 28 mm for total hip Arthroplasty	0.92 (0.45–1.87)	
Offset of chosen stem		
High vs. standard/reduced	1.57 (0.87–2.94)	0.13

BMI, body mass index; CI, confidence interval.

the effect of neuromuscular disease and surgical approach on THA instability.[7] Interestingly, our results demonstrated that factors often associated with instability such as surgical approach, head size, and femoral stem offset were not associated with an increased rate of secondary revisions.

Surgical approach to the hip continues to be a controversial topic in hip arthroplasty. In the HEALTH study, the lateral approach was most commonly used in 65.5% of cases, followed by the posterolateral approach 32% of the time. Our results did not find surgical approach as a predictor of revision surgery. The Norwegian and Swedish Hip Fracture Registries reviewed 33,205 hip fractures in patients 60 years of age and older who were treated with modular HAs.[8] The posterior approach was shown to increase the risk of reoperation because of dislocations. The direct lateral approach reduced the risk of reoperation after hip fractures treated with HA in patients over 75 years of age. However, a later study of 20,908 patients from the Norwegian Hip Fracture Registry specifically looking at patient-reported outcome measures after HA for femoral neck fractures, found that the posterior approach caused less pain, better ambulation, and better satisfaction and overall quality of life than the lateral approach.[9] The risk of reoperation was similar with both approaches. Finally, the muscle sparing direct anterior approach has recently become popular for primary arthroplasty.[10] It has been to shown to be linked to slightly faster functional recovery and improved short-term outcomes.[11] Disadvantages with the anterior approach include a trend toward more major complications, particularly femoral component failure[12–14], although the posterior approach continues to be associated with higher dislocation rates in both THA and HA.[12,15] A systematic review and meta-analysis of the direct anterior approach for HA for femoral neck fracture suggests superior early functional mobility and significantly lower dislocation rates compared with posterior approaches for HA.[16] The influence of surgical approach and/or use of dual mobility components on dislocations when THA is performed for fractures are currently being investigated worldwide.

The femoral head size has been shown to reduce dislocations in THA. This is predominately related to increased head to neck ratio and jump distance. The

TABLE 5. Secondary Post-Hoc Exploratory Analysis for Prognostic Factors for Reoperation (n = 1,000, 79 Events*)

Variable	Hazard Ratio (95% CI)	*P*
Age (10-y increase)	0.93 (0.71–1.22)	0.61
BMI (5-point increase)	1.07 (0.85–1.34)	0.58
Patient limited by comorbidities		
Yes vs. no	1.23 (0.76–2.00)	0.41
Independent ambulation		
Yes vs. no (any aid used)	1.31 (0.78–2.18)	0.31
Type of surgical approach		
Direct anterior vs. posterior/posterolateral	1.18 (0.27–5.11)	
Anterolateral/Lateral vs. posterior/posterolateral	0.92 (0.57–1.49)	Overall: 0.71
Length of operation (minutes)	0.996 (0.988–1.01)	0.34
Use of femoral cement		
Yes vs. no	1.12 (0.68–1.82)	0.66
Femoral head size		
32 mm vs. 28 mm	0.91 (0.53–1.55)	
36 mm vs. 28 mm	0.72 (0.35–1.46)	Overall: 0.38
Implant type		
Total hip arthroplasty vs. hemiarthroplasty	0.96 (1.05–1.67)	0.88

*Femoral head sizes in most HA participants were >36 mm. These participants were not assigned any value under the femoral head size category, and when running the model, they were automatically removed. For that the reason, the overall n value and number of events decreased as compared with the first model (Table 4).

BMI, body mass index; CI, confidence interval.

dislocation rates in the HEALTH study were 4.7% with THA and 2.4% with HA. In our analysis, the femoral head size did not seem to be associated with the need for revision surgery. This could possibly be due to the fact that 83% of the THA cases used 32 mm and 36 mm heads. An analysis of 166,231 primary THAs performed in the Dutch Arthroplasty Registry, examined the effect of the femoral head size and other surgical factors on revision rates.[17] They reported that for all surgical approaches, 32-mm heads reduced the risk of revision for dislocation compared with small head sizes. They also found that 36 mm heads reduced the risk of revision for dislocation only with the posterolateral approach. With the anterior approach, 36-mm heads increased the risk of revision for other reasons.

The AAOS clinical practice guidelines for the management of hip fractures in the elderly recommend the use of cemented femoral stems when performing an arthroplasty procedure for displaced femoral neck fractures.[18] Nearly two-thirds of the arthroplasty procedures in our study were performed with a cemented femoral stem. This could account for the relatively low revision rate because of fewer periprosthetic fractures, and it might provide an explanation of why cementless fixation was not predictive of revision surgery. Data from the Dutch Arthroplasty Registry evaluated 30,830 patients with hip fractures who were treated with THA and HA.[19] Revision rates at 1 year for HA were 1.6% and 2.4% for THAs. Dislocation was the most common reason for revision in both groups (HA 29% and THA 41%). Based on observational data, they found that the risk factors for revision in both the THA and HA groups were male sex, age younger than 80 years, posterolateral approach, and uncemented components. The group concluded that when performing arthroplasty for hip fractures, both a posterolateral approach and uncemented femoral stems have higher risks for revision surgery compared with an anterolateral approach and cemented stems. A recent systematic review and meta-analysis of modern stems concluded that cemented stems for HA result in fewer implant related complications with similar mortality rates.[20] Likewise, Grosso et al retrospectively reviewed the results of a consecutive cohort of 686 patients who underwent HA for the treatment of femoral neck fractures at their institution with a minimum of 2-year follow-up. The overall revision rate was low at 5.6%. Relatively higher conversion rates to THA were seen in the younger population and fewer periprosthetic fractures with the use of cemented stems.[21]

Femoral stem offset when used appropriately can influence abductor moment arm, strength, and overall hip function. The leg length and offset dependent soft-tissue tension can in turn affect hip stability. A patient's ideal anatomical offset can only be determined by preoperative templating.[22] In our study, high offset stems were rarely used and were not found to be predictive of revision surgery. A recent study investigated the influence of femoral component offset on revision rates for primary THA in the New Zealand Joint Registry.[23] Both high and low offset femoral component stems, as compared with standard offset, were found to affect the overall all-cause revision rate of cemented stems.

Our study has several limitations. First, it is important to remember that the surgeons in the HEALTH study might differ from the typical trauma or general orthopaedic surgeon. Nearly all participating surgeons (97.8%) met the thresholds for surgical expertise. To enroll patients in the HEALTH study, surgeons had to be comfortable performing HA or THA routinely for hip fractures. Surgeons who regularly perform THA could theoretically be more versatile with press-fit and cemented implants, better at assessing soft-tissue tension and likely have lower dislocation rates because of better component position. This expertise could theoretically decrease the generalizability of our findings. In addition, although nearly 1500 patients were enrolled in the HEALTH study, arthroplasty registries can sometimes be more informative given their larger sample size. Observational data from numerous arthroplasty registries cited throughout this article have often reached different conclusions than those reported in our study. We are unable to definitively explain why our results differ. Registry data can identify trends and outliers, but it does not allow determination of cause and effect relationships. The low revision rate in HEALTH potentially limited our ability to detect any predictive factors for revision surgery. Further studies are needed to definitively determine the true influence of various patient and surgical factors on the need for revision surgery. Finally, the study is limited by the relatively short-term 2-year clinical follow-up. It is possible that particular patient and surgical factors result in a higher revision surgery rate that will only be observed with longer clinical follow-up. Further follow-up is therefore necessary.

In conclusion, both THA and HA are successful procedures with low reoperation rates when treating low-energy displaced femoral neck fracture patients. We were unable to identify any patient-controlled or surgeon-controlled factors that significantly increased the need for revision surgery in our elderly predominately female patient population. One should not generalize our findings to an active younger femoral neck fracture population.

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