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Systematic review

Salvage of failed internal fixation of intertrochanteric hip fractures: clinical and functional outcomes of total hip arthroplasty versus hemiarthroplasty

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ABSTRACT

Background: Failed internal fixation of intertrochanteric (IT) hip fractures presents a significant challenge in the elderly, osteoporotic population. Conversion total hip arthroplasty (cTHA) and hemiarthroplasty (cHA) are both accepted salvage operations for failed IT fracture fixation, though limited clinical data exist regarding the optimal treatment between these procedures.

Methods: A systematic review of 3 databases (PubMed, Cochrane, and Embase) was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Inclusion criteria were English-language studies that compared clinical or functional outcomes after failed fixation of IT fractures with total hip arthroplasty and hemiarthroplasty in adult subjects (>18 years of age). Data regarding research design, surgical technique, and clinical or functional outcomes were obtained and analyzed from eligible studies using a Mantel-Haenszel random-effects analysis model.

Results: Six studies with 188 patients (100, total hip arthroplasty; 88, hemiarthroplasty) met inclusion and exclusion criteria. There was no significant difference between cTHA and cHA for postoperative dislocation, reoperation, infection, intraoperative fractures, postoperative fractures, or stem subsidence. The mean change in Harris Hip Scores was significantly higher ($P < .001$) in the cTHA group (47.5 ± 4.9) than that in the cHA (38.9 ± 7.2) group at minimum 14-month follow-up.

Conclusions: Despite potential advantages of cTHA or cHA for failed IT fractures, there were no differences in complications between either of the salvage procedures. Our analysis found a slight advantage in functional outcomes (Harris Hip Score) for cTHA at a minimum 14-month follow-up. Our study suggests that cTHA and cHA are both effective salvage procedures. Additional prospective studies are warranted to further delineate outcomes after salvage arthroplasty performed for failed IT fracture fixation.

Introduction and background

Internal fixation with a compression hip screw or cephalomedullary nail is considered the standard of care for most intertrochanteric (IT) proximal femur fractures [1]. However, internal fixation is often associated with failure in elderly, osteoporotic patients who comprise a significant portion of the affected population. Overall, failure rates of osteosynthesis have been cited between 3% and 12% [2-4]. IT fractures may fail to heal for a variety of reasons, including the stability of initial fracture pattern, extent of comminution, quality of the reduction and fixation, and bone quality. Failed treatment of IT fractures can lead to significant disability, pain, and need for revision procedures [1].

Revision osteosynthesis and salvage treatment with hip arthroplasty are the 2 mainstays of treatment for failed internal fixation of IT fractures. Both conversion total hip arthroplasty (cTHA) and conversion hemiarthroplasty (cHA) are generally accepted salvage options for failure of these fixation devices in older patients [5,6]. Several technical hurdles to successful

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arthroplasty in this setting include poor bone stock, residual bone deformity, altered soft tissue anatomy, and retained hardware [1,2]. Owing to these challenges, conversion arthroplasty has been associated with increased risk of perioperative morbidity—prolonged operative times, increased blood loss, intraoperative fracture, and early dislocation [7-9]. Currently, no established guidelines exist regarding conversion arthroplasties after failed internal fixation of IT fractures. Given such limited existing clinical data, the purpose of this systematic review and meta-analysis was to compare functional outcomes and complications of total hip arthroplasty to those of hemiarthroplasty after fixation failure of IT fractures.

Material and methods

Search strategy

A systematic literature search was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and Cochrane Handbook (Fig. 1). Two reviewers independently searched 3 online databases (PubMed, Cochrane, and EMBASE) using the following keywords and their combinations: salvage total hip arthroplasty, IT fracture, hemiarthroplasty, hip, conversion, and failed fixation. Articles published between 2000 and 2017 were included in our literature search and were limited to studies in human subjects published in English. Reference lists of included studies were cross-referenced for supplementary eligible studies. The search terms and inclusion/exclusion criteria were established a priori.

Eligibility criteria

Eligible studies were included based on the following criteria: (1) level I to III evidence, (2) articles published in the English language, (3) human studies, (4) failed IT fractures, (5) studies reporting clinical outcomes, and (6) full-text availability. Exclusion criteria were as follows: (1) basic science articles, (2) studies on primary hip arthroplasty, and (3) potential overlap of patient populations when study was by same author or institutions.

Literature appraisal

Two of the authors screened all titles, abstracts, and full text of retrieved studies to determine eligibility. Disagreements were resolved by discussion between the 2 authors, and if a consensus could not be reached, the senior reviewer resolved the discrepancy. The final decision on inclusion was made on the basis of the full text of the article.

The Methodological Index for Non-Randomized Studies (MINORS) criteria were used for grading the methodological quality of selected studies. MINORS is a validated scoring tool to assess internal and external validity for nonrandomized studies [10]. Studies are assigned 0, 1, or 2 with a maximum of 24 for comparative studies and 16 for noncomparative studies. Although each

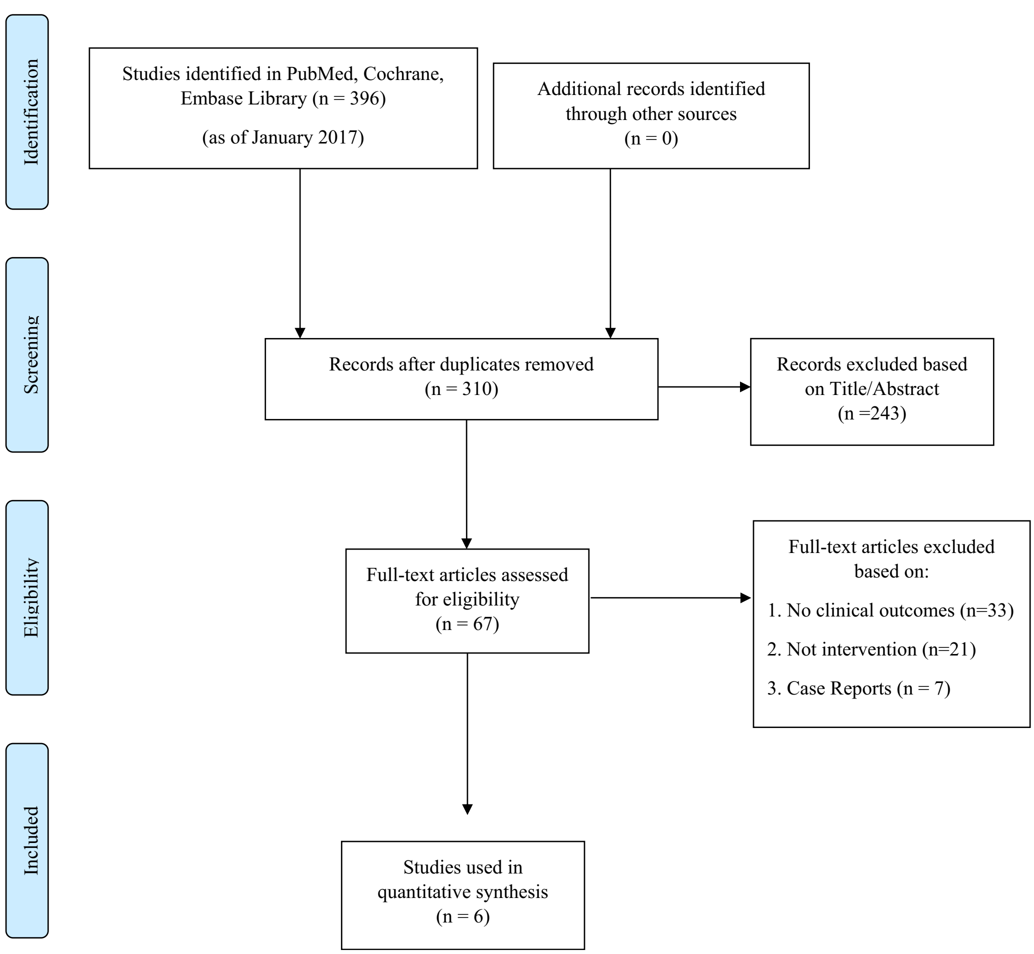

Figure 1. PRIMSA diagram: Flowchart of systematic search strategy.

Table 1
Eligible studies including numbers of patients, follow-up intervals, and outcome measures assessed.

Author	Year	Study design	n	Age range (y)	M/F	Salvage procedure	Follow-up (mo)	Outcome measures
Cho et al. [12]	2010	Retrospective analysis of the outcomes of cTHA vs cHA	18	73 (63-88)	8/10	THA (9), bipolar HA (9)	38.7 (24-72)	Functional outcomes: HHS, VAS, SW, Length of Stay, operative time, transfusion volume. Complications: intraoperative fracture, infection, dislocation, reoperation
Feng et al. [16]	2013	Retrospective analysis of the outcomes of cTHA vs cHA	13	76.5 (58-92)	4/9	THA (4), bipolar HA (9)	31 (14-68)	Functional outcomes: HHS, WOMAC, pain, ambulation
Laffosse et al. [13]	2007	Retrospective analysis of the outcomes of cTHA vs cHA	29	81.1 (70-91)	6/23	THA (7), bipolar HA (22)	20 (6-89)	Functional outcomes: ambulation, pain relief. Complications: intraoperative fracture, postoperative fracture, dislocation, stem subsidence, reoperation
Pachore et al. [14]	2013	Retrospective analysis of the outcomes of cTHA vs cHA	30	67.3 (51-81)	13/17	THA (9), bipolar HA (21)	20 (6-48)	Function outcomes: HHS, VAS, ambulation. Radiographic subsidence. Complications: dislocation, reoperation
Tsai et al. [15]	2016	Retrospective analysis of the outcomes of cTHA vs cHA	79	75.1 (32-90)	40/39	THA (55), bipolar HA (24)	75.6 (24-244)	Functional outcomes: HHS. Radiographic subsidence or loosening. Complications: dislocation, infection, intraoperative fracture, postoperative fracture, reoperation
Zhang et al. [7]	2004	Retrospective analysis of the outcomes of cTHA vs cHA	19	64.1 (21-87)	6/13	THA (16), bipolar HA (3)	88 (24-216)	Functional outcomes: HHS, pain, ambulation. Radiologic loosening and stability. Complications: intraoperative fracture, dislocation, infection, reoperation

included constituent study was scored, studies were not excluded from the systematic review on the basis of their MINORS score.

Data extraction

Included studies were used to extract relevant data including author, year of publication, sample size, study design, level of evidence, and surgical procedure (ie, cHA vs cTHA). The primary outcome measures evaluated in our meta-analysis included postoperative dislocation, reoperation, and infection. Secondary outcomes evaluated included intraoperative fractures, postoperative fractures, stem subsidence, and Harris Hip Score (HHS).

Quantitative analysis

A statistical analysis was conducted using Review Manager 5.3 (Nordic Cochrane Center, Cochrane Collaboration 2009, Copenhagen, Denmark). The heterogeneity between studies was evaluated using the I^2 statistic, and a χ^2 of <0.05 was used to determine the significance of the heterogeneity between studies. Risk ratios (RRs) were reported for dichotomous variables, whereas mean differences and standard deviations were used for continuous variables. All analyses were conducted using the Mantel–Haenszel random-effects model. A random-effects model was chosen because it is the most appropriate and conservative method in the setting of medical decision-making and possible study heterogeneity. It also accounts for both within-study and between-study variance. This methodology has been previously used in similar meta-analyses of observational data [11]. The results of our meta-analysis were then illustrated using forest plots, which used a 95% confidence interval (CI) for each study, and a cumulative weighted mean effect for all the studies involved.

Results

Search results

The results of the electronic database search are outlined in Figure 1. The search yielded 310 results after the removal of all duplicates (117 PubMed, 207 CINAHL, 72 Embase). No additional records were identified through other sources. After title-based exclusion of 243 sources, 67 abstracts were screened for inclusion. Twenty-six articles were deemed potentially eligible and were read in full by 2 reviewers. Six studies published between 2000 and 2016 met the final eligibility criteria and were ultimately included in the review [7,12-16]. All 6 studies were retrospective analyses of outcomes following cTHA and cHA for failed fixation of IT fractures (Table 1).

Methodological quality

All 6 studies represented level III evidence. The noncomparative studies had a mean MINORS score of 10.8—indicating a moderate quality of evidence (Appendix A).

Characteristics of the included studies

All the included studies were retrospective in nature. The data pooled from the eligible studies yielded a total of 188 patients with an age range of 21 to 92 years. The youngest average age in any of the included studies was 64.1 years [7]. Each study reported patient gender; the overall male to female ratio was 1:1.4. The minimum average duration of patient follow-up for any individual study was 20 months [13,14]. Among the entire cohort, patients were followed up for a minimum of 6 months to a maximum of 20 years [13-15].

Table 2
Fractures and procedures in different cohorts.

Author	Initial fracture	IF method	Mean duration to fixation failure	Cause of failure	Time from failure to AR	Implant	Approach
Cho et al. [12]	IT fracture	DHS (10), PFN (6), blade plate (1), Gamma nail (1)	Not specified (NS)	Nonunions (8), hardware failure/cutting out (5), AVN (2), malunion (2), arthritic change (1)	13.6 mo (cTHA) vs 10.4 mo (cHA)	Long stem (16), calcar-replacing implants (4)	Not specified
Feng et al. [16]	Evans type I (3), Evans type II (10) IT fracture	DHS (13)	9.5 mo (6.3-13.1)	Nonunion with cut-out (8), hardware failure (2), AVN (3)	10.7 mo (6.5-15.7)	THA (4), bipolar HA (9)	Not specified
Laffosse et al. [13]	31–A1 (10), A2 (14), A3 (5)	DHS (17), Gamma nail (5), long Gamma nail (1), Judet plating (4), Ender nail (1), PCCP (1)	2 mo (0-5)	Cut-out (21), disassembly (8), implant breakage (0)	<3 mo in 24 of 29 cases	THA (7): dual-mobility acetabular implant (4), cemented PE cup (2), and uncemented cup (1); head size NS (7); bipolar HA (22); modular, uncemented metadiaphyseal fitting stem (29)	Posterolateral
Pachore et al. [14]	IT Fracture (26), IT Fracture with ST extension (4)	SHS (13), PFN (6), Enders nail (3), Smith-Peterson Nail-Plate (2), blade plate (2), 95° sliding screw (2), Jewett nail (1), locking cobra plate (1)		Nonunion (30)	44.6 mo (4-324)	THA (9): cemented cup (4) and uncemented cup (5); 28-mm heads (9); uncemented bipolar HA (19): proximally coated stem (2) and fully coated (17); cemented HA (2)	Posterior
Tsai et al. [15]		DHS (59), Gamma nail (16), dynamic condylar screw (2), reconstruction nail (1), angle plate (1)		Lag screw cut-out (42), fracture collapse (29), nonunion (8)	Not specified	Uncemented THA cup (55), uncemented standard metaphyseal locking stem (41), uncemented diaphyseal locking stem (29), cemented standard stem (9)	Modified Hardinge (62), posterolateral (17)
Zhang et al. [7]	IT fracture	Compression hip screw	40.3 mo (2-288); 6.0 mo (2-9) for nonunion/lag screw penetration, 70.0 mo (15-288) for AVN	Nonunion with penetration of lag screw (8), AVN (10), deep sepsis (1)	Not specified	Standard stem (19), uncemented bipolar HA (1), cemented bipolar HA (2), cemented THA (12), hybrid THA (2), uncemented THA (2)	Posterior

AR, arthroplasty; AVN, avascular necrosis; DHS, dynamic hip screw; IF, internal fixation; PCCP, percutaneous compression plate; PFN, proximal femoral nail; ST, subtrochanteric.

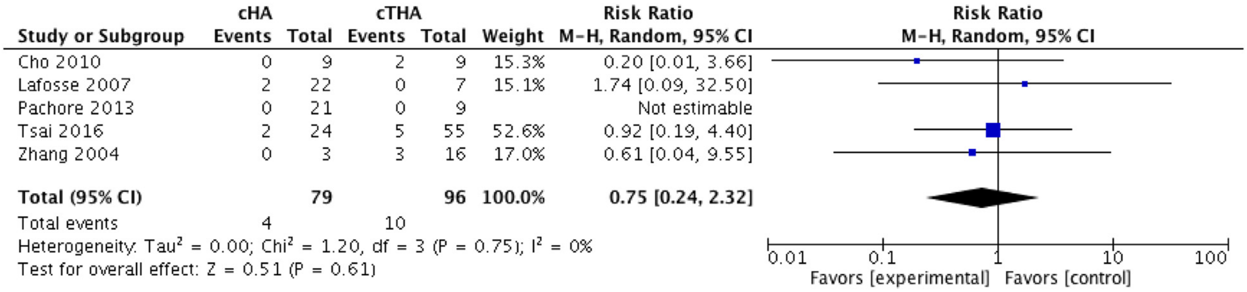

Figure 2. Events of postoperative dislocation.

Only 2 studies commented on classification of initial fracture pattern using either the Arbeitsgemeinschaft für Osteosynthesefragen Classification [13] or the Evans Classification [16]. No other study mentioned initial fracture stability or quantified initial fracture displacement. The preferred method of initial fixation in all studies was a dynamic or sliding hip screw (Table 2).

The cause of fixation failure was reported for all 188 cases; lag screw cut-out accounted for 45% of failures (84 cases), whereas nonunion accounted for nearly 32% (60 cases). The mean time to fixation failure was reported in only 3 studies as 2, 9.5, and 40 months [7,13,16]. In the study with a mean time to fixation failure of 40 months, the time to fixation failure differed considerably between patients who failed secondary to nonunion and/or lag screw cut-out (6 months) and those who suffered from osteonecrosis of the femoral head (60 months) [7]. Reporting on the time from failure to salvage procedure was variable and ranged from <3 to 44.6 months in 4 studies [12-14,16].

Of the 188 cases, there were 100 cTHA and 88 cHA performed. One study did not record the surgical approach used for the salvage procedure [12], and another did not specify the approach beyond extension of the prior incision [16]. In the remaining studies, a combination of posterior, posterolateral, and the modified Hardinge approach was used [7,13-15]. An intraoperative assessment of acetabular cartilage was the primary determinant of implant selection in all studies; patient age was not specified as a selection criterion for total vs hemiarthroplasty. One study preferred bipolar hemiarthroplasty to total hip arthroplasty (THA) in cases in which increased risk of dislocation was a concern (whenever healthy articular cartilage was present) [7]. Four studies reported average estimated blood loss for all salvage arthroplasty procedures combined without directly comparing estimated blood loss during cHA vs cTHA [7,13,15,16]. Another study found no statistically significant difference in transfusion volume between cHA and cTHA [12]. Operative time for cHA vs cTHA was reported by only 2 authors; the mean difference was insignificant and ranged from 7 to 17 minutes [12,13].

The implants and method of fixation used in each study were reported in varying level of detail (Table 2). Cho et al. [12] and Feng et al. [16] did not specify the implant type or whether cement was used in their cases. In the remaining cohort from the other 4 included studies, 126 of 157 femoral stems (80.3%) were uncemented with varying types of stem geometry, which included metaphyseal fitting, diaphyseal fitting, modular metadiaphyseal fitting, and fully-coated calcar-replacing stems [7,13-15]. The decision to cement a standard femoral stem in the other 31 specifying cases was made based on bone quality and femoral canal geometry [7,14,15]. Of the 87 cTHA performed that reported method of fixation, 69 (79%) cups were press-fit [7,13-15]. Sixty-four of the 87 cTHA performed reported the femoral head size used, with 28 mm being the most common (54 cases), followed by 32 mm (8 cases) and 26 mm (2 cases) [14,15]. Bipolar hemiarthroplasty was used in all cases of cHA. Three studies mentioned the manufacturer of the implants used [7,13,15].

A variety of scoring systems were used in the assessment of functional outcomes among the included studies, and the most common of which was the HHS [17] in 4 studies [7,12,14,16]. Other scoring systems that were precluded in the quantitative meta-analysis included the Visual Analog Scale (VAS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Salvati and Wilson score (SW) for clinical outcomes, as well as independent functional outcome reports of pain and mobility.

Complications

The 6 included studies (188 patients) compared cHA vs cTHA as salvage procedures after failed fixation IT fractures. Homogeneity in reported complications among 5 studies permitted meta-analysis for the incidence of postoperative dislocation, reoperation, infection, intraoperative fracture, postoperative fractures, and stem subsidence. There was no significant difference between cHA and cTHA for postoperative dislocation, reoperation, infection, intraoperative fractures, postoperative fractures, or stem subsidence. There was a 10.4% dislocation rate after cTHA (10 among 96 cases) compared with 5% after cHA (4 among 79 cases); however, this did not reach statistical significance in the meta-analysis (relative RR, 0.75; 95% CI, 0.24-2.32; $P = .61$) (Fig. 2). Postoperative infection complicated 2 of 55 cHA and 3 of 71 cTHA (RR, 1.22; CI, 0.20-7.33; $P = .83$) (Fig. 3). Intraoperative fractures occurred in 5.5% of cHA and

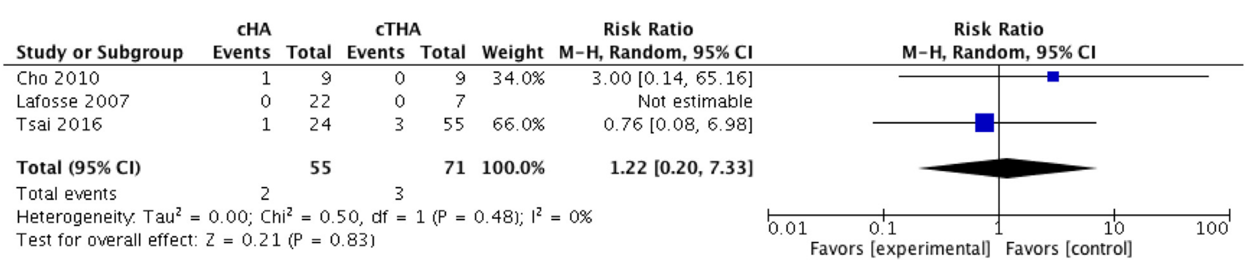

Figure 3. Events of postoperative infection.

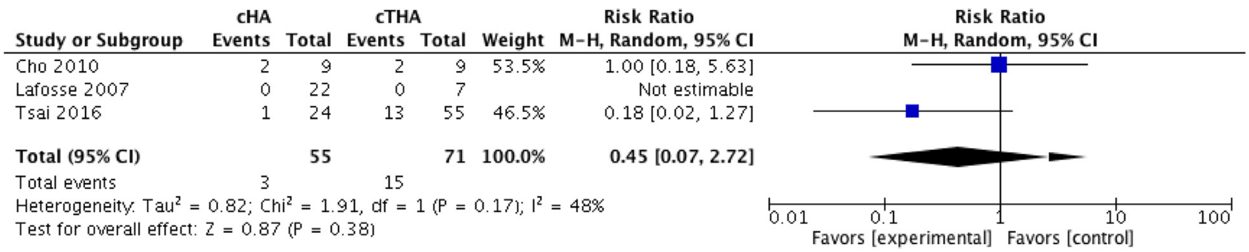

Figure 4. Events of intraoperative fracture.

21.1% of cTHA (3 of 55 and 15 of 71 cases, respectively) (RR, 0.45; CI, 0.07-2.72; $P = .38$) (Fig. 4). All intraoperative fractures occurred in the femur (no acetabular fractures were reported). Only one intraoperative femur fracture occurred during implantation of a cemented standard stem, whereas 9 and 4 intraoperative femur fractures occurred when using cementless standard metaphyseal fitting and diaphyseal fitting stems, respectively [15]. Fractures noted in the metaphyseal-diaphyseal junction were commonly noted during femoral preparation or implant insertion and were managed with cerclage cables; the need to exchange for a longer stem in the instance of intraoperative fracture was not explicitly mentioned [15]. All greater trochanter fractures were managed with wiring [15]. The 4 remaining intraoperative femur fractures occurred in a study that reported frequent use of long diaphyseal fitting (16 of 18 cases) and calcar-replacing stems (4 of 18 cases) but did not clarify whether all incidents of fracture occurred with the use of this particular implant or how these fractures were managed in the operating room [12]. Owing to a paucity of complication events observed in cohorts included in the meta-analysis, RRs were not estimable beyond that of a single study for reoperation (Fig. 5), postoperative fracture (Fig.6), and stem subsidence (Fig. 7) [15].

Functional outcomes

Differences in the reported functional outcomes among the included studies precluded pooling of much of the data. Two studies reported mean changes in HHS after cHA and cTHA [12,16]. Compared with preoperative HHS, cTHA yielded a mean increase in HHS of 47.5 ± 4.9 compared to an increase in HHS of 38.9 ± 7.2 after cHA at a minimum follow-up span of 14 months ($P < .001$) (Table 3). Cho et al. [12] additionally reported significant improvements in VAS and SWs at a minimum of 2-year follow-up after cTHA compared with those after cHA. A shared preoperative mean VAS of 5.6 improved to 0.9 after cTHA compared with 3.1 after cHA ($P < .001$). SWs improved from 13.1 to 31.3 and 12.7 to 25.1 after cTHA and cHA, respectively ($P = .033$) [12]. Mean joint-line cartilage thickness, protrusion acetabuli, and presence of osteophytes were all worse among those who underwent THA in this study [12]. There were no significant differences in operative time, transfusion volume, or length of hospital stay between cTHA and cHA groups [12].

In the series by Feng et al. [16], WOMAC scores were also significantly improved at 1-year follow-up after both salvage procedures. At an average 31-month follow-up, 8 of 13 patients reported no hip pain, 2 reported slight pain, and 3 reported mild pain; only one of the 13 patients required use of an assistive device [16]. Twenty-three of the 29 patients in the series published by Laffosse et al. [13] were followed up over an average period of 20 months. Although none of the patients reported any pain, 6 patients required a cane, 8 required 2 canes or walker, and 3 patients were severely limited in independent mobility.

Three studies reported comparable improvements in HHS after salvage arthroplasty without directly comparing cTHA with cHA [7,14,15]. HHSs increased from an average preoperative mean of 32.4 (range, 27.9-38.4) to 76 (range, 70.6-79.8) by the last follow-up [7,14,15]. Approximately 60% of patients required use of some assistive device for ambulation 2 years after salvage arthroplasty, most of whom used a cane rather than a walker [7,14].

Discussion

Although many surgeons generally accept THA as the most successful salvage procedure for failed internal fixation of IT fractures, our study demonstrates no difference in complication rates between cTHA and cHA (postoperative dislocation, reoperation, infection, intraoperative fractures, postoperative fractures, or stem subsidence). However, we did find a significant increase in HHS of 47.5 ± 4.9 for cTHA compared with an increase of 38.9 ± 7.2 for cHA as of a minimum 14-month follow-up [12,16].

To the best of our knowledge, very few studies have been published about this topic with varying results. The failure rate for these fractures has been reported to be between 4% and 17% in patients with preexisting osteoporosis [6,18-21]. In addition, age and sex have also been associated with higher failure rates in this elderly population [22]. Although dynamic hip screws typically provide excellent results for internal fixation, failure rates have been reported between 7% and 14% [23]. Proximal femoral nails also provide good to excellent results, but failure rates are still cited between 7% and 13% [24-26]. In turn, revision internal fixation or

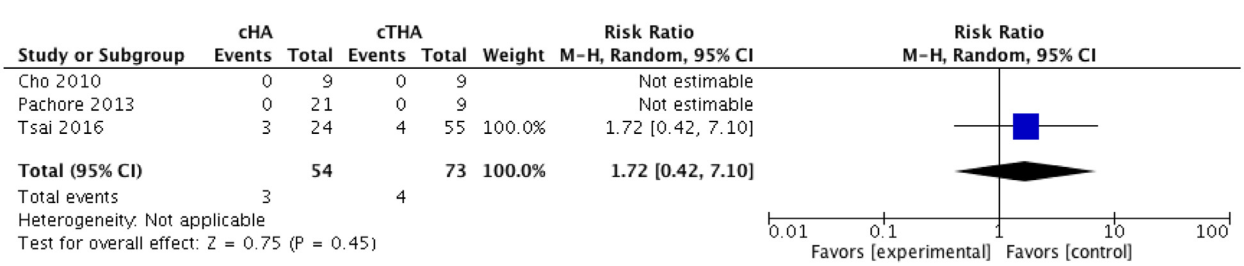

Figure 5. Events of reoperation following conversion arthroplasty.

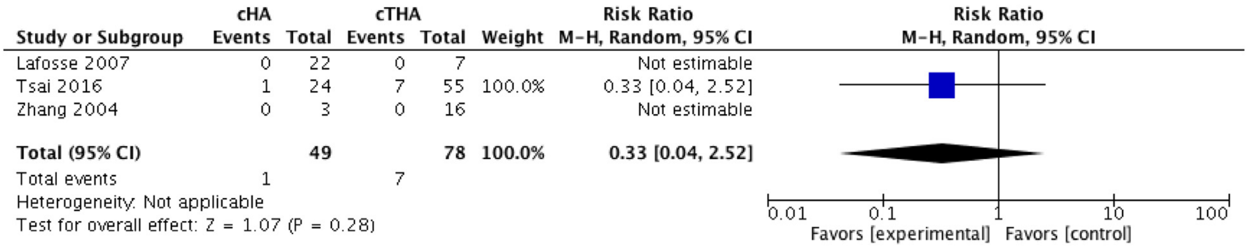

Figure 6. Events of postoperative fracture.

conversion arthroplasty (THA or hemiarthroplasty [HA]) are the 2 main salvage options for treatment of IT fracture fixation failure. As the success of revision osteosynthesis is limited by the host's healing capacity, salvage arthroplasty becomes the mainstay of treatment in this elderly population.

Several technical challenges must be overcome when performing arthroplasty after failed treatment of IT fractures. First, failed retained hardware, which often involve broken plates, screws, and/or intramedullary devices, must be carefully removed from the femur. Although special instrumentation can be useful to limit bone loss or intraoperative fracture during hardware extraction, presence of nonunion and/or osteoporotic bone may still limit proximal femur implant fixation. Often times, calcar-replacement implants or longer distal fixation stems must be used to account for the bone deficiency and to properly restore limb length and achieve durable fixation [6]. One series included in this meta-analysis reported using long-stem or calcar-replacement implants in 89% and 22% of all patients, respectively, regardless of whether cTHA or cHA was performed [12]. Another series reported using calcar-replacement stems, extended-neck stems, or long-stem implants in 51 of 60 salvage hip arthroplasties for failed IT fractures [6]. Regarding the choice of cTHA vs cHA, patient comorbidity and functional demand must be considered in addition to the extent of preexisting arthritis and acetabular cartilage damage at the time of revision.

In the present study, there was no significant difference in infection, reoperation, intraoperative fractures, postoperative fractures, stem subsidence, or postoperative dislocations between either form of salvage arthroplasty. Although cTHA may yield favorable functional outcomes in some patients, any salvage arthroplasty for failed internal fixation can be expected to have higher rates of complications than the equivalent procedure performed primarily [27-30]. Unfortunately, the available literature precluded a pooled-data analysis of the outcomes of cTHA or cHA for failed IT fracture fixation compared with that of primary arthroplasty.

Reviewing the outcomes of THA vs HA in the treatment of femoral neck fractures [31-36] presents several points of consideration to the conversion-arthroplasty surgeon for preoperative decision-making. In a Medicare database cohort of over 70,000 patients aged 65 to 90 years with femoral neck fractures, HA was found to have a lower proportional hazard of reoperation and dislocation than THA, with less than 2% of patients undergoing conversion to THA at 2 years [35]. Primary HA for femoral neck fracture has been cited to offer excellent 10-year survivorship, with 93.6% and 99.4% of patients (with a mean age of 79 years) free from reoperation for any reason and for acetabular cartilage wear, respectively [31]. Other studies have reported higher reoperation rates after THA [34] or no significant difference [33] when compared to HA for intracapsular hip fractures. Patients who undergo HA for femoral neck fractures tend to have more discomfort and groin pain than those who undergo THA [32,33,37]. Age, activity level, length of follow-up, and extent of acetabular cartilage erosion may all be correlated with symptom progression and rate of conversion from HA to THA [32,37]. Similar factors likely account for the varying degrees of pain and functional outcomes between cTHA and cHA in the presented meta-analysis. We found a significant increase in HHS of 47.5 ± 4.9 for cTHA compared to an increase of 38.9 ± 7.2 after cHA at a minimum 14-month follow-up. As pain relief and restoration of function are common indications to perform salvage arthroplasty, it is important to highlight the increase in HHS after cTHA compared with that after cHA in this population. It is reasonable to expect this difference in pain level and HHS to increase with length of follow-up after salvage arthroplasty based on the aforementioned literature. Published outcomes data have shown comparable improvements in HHS between cTHA performed for failed sliding hip screw and cephalomedullary nail constructs at a 3-year follow-up [38]. Although THA addresses acetabular cartilage damage and the need for implant longevity in some patients, longer operating times and increased blood loss can be expected for THA compared with HA [33,36]. Authors have reported these figures to be only slightly higher when primary arthroplasty is performed for proximal femur fractures than those of elective arthroplasty for osteoarthritis [33,36]. These same metrics, however, may increase substantially in conversion procedures requiring extensile dissection and hardware removal [39]. Given the favorable increase in HHS after cTHA in this meta-analysis of studies that used the status of acetabular cartilage as the determining factor between cTHA and cHA, the authors recommend using patient age and preinjury functional status as the primary determinant of whether to resurface the acetabulum in these cases. Such factors likely correlate with patient health and

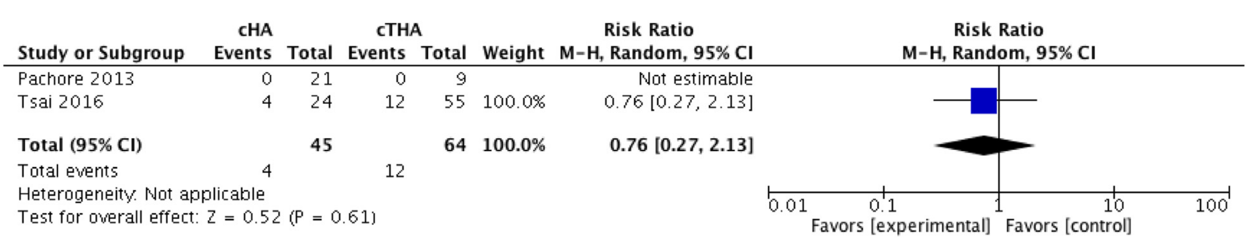

Figure 7. Events of radiographic stem subsidence.

Table 3
Mean change in HHS functional outcome at minimum 14-month follow-up.

	Hemiarthroplasty (cHA)	Total hip arthroplasty (cTHA)	*P* value
Total (n)	18	13	
HHS	38.9 ± 7.2	47.5 ± 4.9	<.001

ability to tolerate the increased surgical burden of cTHA. Furthermore, it is likely difficult to predict the endurance of acetabular cartilage over time after cHA.

The main strength of this study was our ability to identify a high number of overall patients by using an extensive search strategy with broad inclusion criteria to capture most related literature. However, we acknowledge several limitations inherent to the literature available on presented topic. First, our analysis is limited by the heterogeneity in reporting of clinical and functional outcomes, which preclude further pooling of data beyond what are presented. Second, the studies included in our analysis were retrospective in nature, which further reduces the quality of evidence provided by our conclusions. In addition, there were numerous studies that had to be excluded due to the lack of a direct comparison group, insufficient detail of the included cases, or inclusion of multiple fracture types in the cohort (both femoral neck IT and subtrochanteric fractures). Data on these potential subjects could not be sufficiently extracted for analysis. Third, multiple surgeons were included in the analysis who used different surgical approaches and revision prostheses, and there was a significant variation among the included subjects in regard to the retained, failed hardware. Although this variation precluded conclusions unique to initial mode of fracture fixation, surgical approach, or specific revision implants, we believe our results are generalizable to all cases of failed IT fracture fixation. Finally, the choice between cTHA and cHA at the time of salvage is ultimately subjective in nature.

Conclusions

Our study supports previous literature that cTHA and cHA are reliable salvage procedures for failed fixation of IT fractures. The present study found no difference in clinical outcomes but did show more favorable results in functional outcomes (HHS) after cTHA. Nonetheless, salvage arthroplasty procedures performed for failed internal fixation are associated with increased technical demands and risk of complications compared with routine primary hip arthroplasty. Use of tailored implants and careful consideration of fixation method become paramount. Surgeons must understand the increased risk of perioperative morbidities and individually counsel patients according to both health status and functional demand when deciding between cTHA and cHA. Despite these increased challenges, cTHA and cHA provide acceptable clinical outcomes and serve as effective treatment methods for failed femoral IT fracture fixation. Further study of long-term outcomes is necessary to delineate the incidence and causes of reoperation for cHA and cTHA performed for failed internal fixation of IT fractures.

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The investigation was performed at the New York University (NYU) Langone Orthopedic Hospital, New York, NY.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.artd.2018.06.002.

References

[1] Anglen JO, Weinstein JN. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice - a review of the American Board of Orthopaedic Surgery database. J Bone Joint Surg Am 2008;90:700.
[2] Haentjens P, Casteleyn PP, Opdecam P. Hip arthroplasty for failed internal fixation of intertrochanteric and subtrochanteric fractures in the elderly patient. Arch Orthop Trauma Surg 1994;113:222.
[3] Matre K, Havelin LI, Gjertsen JE, Vinje T, Espehaug B, Fevang JM. Sliding hip screw versus im nail in reverse oblique trochanteric and subtrochanteric fractures. A study of 2716 patients in the Norwegian Hip Fracture Register. Injury 2013;44:735.
[4] Ovesen O, Andersen M, Poulsen T, Nymark T, Overgaard S, Röck ND. The trochanteric gamma nail versus the dynamic hip screw: a prospective randomised study. One-year follow-up of 146 intertrochanteric fractures. Hip Int 2006;16:293.
[5] McKinley JC, Robinson CM. Treatment of displaced intracapsular hip fractures with total hip arthroplasty: comparison of primary arthroplasty with early salvage arthroplasty after failed internal fixation. J Bone Joint Surg Am 2002;84-A:2010.
[6] Haidukewych GJ, Berry DJ. Hip arthroplasty for salvage of failed treatment of intertrochanteric hip fractures. J Bone Joint Surg Am 2003;85-A:899.
[7] Zhang B, Chiu K-Y, Wang M. Hip arthroplasty for failed internal fixation of intertrochanteric fractures. J Arthroplasty 2004;19:329.
[8] Winemaker M, Gamble P, Petruccelli D, Kaspar S, de Beer J. Short-term outcomes of total hip arthroplasty after complications of open reduction internal fixation for hip fracture. J Arthroplasty 2006;21:682.
[9] DeHaan AM, Groat T, Priddy M, et al. Salvage hip arthroplasty after failed fixation of proximal femur fractures. J Arthroplasty 2013;28:855.
[10] Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. ANZ J Surg 2003;73:712.
[11] Weinberger JM, Fabricant PD, Taylor SA, Mei JY, Jones KJ. Influence of graft source and configuration on revision rate and patient-reported outcomes after MPFL reconstruction: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc 2017;25:2511.
[12] Cho C-H, Yoon S-H, Kim S-Y. Better functional outcome of salvage THA than bipolar hemiarthroplasty for failed intertrochanteric femur fracture fixation. Orthopedics 2010;33:721.
[13] Laffosse J-M, Molinier F, Tricoire J-L, Bonnevialle N, Chiron P, Puget J. Cementless modular hip arthroplasty as a salvage operation for failed internal fixation of trochanteric fractures in elderly patients. Acta Orthop Belg 2007;73:729.
[14] Pachore JA, Shah VI, Sheth AN, Shah KP, Marothi DP, Puri R. Hip arthroplasty in failed intertrochanteric fractures in elderly. Indian J Orthop 2013;47:572.
[15] Tsai S-W, Chen C-F, Wu P-K, Huang C-K, Chen W-M, Chang M-C. Does implant selection impact postoperative complications following hip arthroplasty for failed intertrochanteric fractures? a retrospective comparative study. Artif Organs 2016;40:798.
[16] Feng W, Hao T, Liu WL, Jia YF, Hao ZT, Bai SB. Clinical outcome of endoprosthetic replacement for failed treatment of intertrochanteric fractures: a retrospective case series. Pak J Med Sci 2012;29:633.
[17] Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. J Bone Joint Surg Am 1969;51:737.
[18] Kyle RF, Gustilo RB, Premer RF. Analysis of six hundred and twenty-two intertrochanteric hip fractures. J Bone Joint Surg Am 1979;61:216.
[19] Davis TR, Sher JL, Horsman A, Simpson M, Porter BB, Checketts RG. Intertrochanteric femoral fractures. Mechanical failure after internal fixation. J Bone Joint Surg Br 1990;72:26.
[20] Haidukewych GJ, Israel TA, Berry DJ. Reverse obliquity fractures of the intertrochanteric region of the femur. J Bone Joint Surg Am 2001;83-A:643.
[21] Bannister GC, Gibson AG, Ackroyd CE, Newman JH. The fixation and prognosis of trochanteric fractures. A randomized prospective controlled trial. Clin Orthop Relat Res 1990:242.
[22] Laros GS. Intertrochanteric fractures: the role of complications of fixation. Arch Surg 1975;110:37.
[23] Watson JT, Moed BR, Cramer KE, Karges DE. Comparison of the compression hip screw with the Medoff sliding plate for intertrochanteric fractures. Clin Orthop Relat Res 1998:79.
[24] Boldin C, Seibert FJ, Fankhauser F, Peicha G, Grechenig W, Szyszkowitz R. The proximal femoral nail (PFN)—a minimal invasive treatment of unstable proximal femoral fractures: a prospective study of 55 patients with a follow-up of 15 months. Acta Orthop Scand 2003;74:53.
[25] Papasimos S, Koutsojannis CM, Panagopoulos A, Megas P, Lambiris E. A randomised comparison of AMBI, TGN and PFN for treatment of unstable trochanteric fractures. Arch Orthop Trauma Surg 2005;125:462.

[26] Adams CI, Robinson CM, Court-Brown CM, McQueen MM. Prospective randomized controlled trial of an intramedullary nail versus dynamic screw and plate for intertrochanteric fractures of the femur. J Orthop Trauma 2001;15:394.
[27] Mahmoud SSS, Pearse EO, Smith TO, Hing CB. Outcomes of total hip arthroplasty, as a salvage procedure, following failed internal fixation of intracapsular fractures of the femoral neck: a systematic review and meta-analysis. Bone Joint J 2016;98-B:452.
[28] Mehlhoff T, Landon GC, Tullos HS. Total hip arthroplasty following failed internal fixation of hip fractures. Clin Orthop Relat Res 1991:32.
[29] Tabsh I, Waddell JP, Morton J. Total hip arthroplasty for complications of proximal femoral fractures. J Orthop Trauma 1997;11:166.
[30] Enocson A, Mattisson L, Ottosson C, Lapidus LJ. Hip arthroplasty after failed fixation of trochanteric and subtrochanteric fractures. Acta Orthop 2012;83:493.
[31] Haidukewych GJ, Israel TA, Berry DJ. Long-term survivorship of cemented bipolar hemiarthroplasty for fracture of the femoral neck. Clin Orthop Relat Res 2002:118.
[32] Gebhard JS, Amstutz HC, Zinar DM, Dorey FJ. A comparison of total hip arthroplasty and hemiarthroplasty for treatment of acute fracture of the femoral neck. Clin Orthop Relat Res 1992:123.
[33] Blomfeldt R, Tornkvist H, Eriksson K, Soderqvist A, Ponzer S, Tidermark J. A randomised controlled trial comparing bipolar hemiarthroplasty with total hip replacement for displaced intracapsular fractures of the femoral neck in elderly patients. J Bone Joint Surg Br 2007;89:160.
[34] Keating JF, Grant A, Masson M, Scott NW, Forbes JF. Randomized comparison of reduction and fixation, bipolar hemiarthroplasty, and total hip arthroplasty: treatment of displaced intracapsular hip fractures in healthy older patients. J Bone Joint Surg Am 2006;88:249.
[35] Wang Z, Bhattacharyya T. Outcomes of hemiarthroplasty and total hip arthroplasty for femoral neck fracture. J Orthop Trauma 2017;31:260.
[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 Joint Surg Br 2010;92:1422.
[37] Phillips TW. Thompson hemiarthroplasty and acetabular erosion. J Bone Joint Surg Am 1989;71:913.
[38] Pui CM, Bostrom MP, Westrich GH, et al. Increased complication rate following conversion total hip arthroplasty after cephalomedullary fixation for intertrochanteric hip fractures: a multi-center study. J Arthroplasty 2013;28:45.
[39] Lee Y-K, Kim JT, Alkitaini AA, Kim K-C, Ha Y-C, Koo K-H. Conversion hip arthroplasty in failed fixation of intertrochanteric fracture: a propensity score matching study. J Arthroplasty 2017;32:1593.