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Review

Outcomes of elderly patients with nondisplaced or minimally displaced femoral neck fractures treated with internal fixation: A systematic review and meta-analysis ☆

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ABSTRACT

Background: Internal fixation remains the treatment of choice for non-displaced femoral neck fractures in elderly patients. Improved outcomes with arthroplasty following displaced femoral neck fractures may indicate that outcomes of non-displaced patterns should be reexamined. The aim of our study was to conduct a systematic review of the orthopaedic literature to determine the outcomes of internal fixation for the treatment of non-displaced and minimally displaced femoral neck fractures in elderly patients.
Methods: Relevant articles were identified using PubMed, Embase, and CENTRAL databases. Manuscripts were included if they contained (1) patients 60 years or older with (2) nondisplaced or minimally displaced (Garden I or II) femoral neck fractures (3) treated with internal fixation (4) separately reported outcomes in this patient population. The primary outcome was reoperation. Secondary outcomes included mortality, patient-reported outcomes, length of hospitalization, infection, and transfusions. Fixed and random effects modeling was used to determine pooled estimates of the outcomes.
Results: Twenty-seven studies were identified with a total of 21,155 patients, all of which were treated with internal fixation. The pooled risk of reoperation was 14.1% (95% CI: 10.6–18.2). The risk of one-year mortality was 14.6% (95% CI: 11.5–18.2) based on the reporting in 15 studies.
Conclusions: The risk of reoperation and mortality following the treatment of nondisplaced femoral neck fractures in the elderly with internal fixation exceeds 14%. This complication profile may be unacceptably high. Arthroplasty may offer improved short-term functional outcomes and a reduced risk of reoperation. However, there is currently little evidence to consider this treatment to be an alternative to internal fixation.

Contents

☆ Level of Evidence: III

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Introduction

Femoral neck fractures are a devastating injury in the elderly population and are increasing in frequency in the United States as the population ages. It is estimated that the global number of hip fractures will increase to six million by 2050 [1]. Historically, these injuries have been associated with mortality as high as 24% in the first year [2], and equally high rates of dysfunction [3,4]. These poor outcomes place an ever-growing burden on the health care system and resources.

Nondisplaced, or valgus impacted femoral neck fractures, which represents approximately 20% of all femoral neck fractures, have historically been considered inherently stable [5]. The standard treatment for this injury is internal fixation performed within the first 24–48 h with the goals of preserving the native hip, reducing pain, and improving mobility. Internal fixation may be an appealing treatment in younger patients who have decades of ambulation left in life. However, host factors such as impaired healing potential, multiple medical comorbidities, and poor functional reserve may lead to higher than expected complication rates in elderly patients following internal fixation [6]. Despite the growing body of literature of displaced femoral neck fracture outcomes to examine the role of arthroplasty, less attention has been paid to the outcomes of internal fixation in elderly patients with nondisplaced femoral neck fractures.

The objective of this study was to perform a systematic review and meta-analysis of the current literature reporting the outcomes of patients 60 years of age or older who undergo internal fixation for nondisplaced or minimally displaced femoral neck fractures. The study aimed to measure the risk of mortality, reoperation, and transfusion in this patient population, as well as, pooled estimates for the length of hospitalization and common patient-reported outcomes.

Methods

Literature search

This systematic review was conducted with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement and registered with PROSPERO (CRD42018096737) [3]. The following databases were searched on 2 May 2018 for relevant studies: PubMed, Embase and Cochrane CENTRAL. The search terms were developed in consultation with a medical librarian and the comprehensive search strategies for each database are listed in the Appendix. The searches combined MeSH headings and title words related to the treatment of nondisplaced or minimally displaced femoral neck fractures (i.e., Garden 1/2, Internal Fracture Fixation, Femoral Neck).

DistillerSR (Evidence Partners, Ottawa, ON), an online reference management system for systematic reviews, was used for screening and study selection. Two authors (ALO and JTR) independently reviewed the list of potentially relevant titles and excluded studies not related to nondisplaced or minimally displaced femoral neck fractures in patients 60 years of age or older. The remaining list of potential studies was then recompiled, and the abstracts of the studies were reviewed independently to identify relevant articles. A full-text review of the remaining studies was then completed to determine the final eligibility. A disagreement between the two observers was resolved by consensus after reviewing the full-text articles.

Manuscripts were included for review if (1) they were available in English, (2) if the patients included were 60 years of age or older, (3) if the reported femoral neck fractures in the study were nondisplaced or minimally displaced (Garden 1 or 2), and (4) and if any of the outcomes reported in the study included: the risk of reoperation, mortality, average length of stay, the risk of transfusion, patient-reported outcomes (including the Harris Hip Scores (HHS) and Koval walking scores), or the risk of a deep surgical site infection. All trial designs were eligible for review, and there was no limitation based on the year of publication.

Potential studies that included patients under 60 years of age or with displaced fractures were eligible if the data for patients otherwise meeting inclusion criteria were reported separately. Manuscripts including interventions other than internal fixation, such as arthroplasty or non-operative treatment, were included if internal fixation outcomes were reported separately. Conference proceedings and unpublished manuscripts were excluded. When two studies from the same institution published results on the same cohort of patients, the newer study was selected to avoid duplicate data. Studies were excluded if they did not report any of the outcomes of interest, if they reported outcomes of displaced fracture patterns that could not be separated from the nondisplaced fracture data, or if they reported the outcomes of patients under the age of 60 years that could not be isolated from the patients over 60 years of age.

Data extraction and statistical analysis

Two authors extracted the outcome of interest data from the relevant studies identified from the literature review. If a trial reported multiple methods of internal fixation, such as dynamic hip screws or multiple cannulated screws, the data was combined. The risk of reoperation, mortality, and transfusion from each trial were expressed as the total number of events. The average length of hospital stay and patient-reported outcomes from each trial were reported as mean values of the outcome.

Pooled estimates of the clinical outcomes of interest were calculated using fixed and random effects models and were displayed

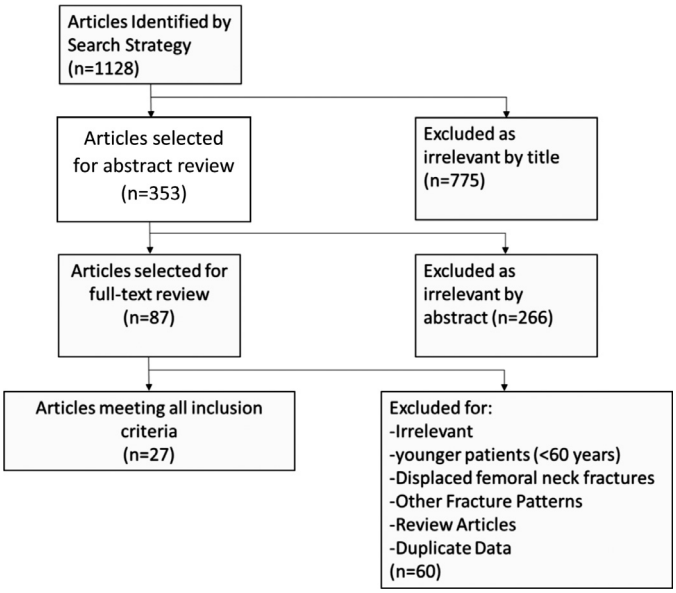

Fig. 1. PRISMA flowchart.

in forest plots. A random effects model assumes that studies randomly sample the target population with different true underlying effects and that these true effects follow a normal distribution. In contrast to a fixed effects model, the random effects model takes into account inter-study variability [7]. Heterogeneity in reported outcomes was measured using the I^2 statistic, or the percentage of inter-study variability that is due to true differences and not sampling error. For reference, the Cochrane group considers heterogeneity above 40% as important and heterogeneity above 75% as considerable [7]. For pooled estimates with an I^2 greater than 75% in this meta-analysis, we reported the random effects model estimates. For pooled analyses with an I^2 less than or equal to 75%, we reported fixed effects model estimates. Statistical analyses were performed using the RStudio packages *meta* and *metafor* (RStudio, Boston, MA).

The quality of the evidence in the selected studies was assessed using the Users' Guides to the Medical Literature to evaluate the risk of bias [8]. This guide uses four criteria: 1) duration of follow up, 2) the proportion of patients who completed follow up 3) a well-described and consistently applied assessment of clinical outcomes 4) a study sample with broad eligibility criteria to be considered representative of the fracture population. Studies were considered to have a low risk of bias if it had a representative population, well-defined clinical outcomes, and at least 80% of patients completing follow up at least 12-months from injury. Studies were at a high risk of bias if the samples were non-representative, if the outcomes were not well defined, if the follow up was less than 12-months, and if less than 70% of patients followed up.

Results

The initial literature search identified 1,128 manuscripts. Three hundred fifty-three potentially relevant titles were selected for abstract review. The full text of 87 articles was reviewed. After applying the selection criteria, 27 articles were eligible for analysis. In total, there was one randomized controlled trial, six prospective cohorts, 14 retrospective reviews, and six case series that were conducted in eleven different countries (Fig. 1).

Demographics

The demographics of the patients from the 27 manuscripts that met inclusion criteria are displayed in Table 1. These studies report on a total of 21,155 patients. The majority of patients came from a study by Lin et al., which reported on 13,772 patients in a 2015 retrospective cohort study [25]. The mean patient age across all of the studies was 74.4 years. The mean follow-up time in months across all of the studies was 82.2 months. The included manuscripts did not consistently report the number or percentage of patients by gender. The summary of the total events reported in these studies is reported in Table 2. Not every outcome of interest was reported in every single study.

Reoperation

Twenty-six studies reported reoperation following internal fixation for a femoral neck fracture. A total of 4,294 reoperation events were reported across the series. The most common reason for reoperation was symptomatic hardware, followed by mechanical failure, fracture displacement or screw cutout (Table 3). Studies did not consistently report what the second procedure was (i.e., revision internal fixation or arthroplasty) or which patients underwent third or fourth procedures. Random effects modeling estimated a 14.1% (95% CI 10.6–18.2) pooled reoperation rate across the studies (Fig. 2). There was considerable heterogeneity with an I^2 value of 96.4%.

Mortality

Nineteen studies reported a mortality rate (Table 2). Studies reported the risk of mortality from one-month to ten-years post-injury. A total of 9,529 deaths were reported among 15,631 combined patients in these 19 studies. Three studies reported one-month mortality, in which a total of 259 deaths occurred in 14,054 patients. Fifteen studies reported one-year mortality and included a total of 2,098 deaths in 15,290 patients. Random effects modeling estimated a one-year risk of mortality of 14.6% (95% CI: 11.5–18.2). There was considerable heterogeneity in the data with an I^2 value of 82.3% (Fig. 3).

Transfusion

Four studies reported the total number of patients who received blood transfusions either during their index surgery or in the postoperative period (Table 2). In total, 39 patients out of a reported 234 patients received blood transfusions. Fixed effects modeling estimated a pooled risk of transfusion of 11.6% (95% CI: 8.1–16.5) patients with no observed heterogeneity across the studies ($I^2 = 0.0\%$).

Infection

Nine studies reported the number of infections amongst their patients. Four deep infections occurred out of a reported 562 patients (Table 2). Fixed effects modeling estimated a pooled risk of a deep surgical site infection of 1.0% (95% CI: 0.5–2.1) with an I^2 value of 0.0%.

Length of stay

Seven studies reported the length of the initial hospitalization as measured in days. Random effects modeling estimated an average length of stay as 10.3 days (95% CI: 6.9 −13.8). There was considerable heterogeneity with an I^2 value of 98.5%.

Table 1
Study characteristics and patient demographics.

Study (year)	Publication	Study design	Location	No. patients	Age (mean, years)	Follow up (mean, months)	Implants used
Stromqvist et al. [9]	Clinical Orthopaedics and Related Research	Retrospective Cohort	Sweden	271	78	24	271 Hook Pins
Hui et al. [5]	JBJS British Volume	Retrospective Cohort	United Kingdom	57	85.26	6	57 Sliding Hip Screw
Wu et al. [10]	Journal of Orthopaedic Surgery	Retrospective Cohort	Taiwan	62	73.4	34.29	37 Knowles pins, 25 DHS
Itadera et al. [11]	Journal of Orthopaedic Science	Prospective Cohort	Japan	10	83.2	22.8	10 MCS
Tidermark et al. [3]	Journal of Orthopaedic Trauma	Prospective Cohort	Sweden	24	80	24	24 Olmed Screws
Sikand et al. [12]	Injury	Prospective Cohort	England	110	77	12	104 MCS, 6 DHS
Chen et al. [13]	The Journal of Trauma	Case Series	China	37	83.76	24	37 MCS
Yin-Shiunn et al. [14]	The Journal of Trauma	Retrospective Cohort	Taiwan	102	72.3	12	33 Minimally invasive DHS 25 Conventional DHS; 32 MCS
Bjorgul et al. [15]	Acta Orthopaedica	Retrospective Cohort	Norway	225	79	38	225 Olmed Screws
Palm et al. [4]	Acta Orthopaedica	Prospective Cohort	Denmark	113	78	12	37 olmed screws; 76 Hanson pins
Gjertsen et al. [16]	Acta Orthopaedica	Retrospective Cohort	Norway	4468	81	12	4468 MCS
Murphy et al. [17]	Clinical Orthopaedics and Related Research	Retrospective Cohort	United States	358	81	45	358 MCS
Clement et al. [18]	Journal of Orthopaedic Science	Case Series	United Kingdom	162	80.8	36	162 MCS
Shields et al. [19]	Archives of Orthopaedic and Trauma Surgery	Retrospective Cohort	United States	120	85.1	12	120 MCS
Kain et al. [20]	Clinical Orthopaedics and Related Research	Case Series	United States	120	80	60	120 MCS
Manohara et al. [21]	Journal of Orthopaedic Surgery	Retrospective Cohort	Singapore	100	78	39	100 MCS
Kim et al. [22]	Archives of Orthopaedic and Trauma Surgery	Retrospective Cohort	Korea	60	77.5	46.8	60 MCS
Park et al. [23]	Hip and Pelvis	Prospective Cohort	Korea	19	77	24	19 CMN nails
Gregersen et al. [24]	Geriatric Orthopaedic Surgery & Rehabilitation	Case Series	Denmark	167	82	24	167 MCS
Lin et al. [25]	BMC Musculoskeletal Disorders	Retrospective Cohort	Taiwan	13,772	76	120	Not listed
Han et al. [26]	European Journal of Trauma and Emergency Surgery	Case Series	Korea	52	77.7	11.7	44 MCS; 5 DHS; 3 knowels pins
Griffin et al. [27]	Journal of Orthopaedics	Case Series	United States	334	81.5	24	334 MCS
Min et al. [28]	Hip and Pelvis	Retrospective Cohort	Korea	25	72.3	12	10 MCS, 15 DHS
Do et al. [29]	Injury	Retrospective Cohort	Norway	383	81	77	383 MCS
kang et al. [30]	BMC Musculoskeletal Disorders	Retrospective Cohort	Korea	81	73.1	36.8	81 MCS
Reina et al. [31]	Orthopaedics & Traumatology, Surgery & Research	Prospective Cohort	France	89	88	6	25 compression screw-plates, 18 MCS, 5 CMN
Lu et al. [32]	Archives of Orthopaedic and Trauma Surgery	Randomized Control Trial	China	41	85.85	38.68	41 MCS

CMN= Cephalomedullary nail.
MCS= Multiple cannulated screws.
DHS= Dynamic Hip Screw.

Patient-reported outcomes

Two studies reported postoperative Harris Hip Scores (HHS). Yih-Shiunn et al. performed a retrospective review in 2006 at the Tapei City Hospital in Taiwan to compare the outcomes of nondisplaced femoral neck fractures treated with a minimally invasive dynamic hip screw (DHS) to conventional implants. This study included 33 patients with minimally invasive DHS, 25 treated with conventional DHS, and 28 treated with multiple cannulated screws (MCS). At the final follow up, the mean HHS between these groups were not significantly different: 82.4 in the minimally invasive DHS group, 80.2 in the conventional DHS group, and 80.1 in the MCS group (ANOVA, $p = 0.45$) [33]. Yin-Shiunn et al. had previously performed retrospective outcomes analysis of this same cohort of nondisplaced elderly femoral neck fracture patients from their center. This study was excluded because of duplicate results [14]. Lu et al. performed a randomized control trial, where elderly patients with nondisplaced femoral neck fractures received internal fixation or hemiarthroplasty. They measured 12-month and 48-month HHS in their 41 patients receiving internal fixation to be 77.25 and 80.0 respectively [32].

Park et al. prospectively collected Koval walking scores on 19 patients over 70 with nondisplaced femoral neck fractures. In the 2015 study, performed in Korea, all patients were treated with a proximal femoral nail. The mean preoperative Koval score, with a lower score indicating higher function, was 2.6 and the mean 24-month follow-up score was 2.81. If the two patients who had complications (AVN and nonunion) in the series were excluded the mean preoperative and 24-month post-operative scores were 2.71 and 2.78 respectively [23]. Similarly Kang et al. measured Koval scores before surgery and at final follow up to be 1.5 and 2.8 respectively [30].

Several studies reported postoperative pain. Hui et al. reported the six-month outcomes, including pain, of 57 patients who underwent internal fixation for nondisplaced femoral neck fractures. Twenty-eight patients surviving to six months reported no to mild

Table 2
Total number of events per outcome.

Outcome	Number of studies reporting outcome	Total number of events/total number of patients in reporting studies, (%)
Reoperation	27	4294/21,079 (20.3%)
1-month mortality	3	259/14,054 (1.8%)
3-month mortality	2	676/13,834 (4.9%)
6-month mortality	2	1153/13,861(8.3%)
1-year mortality	14	2111/15,397 (13.7%)
2-year mortality	3	3066/13,858 (22.1%)
5-year mortality	2	6069/13,892 (43.9%)
10-year mortality	2	9529/13,872 (68.7%)
Blood transfusion	4	39/234 (16.7%)
Infection	9	4/562 (0.7%)

Table 3
Total number of reoperations by Indication.

Reason for reoperation	Total number ($n = 4294$)	Percentage
Symptomatic hardware	1456	33.9%
Hardware cut out/mechanical Failure/secondary displacement	1086	25.3%
Nonunion	682	15.9%
Avascular necrosis	589	13.7%
Infection	461	10.7%
Peri-prosthetic fracture	270	6.2%
Malunion	27	0.6%
Secondary arthritis	6	0.1%

pain, while three patients experienced moderate or severe pain [5]. Tidermark et al. reported the 24-month visual analog scores (VAS) of 14 patients with nondisplaced fractures. Twelve of the 14 had scores less than 30 (86%), and two patients (14%) had pain with walking correlating to VAS scores above 30 [3].

Sensitivity analysis

A sensitivity analysis was performed by removing the retrospective review performed by Lin et al. This study contained 13,772 patients, representing approximately 62% of the total patients across the reviewed studies [25]. This analysis would determine how much this single study influenced the results of the meta-analysis. The pooled estimates were then recalculated on the remaining 26 studies. The reoperation rate does not change from 14.1%, but the I^2 value decreases from 96.4% to 84.8%. One-year mortality changed from 14.6% to 14.3%, and its I^2 decreased from 82.3% to 75.1%. The risk of a deep infection, transfusion, and the mean length of hospitalization were unaffected by the sensitivity analysis.

Quality of the evidence

The risk of bias assessment for each study is demonstrated in Table 4. Nine of the 27 studies (32%) were assessed to have a low risk of bias. Eleven of the 27 studies (39%) were evaluated to have a moderate risk of bias. Seven of the 27 studies (25%) were assessed as having a high risk of bias. The most common indicator of bias was not reporting the percentage of patients completing follow up. The second most common indicator of bias was having narrow eligibility criteria.

Discussion

The results of this systematic review demonstrate that the complication profile of internal fixation for nondisplaced femoral neck fractures in the elderly is high. All but one study in this review reported the risk of reoperation and most studies reported one-year mortality. Few studies reported the length of index hospitalization, patient-reported outcomes, transfusion, or the risk of infection.

The most common cause of reoperation was the removal of symptomatic implants. This finding deviates from previous literature, in which nonunion was the most common complication leading to reoperation for internal fixation of nondisplaced femoral neck fractures. Parker et al. reported an 8% risk of nonunion in nondisplaced fractures treated with multiple cannulated screws with a 12-week median time to revision surgery. The authors concluded that this is likely due to the failure of the implant to resist the mechanical forces [34]. Kain et al. reported that 10% of their cohort of nondisplaced fractures underwent conversion to total hip arthroplasty from ORIF and 3% underwent removal of symptomatic implants [20]. While implant removal may have less surgical site morbidity than a revision to arthroplasty, the patient is still exposed to the potential complications associated with anesthesia in the elderly, including adverse cardiovascular events.

The estimated risk of mortality at one-year following internal fixation is similar to previously reported values for hip fractures in general. Several of the included studies identified risk factors associated with postoperative mortality after nondisplaced hip fracture. These include older age, ambulatory status, male gender, and medical comorbidities [18,21]. Specifically, patients with dementia have a 1.77 fold increase in one-year mortality after undergoing surgery compared to their peers [35].

Few studies in this review compared internal fixation to alternative surgical treatment strategies. Three of the included studies directly compared the outcomes of internal fixation to arthroplasty for nondisplaced femoral neck fractures in the elderly. In 2004, Sikand et al. performed a prospective audit of all elderly patients who sustained a femoral neck fracture. Of the 139 patients with nondisplaced femoral neck fractures treated surgically, 21 underwent hemiarthroplasty while 110 underwent internal fixation. The hemiarthroplasty group had a significantly high one-month mortality (21% vs 2%, $p < 0.01$) and one-year mortality (38% vs 16%, $p = 0.0072$) compared to the internal fixation group. However, the internal fixation group had a significantly higher risk of reoperation after one year [12]. More recently, Lu et al. performed a randomized control trial of 41 elderly patients treated with internal fixation and 37 elderly patients treated with hemiarthroplasty for a nondisplaced femoral neck fracture. After the final follow up, 21.4% of the internal fixation group had undergone reoperation while only 5.4% of the hemiarthroplasty group had undergone reoperation ($p < 0.01$). Post-operative HHS were similar between the two groups by final follow up. However, patients receiving hemiarthroplasty had significantly higher HHS during early follow up (6–12 months) [32]. Finally, Kang et al. retrospectively reviewed the outcomes of patients over 65-years-old with nondisplaced femoral neck fractures. Eighty-one patients were treated with internal fixation, and 62 were treated with bipolar hemiarthroplasty. The results demonstrated that patients treated with hemiarthroplasty had a significantly lower risk of complication compared to internal fixation patients. There was no difference in risk of reoperation or degradation of Koval walking score between the two groups. [30] Taken together, these three studies demonstrate that arthroplasty may provide some increased functional benefits to elderly patients with nondisplaced femoral neck fractures during the 6–12 months following their injury.

Applying the findings of these comparative studies in clinical practice should be made with caution. The arthroplasty groups

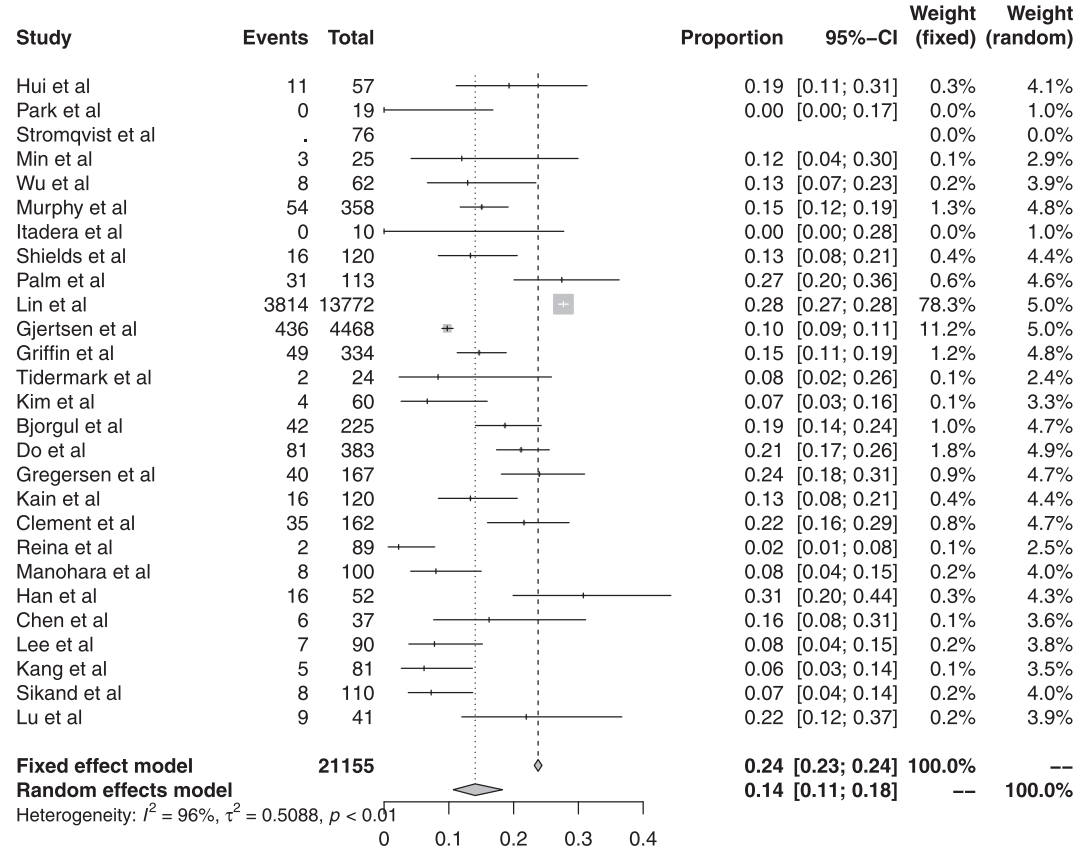

Fig. 2. Pooled estimates of reoperation.

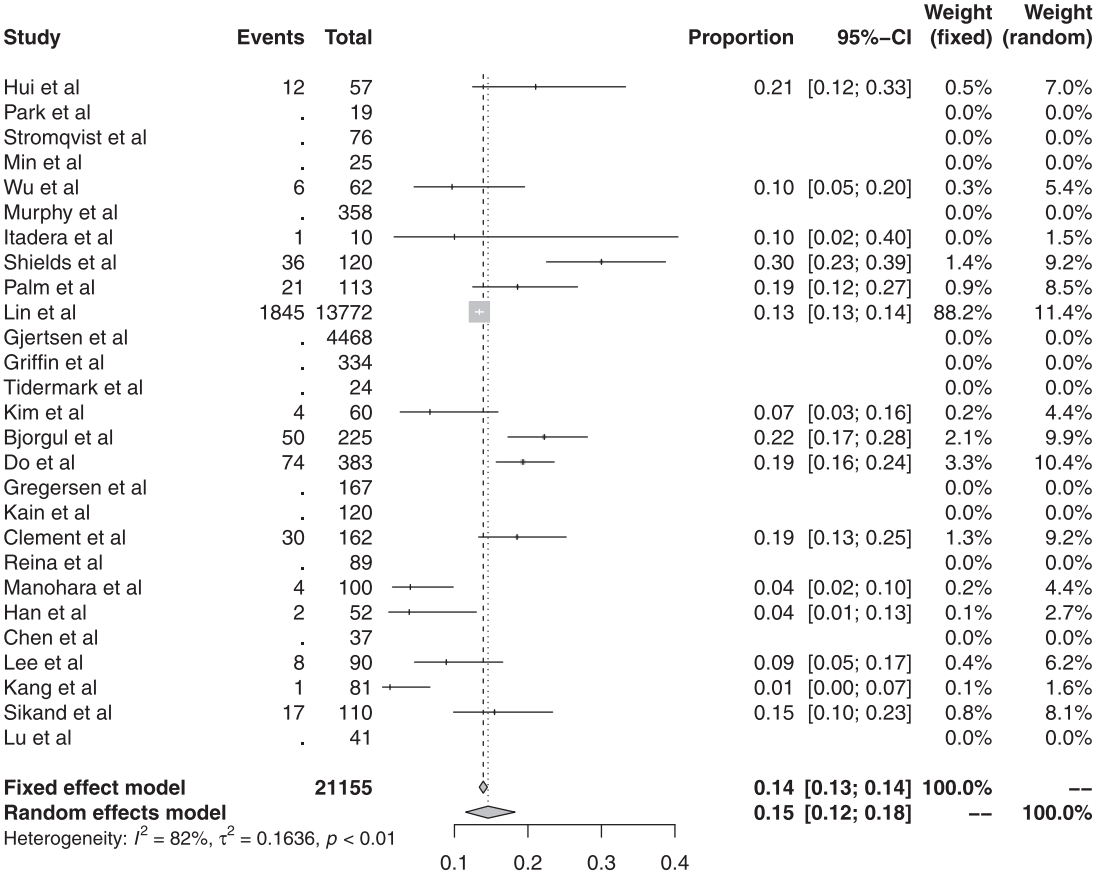

Fig. 3. Pooled estimates of one-year mortality.

Table 4
Quality of evidence assessment.

Study (year)	Bias assessment	Eligibility criteria	Outcome descriptions	Follow up length	Percent of follow up
Stromqvist et al. [9]	Moderate risk	Broad	Inconsistent or lacking description	13–24 months	>90%
Hui et al. [5]	Moderate risk	Broad	Consistent, well-described	7–12 months	<70%
Wu et al. [10]	Low risk	Broad	Consistent, well-described	More than 24 months	80–90%
Itadera et al. [11]	Low risk	Broad	Consistent, well-described	13–24 months	80–90%
Tidermark et al. [3]	High risk	Narrow	Inconsistent or lacking description	13–24 months	<70%
Sikand et al. [12]	High risk	Narrow	Consistent, well-described	7–12 months	Not mentioned
Chen et al. [13]	High risk	Narrow	Consistent, well-described	13–24 months	Not mentioned
Yin-Shiunn et al. [14]	Low risk	Broad	Consistent, well-described	7–12 months	80–90%
Bjorgul et al. [15]	Low risk	Broad	Consistent, well-described	More than 24 months	70–80%
Palm et al. [4]	Moderate risk	Broad	Consistent, well-described	7–12 months	Not mentioned
Gjertsen et al. [16]	Moderate risk	Broad	Consistent, well-described	7–12 months	Not mentioned
Murphy et al. [17]	High risk	Narrow	Consistent, well-described	More than 24 months	Not mentioned
Clement et al. [18]	Low risk	Broad	Consistent, well-described	13–24 months	> 90%
Shields et al. [19]	Low risk	Broad	Consistent, well-described	7–12 months	>90%
Kain et al. [20]	Moderate risk	Broad	Consistent, well-described	More than 24 months	<70%
Manohara et al. [21]	Moderate risk	Broad	Consistent, well-described	More than 24 months	Not mentioned
Kim et al. [22]	Low risk	Broad	Consistent, well-described	More than 24 months	>90%
Park et al. [23]	High risk	Narrow	Consistent, well-described	More than 24 months	Not mentioned
Gregersen et al. [24]	High risk	Narrow	Consistent, well-described	13–24 months	Not mentioned
Lin et al. [25]	Moderate risk	Broad	Consistent, well-described	More than 24 months	< 70%
Han et al. [26]	Moderate risk	Broad	Consistent, well-described	13–24 months	Not mentioned
Griffin et al. [27]	Moderate risk	Broad	Consistent, well-described	13–24 months	Not mentioned
Min et al. [28]	Moderate risk	Broad	Inconsistent or lacking description	7–12 months	80–90%
Do et al. [29]	Moderate risk	Broad	Consistent, well-described	More than 24 months	Not mentioned
Kang et al. [30]	Moderate risk	Broad	Consistent, well-described	13–24 months	<70%
Riena [31]	High risk	Broad	Inconsistent or lacking description	3–6 months	Not mentioned
Lu et al. [32]	Low risk	Broad	Consistent, well-described	More than 24 months	>90%

were small in size and may not show the true differences in outcomes compared to internal fixation. Furthermore, these patients were not stratified by age, comorbidities, or functional status, which have been identified as key determinates of clinical outcomes following arthroplasty in displaced femoral neck fractures [36–38]. The decision to perform primary arthroplasty for nondisplaced femoral neck fractures warrants further investigation to identify which patients are appropriate for such treatment.

The primary limitation of this review is the heterogeneity of the included patients. With a lower age limit of 60 years, there is likely a diversity of pre-fracture comorbidities and levels overall health. Many of the included studies did not stratify their cohorts by age or functional status. Therefore, the pooled estimates include patients who range from active community ambulators to non-ambulatory nursing home patients. Pre-fracture ambulatory status, age, and comorbidities have proven to be strong predictors of functional outcomes in fracture patients [36–38]. As such, surgeons would likely to make their surgical treatment decisions in the context of these patient factors. Frail, non-ambulatory patients may receive internal fixation to avoid the morbidity of arthroplasty while the more active and healthy elderly patient would benefit from hemiarthroplasty or even total hip arthroplasty. Stratifying patients by functional status and comorbidities prior to meta-analysis could determine more accurate pooled estimates.

Several other factors may have increased the heterogeneity between studies. Study outcomes were reported at inconsistent time intervals. Several of the included studies were performed over 20 years ago with implants that are not in contemporary use. The included studies were performed in a number of countries in North America, Europe, and Asia. Cultural and regional differences in treatment philosophies may also impact the heterogeneity in outcomes. Also, the variety of implants, each with a unique complication profile, reported across the selected studies may contribute to intra- and inter-study variability. Random effects modeling should account for these variations and assume a different true effect for each study. However, the pooled estimates of reoperation, one-year mortality, and length of hospitalization demonstrated considerable heterogeneity.

Finally, the meta-analysis was limited by the quality of the evidence presented in the selected studies. Two-thirds of the included studies demonstrated moderate to high risk of bias mainly related to the lack of follow up. Furthermore, there were few prospective studies in this systematic review, including one randomized control trial and many of the included studies were retrospective in nature. Retrospective studies, especially registry reviews, are at high risk for bias and confounding. A single retrospective study contained approximately two-thirds of the patients of this review. The authors note that the health insurance database queried for the review does not record all clinical information and is open to selection bias [6]. The results from this study could have skewed the results of the meta-analysis. However, our sensitivity analysis demonstrated that the pooled estimates did not significantly change when this trial was removed. The lack of high-quality evidence of nondisplaced femoral neck fracture outcomes warrants further investigation into the lingering controversies in hip fracture management [1].

Conclusion

In conclusion, this systematic review and meta-analysis demonstrated a high complication rate of nondisplaced or minimally displaced hip fractures in elderly patients treated with internal fixation. The one-year risk of reoperation was 14.1%, and the risk of mortality was 14.6% across the included studies. This may be unacceptably high in a population that is at increased susceptibility to surgical complications, even with minor surgical procedures like removal of symptomatic implants [3]. Furthermore, failed internal fixation may lead to complex revision procedures, secondary arthroplasty being the most common, that demonstrate poor results [39–41]. It may, therefore, be reasonable to explore alternatives to internal fixation for treating this fracture pattern.

There is currently little evidence that arthroplasty is that alternative treatment. The few studies in this review that compared arthroplasty to internal fixation demonstrated improved short-term functional outcomes and a reduced risk of reoperation at the cost of an increased risk of mortality. This may be appealing for

younger, more active elderly patients, who are at an increased risk of reoperation compared to older, frail patients [24]. The cohorts were small, and the results did not discern which elderly patients would be candidates for arthroplasty. It is therefore difficult to conclude treatment superiority. The decision to treat nondisplaced femoral neck fractures elderly patients with arthroplasty should be made based on the individual patient, their goals of treatment, and the patient's functional status.

Declaration of Competing Interest

Gerard Slobogean reports being a paid consultant for Zimmer Biomet and Smith & Nephew and receives research support from the US Department of Defense and the Patient-Centered Outcomes Research Institute. Nathan O'Hara reports stock options with Arbutus Medical Inc. Archie Overmann, John Richards, and Jean-Claude D'Alleyrand have no disclosures to report.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2019.09.039.

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