INTERNAL FIXATION COMPARED WITH ARTHROPLASTY FOR DISPLACED FRACTURES OF THE FEMORAL NECK

A META-ANALYSIS

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Background: The optimal choice for the stabilization of displaced femoral neck fractures remains controversial, with alternatives including arthroplasty and internal fixation. Our objective was to determine the effect of arthroplasty (hemiarthroplasty, bipolar arthroplasty, and total hip arthroplasty), compared with that of internal fixation, on rates of mortality, revision, pain, function, operating time, and wound infection in patients with a displaced femoral neck fracture.

Methods: We searched computerized databases for randomized clinical trials published between 1969 and 2002, and we identified additional studies through hand searches of major orthopaedic journals, bibliographies of major orthopaedic textbooks, and personal files. Of 140 citations initially identified, fourteen met all eligibility criteria. Three investigators independently graded study quality and abstracted relevant data, including information on revision and mortality rates.

Results: Nine trials, which included a total of 1162 patients, provided detailed information on mortality rates over the first four postoperative months, which ranged from 0% to 20%. We found a trend toward an increase in the relative risk of death in the first four months after arthroplasty compared with the risk in the first four months after internal fixation (relative risk, 1.27). At one year, the relative risk of death was 1.04. The risk of death after arthroplasty appeared to be higher than that after fixation with a compression screw and side-plate but not higher than that after internal fixation with use of screws only (relative risk = 1.75 and 0.86, respectively; p < 0.05). Fourteen trials that included a total of 1901 patients provided data on revision surgery. The relative risk of revision surgery after arthroplasty compared with the risk after internal fixation was 0.23 (p = 0.0003). Pain relief and the attainment of overall good function were similar in patients treated with arthroplasty and those treated with internal fixation (relative risk, 1.12 for pain relief and 0.99 for function). Infection rates ranged from 0% to 18%, and arthroplasty significantly increased the risk of infection (relative risk, 1.81; p = 0.009). In addition, patients who underwent arthroplasty had greater blood loss and longer operative times than those who were treated with internal fixation.

Conclusions: In comparison with internal fixation, arthroplasty for the treatment of a displaced femoral neck fracture significantly reduces the risk of revision surgery, at the cost of greater infection rates, blood loss, and operative time and possibly an increase in early mortality rates. Only larger trials will resolve the critical question of the impact on early mortality.

Level of Evidence: Therapeutic study, <u>Level I-2</u> (systematic review of Level-I randomized controlled trials [studies were homogeneous]). See Instructions to Authors for a complete description of levels of evidence.

More than 220,000 fractures of the hip occur each year in North America, leading to an annual nine-billion-dollar cost to the health care system[1]. The optimal surgical treatment of displaced femoral neck fractures remains controversial[2,3]. Alternatives include prosthetic replacement (arthroplasty) and internal fixation. Arthroplasty options include hemiarthroplasty, bipolar arthroplasty, and total hip arthroplasty. Proponents of prosthetic replacement argue that replacement of the femoral head eliminates the necessity for revision surgery due to avascular necrosis and nonunion, both of which are serious problems following internal fixation[3]. Surgeons who

favor internal fixation report decreased operative time, blood loss, and risk of mortality because the procedure is quicker and often simpler than arthroplasty[4].

There have been a number of observational studies comparing internal fixation and prosthetic replacement for the treatment of displaced hip fractures[5-16]. These studies have been limited by a lack of independent outcomes assessment, limited assessment of possible confounding variables, and possible bias associated with unmeasured or unknown confounders inherent in observational studies.

Recently, a number of randomized trials were performed to compare treatment of displaced femoral neck fractures with prosthetic replacement (hemiarthroplasty, bipolar arthroplasty, or total hip arthroplasty) with treatment with internal fixation (with a fixed-angle screw and plate or with multiple screws)[17-34]. These trials have overcome the limitations of earlier studies by decreasing bias through randomization. However, their small sample sizes (range, twenty to 409 patients) and wide confidence intervals surrounding the treatment effects have limited the inferences that clinicians can make on the basis of their results.

Previous systematic reviews have included few randomized trials, and the authors have relied on nonrandomized comparative studies to make inferences regarding patient care[35]. One previous meta-analysis of 106 published reports pooled data that included only one randomized trial[35]. Meta-analysis of observational studies remains controversial because of disparate beliefs regarding the validity of pooling data derived from nonrandomized trials. Given the recent increase in the number of published randomized trials evaluating alternative strategies for treatment of hip fractures, we conducted a meta-analysis of randomized trials to assess the clinical results, with regard to rates of mortality and revision surgery, of prosthetic replacement compared with those of internal fixation in the treatment of femoral neck fractures. We hypothesized that internal fixation would be associated with a greater risk of revision surgery but a decreased risk of mortality.

Materials and Methods

Eligibility Criteria

We identified articles published in the English-language literature that met the following eligibility criteria: (1) the target population consisted of patients sixty-five years of age or older with a displaced femoral neck fracture, (2) the intervention was internal fixation (with a screw and a side-plate or with multiple screws) compared with arthroplasty (hemiarthroplasty, bipolar arthroplasty, or total hip arthroplasty), (3) the outcome measure was the available mortality data, and (4) the study was a published or unpublished randomized or quasi-randomized trial. Quasi-randomized trials are those in which patients are allocated according to known characteristics such as their date of birth, hospital chart number, or day of presentation.

Identification of Studies

We conducted a Medline search of articles published from 1969 to June 2002, identifying the population (hip fracture or femoral neck fracture), the intervention (internal fixation), and the methodology (clinical trial). We used the keywords "femoral neck fracture" AND "arthroplasty." We also utilized the clinical queries search engine for PubMed (www4.ncbi.nlm.gov/pubmed/) and conducted a sensitivity search using the keywords "femoral neck fracture" AND "arthroplasty" as well as "femoral neck fracture" AND "internal fixation." Two of us (M.B. and S.S.) reviewed the reference lists of all key articles for additional eligible articles. We noted frequently cited articles and conducted a Science Citation Index search (SciSearch) to locate potentially relevant studies that had cited those articles. Additional strategies to identify relevant studies included (1) a manual search of the table of contents of four major orthopaedic journals (*The Journal of Bone and Joint Surgery* [American and British], *Journal of Orthopaedic Trauma,* and *Clinical Orthopaedics and Related Research*) from 1998 through June 2002; (2) a review of the bibliographies of two major textbooks in orthopaedic trauma (*Rockwood and Green's Fractures in Adults,* by Rockwood and Green, and *Skeletal Trauma,* by Browner et al.); (3) a review of the titles of presentations and posters in the programs for the meetings of three major orthopaedic societies (American Academy of Orthopaedic Surgeons, Orthopaedic Trauma Association, and Canadian Orthopaedic Association) held from 1996 through 2002; and (4) discussion with content experts (five orthopaedic traumatologists).

Three of us (M.B., S.S. and P.J.D.) reviewed the titles and, if the title suggested any possibility that the article might meet eligibility criteria, we retrieved and reviewed the abstracts. We then chose potentially eligible studies for retrieval. The review of the complete articles for eligibility included only the methods section and was thus blinded with regard to author, institution, journal, and results.

Assessment of Methodological Quality

Four of us (S.N., W.O., M.F.S., and K.J.K.) assessed the methodological quality of each study with respect to randomization (present and concealed); blinding of patients, clinicians, and those assessing outcomes; and proportion of patients lost to follow-up. A 21-point study-quality assessment scale that we transformed into a 100-point scale was used to provide an additional rating of methodological quality[36]. The review of methodological quality was also blinded with regard to author, institution, journal, and results.

Data Extraction

Two of us (S.S. and M.B.) abstracted all relevant information regarding the population, intervention, and outcomes from each selected article. We noted whether the authors of the study reported important characteristics associated with outcomes of hip fracture management, such as patient age, gender, American Society of Anesthesiologists (ASA) grade, delay before surgical treatment, mental status, level of independence, type of anesthetic administered, nutritional status, and patient comorbidities.

In addition to the data on mortality rates, we abstracted

data on revision rates (secondary surgery following the index procedure as a result of implant failure, dislocation, intractable pain, or infection), rates of wound infection (at the bone-implant interface), postoperative pain, postoperative function, intraoperative blood loss, and operative time.

From all articles that reported postoperative pain, we extracted information on the proportion of patients with no or minimal pain. Two of us (S.S. and M.B.) reviewed all articles presenting scores for function and for activities of daily living to identify the proportion of patients with overall good postoperative function. We defined good function across all functional outcome measures as the patient's ability to independently carry out activities of daily living.

An author of each study received summary data extraction sheets with a request to verify their accuracy. Nine of the fourteen authors confirmed the accuracy of the extracted data and provided additional information that had not been reported in their published papers[17-21,23,26-28].

Assessing Reviewer Agreement

We used a kappa value, a measure of chance-corrected agreement, to provide most estimates of agreement among reviewers with regard to titles, abstracts, and methods sections of potentially relevant articles. Donner and Klar[37] as well as Fleiss[38] provided persuasive arguments favoring the use of this statistic instead of other measures of agreement[37,38]. For variables with more than two categories, we used a weighted kappa with quadratic weights. For continuous variables, we chose quantitated agreement with use of an intraclass correlation coefficient that yields identical values to weighted kappa with quadratic weights. We chose an a priori criterion of $\kappa \geq 0.65$ for adequate agreement.

Data Analysis

We pooled data across studies, and we calculated relative risks and associated 95% confidence intervals for each outcome with use of the random-effects model of DerSimonian and Laird[39]. This model assumes that the studies included in this review represent a random sample of all of the potentially available studies. While we are confident that our search strategy identified all of the relevant trials on this topic, it remains plausible that not every study ever conducted was identified. The random-effects model accounts for this fact and assumes that we have a representative sample of all existing studies (published, nonpublished, and in progress). The Breslow-Day test[40] was used to assess the consistency or homogeneity of the estimates across studies, with a significance threshold of $p < 0.1$. We pooled data from studies on hemiarthroplasty, bipolar arthroplasty, and total hip arthroplasty, as we believed that those procedures would result in a similar direction of treatment effect. However, we conducted analyses of each implant separately in order to explore whether our hypothesis was valid.

We used estimates of relative risk to calculate the risk difference and the number needed to treat[40]. For example, if the mortality rate is 5% with internal fixation and 10% with hemiarthroplasty, then the relative risk for mortality with internal

fixation is 0.5 (0.05/0.10). This implies a 50% relative risk reduction ($1 - 0.5 \times 100$). One can convert the risk difference of 5% (i.e., 10% − 5%) to a number needed to treat, which is the reciprocal of the risk difference (number needed to treat = 1/ risk difference = 1/0.05 = 20). In this example, for every twenty patients treated with internal fixation rather than hemiarthroplasty, one death will be avoided. To develop estimates of the number needed to treat across pooled data, we used pooled risk differences weighted by study size. For continuous variables, we calculated means weighted by study size[40].

To assess publication bias, we constructed, for each outcome, inverted funnel plots comparing the magnitude of the relative risk against sample size[41]. This method uses a scatterplot of studies that relates the magnitude of the treatment effect to the weight of the study. An inverted, funnel-shaped, symmetrical appearance of dots suggests that no study has been left out, whereas an asymmetrical appearance of dots, typically in favor of positive outcomes, suggests the presence of publication bias.

Evaluation of Heterogeneity

Major differences in the apparent effect size found across studies define important heterogeneity of study results. If investigators find important heterogeneity they must examine the study populations, treatments, measures of outcome, and methodology to determine the source of the heterogeneity[42,43]. Before analyzing the data, we developed hypotheses regarding potential sources of heterogeneity. We hypothesized that heterogeneity may be due to differences in populations (proportion of cognitively impaired patients compared with proportion of those with normal cognition), interventions (type of implant used), or methodological features (methodological quality score of >70 or <70, completeness of follow-up, concealment of randomization, randomized or pseudorandomized). We decided beforehand to group studies in which >70% patients were cognitively impaired for the sensitivity analysis. For each determinant of heterogeneity, we compared relative risks across categories and determined whether these relative risks were significantly different when analyzed with the method of Fleiss[38].

Results

Literature Search

We identified 140 citations that addressed the general topic of comparison of arthroplasty and internal fixation for the treatment of hip fracture: 118 were identified from Medline; fourteen, from the Cochrane Randomized Trials Database; seven, from discussions with content experts; and one, from manual searches. Of 140 studies, thirty-four were considered to be potentially eligible. The weighted kappa for overall agreement regarding the application of study inclusion criteria to study titles was 0.82 (95% confidence interval, 0.79 to 0.85). We excluded twenty of these studies: twelve were nonrandomized comparisons, four were review articles, one was a survey, one was published in a non-English-language journal[33], one was reported to be a randomized study but was

TABLE I Comparison of Arthroplasty and Internal Fixation with Regard to Mortality and Revision Rates							
	Total Sample Size Pooled (no.)	Events		Relative Risk*	95% Confidence Interval	P Value	Heterogeneity P Value
		Arthroplasty	Internal Fixation				
Mortality							
<4 mo	1162	55/615	34/547	1.27	0.84-1.92	0.25	0.45
1 yr	1767	226/984	160/783	1.04	0.84-1.29	0.68	0.03
>1 yr	1596	412/895	251/701	1.12	0.90-1.43	0.30	<0.01
Revision	1901	111/1051	299/850	0.23	0.13-0.42	0.0003	<0.01

*The relative risk of the outcome (i.e., mortality or revision) with arthroplasty compared with that with internal fixation. Values of >1.0 favor internal fixation, and values of <1.0 favor arthroplasty.

actually an observational study[34], and one was a randomized trial that had been followed by publication of an article on the same trial with longer follow-up[26]. Thus, twelve published studies and two published abstracts comparing internal fixation with arthroplasty (hemiarthroplasty, bipolar arthroplasty, or total hip arthroplasty) ultimately proved eligible for the investigation[17-23,25,27-34].

Study Characteristics
Tables in the Appendix present the eligibility criteria, outcomes, and methodology of the fourteen studies. At least two of the fourteen studies were quasi-randomized, randomization was not concealed in any study, randomization was performed with use of envelopes in seven studies, and outcome assessment was blinded in only two studies. Agreement among reviewers with regard to the assessment of study quality was excellent (intraclass correlation, 0.81; 95% confidence interval, 0.66 to 0.95). The kappa value for the various components of study design— such as randomization; blinding of patients, clinicians, and those assessing outcomes; performance of the statistical analysis; and follow-up—ranged from 0.50 to 1.0. In the majority of the studies, the two groups were not compared in terms of key baseline characteristics. For instance, prefracture mental status and delay until surgical treatment were reported in only seven studies, prefracture independence level was reported in only six, the type of anesthetic and patient comorbidities were described in only four, and preoperative nutritional status was mentioned in only two.

Mortality
Nine reports, on a total of 1162 patients, provided postoperative mortality data at four months or less. The results of the pooled statistical analyses are listed in Table I. Mortality rates over the first four postoperative months ranged from 4.3% to 20% after the arthroplasties and from 0% to 12.1% after the internal fixation procedures. There was a trend toward increased mortality four months after arthroplasty compared with that four months after internal fixation (relative risk, 1.27; 95% confidence interval, 0.84 to 1.92, p = 0.25; homogeneity, p = 0.45). The funnel plot did not suggest publication bias.

Twelve reports, on a total of 1767 patients, provided one-year mortality rates, which ranged from 4.3% to 48% af-

ter the arthroplasties and from 0% to 65% after the internal fixation procedures. There was a trend toward increased mortality after arthroplasty compared with that after internal fixation, with wide variability between studies (relative risk, 1.04; 95% confidence interval, 0.84 to 1.29, p = 0.68; homogeneity, p = 0.03). The funnel plots did not suggest publication bias.

We explored potential sources of study heterogeneity for one-year mortality rates (see Appendix). Studies with quality scores of >70 favored arthroplasty with regard to one-year mortality, whereas those with scores of <70 favored internal fixation (relative risk of mortality, 0.88 and 1.49, respectively; p > 0.05). In addition, studies including a high percentage of cognitively impaired patients favored arthroplasty, whereas studies involving mostly unimpaired patients favored internal fixation (relative risk of mortality, 0.75 and 1.37, respectively; p < 0.05). The type of arthroplasty (hemiarthroplasty, bipolar arthroplasty, or total hip arthroplasty) did not significantly alter the risk of mortality at one year (see Appendix). The analysis suggested, however, that the technical aspects of the internal fixation may make a difference. The risk of death associated with arthroplasty appeared to be higher compared with the risk associated with compression screw and side-plate fixation but not compared with the risk associated with internal fixation with screws alone (relative risk, 1.75 and 0.86, respectively; p < 0.05). The single study that included patients with Garden type-II, III, and IV fractures[23] did not significantly change the overall pooled effect of internal fixation compared with arthroplasty on mortality.

Revision Surgery
All fourteen studies, which included a total of 1933 patients, provided information on revision surgery. Revision rates ranged from 0% to 24% in the arthroplasty groups and from 10% to 48.8% in the internal fixation groups. Arthroplasty substantially reduced the risk of revision, and the results were consistent from study to study (relative risk, 0.23; 95% confidence interval, 0.13 to 0.42, p = 0.0003; homogeneity, p < 0.01) (Table I). Compared with internal fixation, arthroplasty reduced the relative risk of revision surgery by 77%. The risk difference of 18% translated into a number needed to treat of 5.6, which meant that for every six patients treated with arthroplasty instead of internal fixation, one revision surgery could be avoided.

Revisions following internal fixation were often due to nonunion (weighted mean, 18.5%; range, 5% to 28%) and avascular necrosis (weighted mean, 9.7%; range, 5% to 18%). While no nonunions or avascular necrosis occurred after the hemiarthroplasties, dislocations did occur after all types of arthroplasty (weighted mean, 0.82%; range, 0% to 22%). When we considered only total hip arthroplasty, we found an even greater risk of dislocation (weighted mean, 6.9%; range, 0% to 22%). There was insufficient data to determine the relative influence of the surgical approach on dislocation rates among current studies.

The sensitivity analysis revealed that studies in which randomization was possibly concealed (with use of envelopes), for which the quality score was >70, and that involved cognitively impaired patients tended to demonstrate a greater reduction in the risk of revision surgery following arthroplasty. We did not find any differences in risk associated with the type of arthroplasty (hemiarthroplasty, bipolar arthroplasty, or total hip arthroplasty). Once again, however, the technique of internal fixation appeared to have a large effect. Arthroplasty appeared to decrease the risk of revision, compared with that associated with internal fixation, far more when the internal fixation had been done with screws alone (relative risk, 0.11) than when it had been performed with a compression screw and side-plate (relative risk, 0.59) (p < 0.01 for difference in estimates). Funnel plots did not suggest the presence of publication bias.

Pain, Function, and Infection

The authors of six studies involving a total of 1153 patients reported on pain relief, and the authors of twelve studies involving a total of 1179 patients reported on function (see Appendix). Arthroplasty and internal fixation were similar with regard to provision of pain relief and good function, with a relative risk of no or little pain of 1.12 (95% confidence interval, 0.88 to 1.35) and a relative risk of good function of 0.99 (95% confidence interval, 0.90 to 1.10). Infection, which was reported on in twelve studies involving a total of 1822 patients, developed in 0% to 18% of patients treated with arthroplasty and in 0% to 10% of those treated with internal fixation. The risk of infection associated with arthroplasty was significantly higher than that associated with internal fixation (relative risk, 1.81; 95% confidence interval, 1.16 to 2.85, p = 0.009; homogeneity, p = 0.16). The risk difference between the two treatments was 3.4%, which means that for every twenty-nine patients treated with internal fixation rather than arthroplasty, one infection would be prevented (number needed to treat = 1/0.034 = 29.4).

Blood Loss and Surgical Time

Blood loss was estimated in four studies that included a total of 343 patients, and surgical time was reported in five studies that included a total of 447 patients. Patients who underwent arthroplasty had greater blood loss than those who were treated with internal fixation (weighted mean difference, 176.4 mL; 95% confidence interval, 132.4 to 220.4, p < 0.05).

Similarly, the surgical time for the arthroplasties was greater than that for the internal fixation procedures (weighted mean difference, 29.0 minutes; 95% confidence interval, 23.2 to 34.8, p < 0.05).

Discussion

The primary finding of this meta-analysis was that, relative to internal fixation, arthroplasty substantially reduces the prevalence of surgical revision, with very tight confidence intervals suggesting that the reduction in relative risk is at least 50%. However, this benefit probably comes at the price of a substantially increased risk of infection, more surgical blood loss, and a longer operating time. Arthroplasty and internal fixation do not differ with regard to their impact on postoperative pain and function. The apparent effects on mortality ranged greatly among the studies, and the relative effects of the two procedures on death rates remain uncertain.

Strengths and Limitations of the Investigation

Much of the clinical information available today was derived from observational research studies, which, regardless of the integrity and care with which they are conducted, are open to bias. Randomized trials reduce this risk of bias. The inferences that clinicians can make from individual randomized trials, however, are often limited by relatively small sample sizes and resulting imprecision in the estimates of treatment effects. Meta-analysis combines data from different studies that address a similar question, using accepted statistical methods, to obtain a more reliable estimate of the overall treatment effect.

The current investigation met most of the methodological criteria for research overviews[44]. Specifically, we developed explicit inclusion and exclusion criteria, assessed the methodological quality of the studies, demonstrated the reproducibility of study selection and assessment criteria, undertook a quantitative analysis, and explored possible reasons for differences in results between studies. Our decision to include only articles published in English was based on the recent finding by Moher et al. that language-restricted meta-analyses do not lead to biased estimates of the effectiveness of intervention[45]. However, we cannot completely rule out the possibility that estimates were biased by our exclusion of non-English-language papers.

Despite our comprehensive search strategy, we may have failed to identify all relevant randomized trials as a result of (1) a publication bias[46] against studies that did not demonstrate a significant difference in effect between two treatments or (2) a selection bias[46] against choosing studies that favored a particular treatment. We limited these biases by rigorously searching many databases, bibliographies, and programs of annual orthopaedic meetings for all potentially eligible studies, both published and unpublished. We further limited selection bias by conducting all aspects of the selection process in duplicate with blinded assessments. Moreover, in contrast to situations in which investigators are testing a new drug, it is hard to state the direction of publication bias for arthroplasty or internal fixation. Finally, the funnel plots that we con-
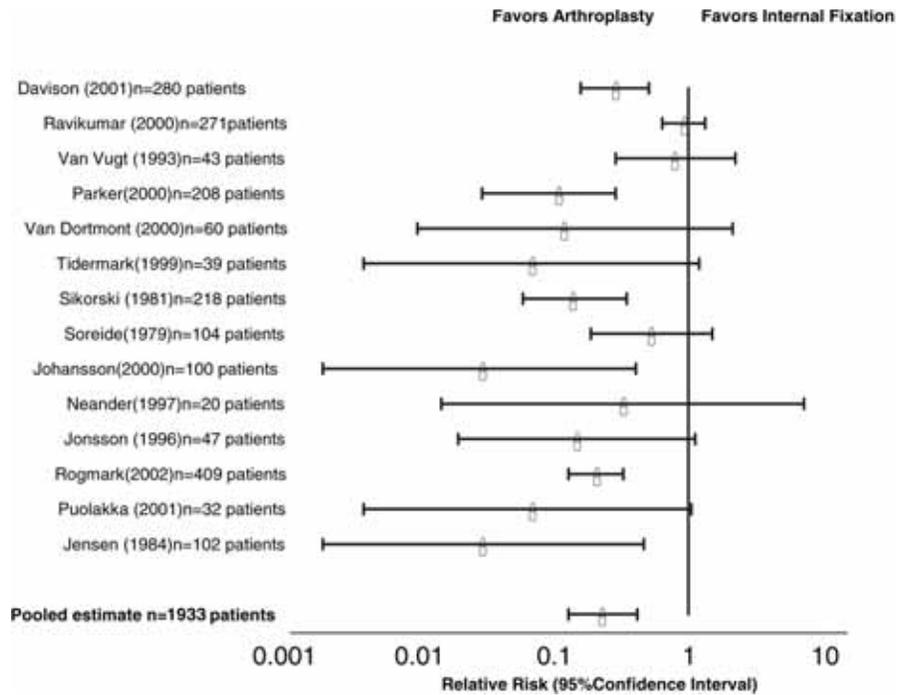
Fig. 1
The effect of arthroplasty compared with that of internal fixation on revision rates.

structed did not suggest publication bias.

Whatever the rigor with which studies are identified, assessed, and analyzed, the results from statistical pooling are only as valid as the studies included in the analysis. Bias in randomized trials can be limited by randomization, concealment of allocation, blinding, and complete follow-up. Randomization was probably not concealed in any of the trials in the current review, the outcome assessor was not blinded in at least eight studies, and the loss to follow-up was >15% in four studies. Since lack of concealment can destroy randomization, demonstration of baseline comparability between groups becomes crucial in unconcealed studies. Reports suggest that the prognosis after hip fracture is influenced by increased age, dementia, cardiopulmonary disease, a higher American Society of Anesthesiologists (ASA) grade, operative delay, male gender, residency in a nursing home, anemia, and nutritional status[47-54]. The fact that reporting of potentially important prognostic factors was limited in the majority of the trials raises concerns about the validity of the results.

There was a trend for higher-quality studies to show a greater advantage for arthroplasties in terms of the risk of mortality, and considerably better results in terms of the risk of revision, than lower-quality studies. This suggests that, despite the studies' methodological limitations, we can be confident that arthroplasty reduces the need for revision.

Results of meta-analyses gain strength when they are replicable. Our systematic review included only randomized trials (as opposed to randomized trials and observational studies),

and our analysis included twelve more randomized trials than were included in a previous meta-analysis[35]. Despite differences in methodology, the results of the two reviews are very similar. Lu-Yao et al.[35] reported a 66% reduction in the risk of revision surgery with arthroplasty (95% confidence interval, 42% to 79%), whereas we reported a 77% reduction (95% confidence interval, 58% to 87%). Our review does raise a possible concern about an increased death rate after arthroplasty (relative risk of death at four months, 1.27), whereas the previous review did not (1.0). The overall variability in the event rates of revision and mortality reported among the included studies likely reflects differences across study quality, the types of implants that were used, and patient mix.

Clinical Implications
The fact that arthroplasty was associated with a relative risk reduction of 77% for the need for postoperative revision, combined with the narrow confidence interval and the fact that the highest-quality studies suggested an even larger effect, provides a compelling argument for performing an arthroplasty (Fig. 1). The argument gains force when one considers that the rates of revision after internal fixation ranged from approximately 10% in low-risk patients to approximately 50% in high-risk patients. Thus, if approximately ten low-risk patients and two high-risk patients were treated with arthroplasty instead of internal fixation, one revision would be avoided in each group. Proponents of internal fixation, however, may argue that, even if internal fixation is performed in a

high-risk patient, there is at least a 50% chance that the patient will not require subsequent revision surgery.

Arthroplasty was associated with a greater risk of hip dislocation and wound infection. According to the best estimates from our meta-analysis, an orthopaedic surgeon can expect that, for every 100 average patients treated with arthroplasty instead of internal fixation, seventeen revision surgeries can be avoided, at the expense of one hip dislocation and four more wound infections. We did not find sufficient data to determine whether operative approach (anterior or posterior) had a significant influence on rates of dislocation. A previous meta-analysis of observational studies suggested that the short-term mortality rate is lower with an anterior approach and that there is a trend for lower dislocation rates with the anterior approach as well (relative risk, 0.5; 95% confidence interval, 0.3 to 1.2)[35].

The current meta-analysis lacks the power to demonstrate whether there is an increased risk of mortality with arthroplasty (Fig. 2), although the point estimate of relative risk (1.27) of early mortality (less than four months postoperatively) suggests that this might be the case. If we believe this estimate, then while the performance of an arthroplasty instead of internal fixation in 100 patients may prevent seventeen revisions, this benefit may come at the consequence of four additional deaths.

We found that arthroplasty was associated with a greater reduction in the risk of mortality (relative risk, 0.75) and revision surgery (relative risk, 0.05) in studies that included mostly cognitively impaired patients than in studies of mostly unimpaired patients. The reason for this effect remains unclear. Our analysis also suggested that the technical aspects of the internal fixation may make a difference. Arthroplasty appeared to increase the risk of death when compared with compression screw and side-plate fixation but not when compared with internal fixation with screws only (relative risk, 1.75 and 0.86, respectively; p < 0.05). A previous meta-analysis of randomized trials comparing various methods of internal fixation of femoral neck fractures showed nonsignificant differences between implants; however, a specific comparison between compression screw and side-plate fixation and fixation with three or more screws (four trials including a total of 414 patients) with regard to fracture-healing complications suggested a trend in favor of compression screw and side-plate fixation (odds ratio, 0.76; 95% confidence interval, 0.47 to 1.25)[55].

Planning a Large Randomized Trial

If all trials are small, the confidence intervals may be wide even for combined data. Yusuf suggested that meta-analyses of small randomized trials can generate hypotheses to be tested in more reliable, larger randomized trials[56]. Our meta-analysis provides strong enough evidence that arthroplasty for the treatment of displaced femoral neck fractures significantly reduces the rate of revision surgery compared with that following internal fixation. On the other hand, trends toward lower mortality rates with internal fixation than with arthroplasty were associated with wide confidence intervals. At one ex-

Fig. 2

The effect of arthroplasty compared with that of internal fixation on one-year mortality rates.
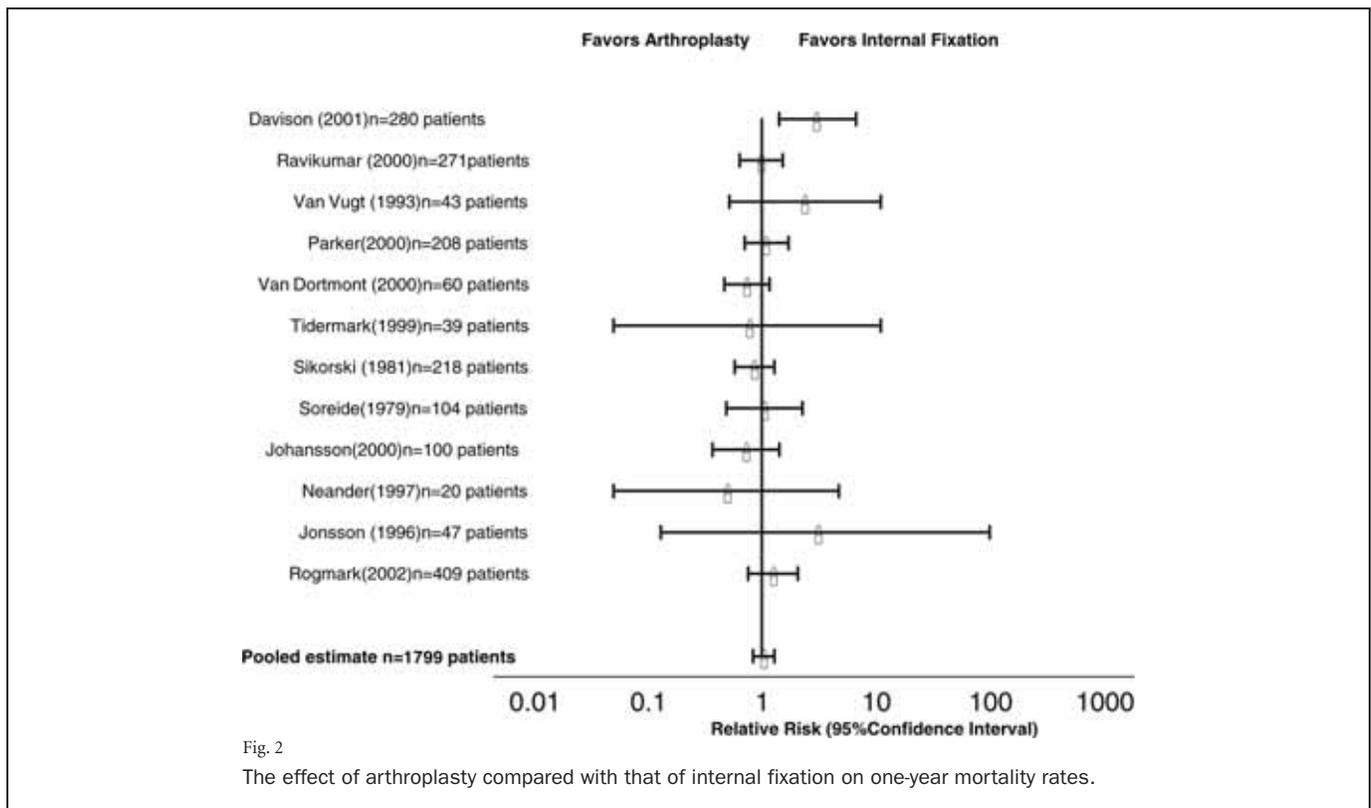
treme arthroplasty was associated with a 16% *reduction* in mortality risk, while at the other extreme it was associated with a 92% *increase* in mortality risk. Clearly, a true reduction in the mortality risk with arthroplasty would provide compelling evidence for abandoning internal fixation of displaced femoral neck fractures in patients older than sixty-five years of age; however, a true increase in the risk of mortality with arthroplasty would raise serious questions regarding its use in such patients. These findings, along with reports that results of meta-analyses have proved to be discrepant with findings from subsequent large, randomized controlled trials[57], suggest the need for a large, randomized trial comparing arthroplasty and internal fixation for the treatment of displaced femoral neck fractures in patients sixty-five years of age or older.

In the current group of trials, the weighted control mortality rate within the first year after arthroplasty was 20% (95% confidence interval, 18% to 24%). If we assume that internal fixation will reduce this risk by at least 5% (risk reduction of 1.04; Table I), then an appropriately planned randomized trial, performed with the method described by Pocock[58], that has study power of 80%, an alpha value of 0.05, a rate of success of arthroplasty of 80%, and a rate of success of internal fixation of 81% reveals that a sample size of 26,641 patients is required. However, across a plausible range of treatment effects (based on treatment effects derived from four-month data—range, 10% to 40% reduction in the risk of mortality with internal fixation), a trial may need as few as 346 patients or as many as 6075 patients.

In summary, in comparison with internal fixation, arthroplasty for the treatment of displaced femoral neck fractures significantly reduces the risk of revision surgery at the cost of greater infection rates, blood loss, and operative time and possibly an increase in early mortality rates. Only larger trials will resolve the critical question of the impact on early mortality. The design of such trials will be challenging because of the need to standardize critical aspects of perioperative management, surgical technique, and rehabilitation across institutions with varying levels of experience and surgeons with varying levels of expertise in both internal fixation and arthroplasty.

Appendix

Tables presenting characteristics, methodologies, and outcomes of the studies analyzed and a sensitivity analysis of the study characteristics are available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ∎

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