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Original research

Computer navigation in total hip arthroplasty: A meta-analysis of randomized controlled trials

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ABSTRACT

Objective: Traditional operation frequently depends on experience of doctors and anatomic landmark visual observation, which often leads to deviation in acetabular prosthesis implantation. Computer navigation technique greatly improves accuracy of prosthesis implantation. The present meta-analysis aimed at assessing the accuracy and clinical significance of computer navigation for acetabular implantation.

Methods: All studies published through March 2013 were systematically searched from PubMed, EMBnse, Science Direct, Cechrane library and other databases. Relevant journals or conference proceedings were searched manually. Only randomized controlled trials (RCTs) were included. Two independent reviewers identified and assessed the literature. Mean difference (MD) and Odds ratio (OR) of radiologic and clinical outcomes were pooled throughout the study between navigated and conventional THA. The meta-analysis was conducted by RevMan 5.1 software.

Results: Thirteen studies were included in the review, with a total sample size of 1071 hips. Statistically significant differences were observed between navigated and conventional groups in the number of acetabular cups implanted beyond the safe zone [OR = 0.13, 95% confidence interval (CI) (0.08–0.22); $P < 0.00001$], operative time [MD = 19.87 min, 95% CI (14.04–24.35); $P < 0.00001$] and leg length discrepancy [MD = −4.16 mm, 95% CI (−7.74 to −1.48); $P = 0.004$]. No significant differences in cup inclination, anteversion, incidence of postoperative dislocation or deep vein thrombosis were found.

Conclusions: The present meta-analysis indicated that the use of computer navigation in patients undergoing THA improves the precision of acetabular cup placement by decreasing the number of outliers, and decreases leg length discrepancy. More high quality RCTs are required to further confirm our results.

1. Introduction

Total hip arthroplasty (THA) is widely performed in patients with hip disease and has become one of the most common and successful orthopedic interventions. Correct selection and precise placement of the acetabular component is the key to surgical success and leads to a good long-term prognosis. Malpositioning of the acetabular component in THA may result in complications such as impingement of the prosthesis, limited range of movement, joint dislocation, increased wear of the polyethylene (PE) liner due to uneven stress, periprosthetic osteolysis and aseptic loosening of the prosthesis, which necessitate early revision arthroplasty [1–5]. Lewinnek et al. proposed a “safe zone” for positioning the acetabular cup, at abduction 40° ± 10° and anteversion 15° ± 10° [5]. They found that cups positioned outside this zone had a fourfold increased risk of dislocation; cups below 5° anteversion suffered posterior dislocation and cups above 25° anteversion tended to exhibit anterior dislocation [6]. However, placement of the acetabular component in THA is usually based on anatomia locator guides and the experience of the surgeon. In lots of cases, cups had been placed outside the safe zone when measured postoperatively [15,22].

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Computer-assisted navigation systems are widely used in orthopedic surgery [7–9] and can increase the accuracy of acetabular component implantation. THA assisted by computed tomography (CT)-based or image-free computer navigation has been developed in recent decades to improve the orientation of prostheses, especially the acetabular component, as far as possible [10]. In this study, we conducted a meta-analysis pooling the data from relevant randomized controlled clinical trials (RCTs) to evaluate the use of computer-assisted navigation in THA.

2. Materials and methods

2.1. Search strategy

We conducted a meta-analysis of all English and non-English articles identified from electronic databases including Medline (1966 to March 2013), Embase (1980 to March 2013) and the Cochrane Central Register of Controlled Trials. The search strategy is presented in Fig. 1. Only studies conducted on human subjects were included. In addition, the same search terms were used to search manually for further relevant studies such as those of the European Federation of National Associations of Orthopaedics and Traumatology and the British Orthopaedic Association Annual Congress, as well as in Google. Manual searches, including those of reference lists of all included studies, were used to identify trials that the electronic search may have failed to identify. We used the following key words: “Arthroplasty, Replacement, Hip” (Medical Subject Heading (MeSH) terms), total hip arthroplasty, randomized controlled trial, “Surgery, Computer-assisted” (MeSH terms) and navigation, in combination with the Boolean operators AND or OR.

2.2. Selection criteria and quality assessment

We included all published RCTs and quasi-RCTs (in which the method of allocating participants to a treatment was not strictly random; e.g. by date of birth, hospital record number, alternation) comparing computer navigation with the conventional technique in patients undergoing THA. Exclusion criteria comprised the following (by implication): trials with a retrospective design; trials that did not randomize patients into two relevant groups; and studies focusing on an orthopedic population. Quality criteria included randomization method, concealment of allocation, blinding and intention-to-treat analysis.

2.3. Data extraction

For each eligible study, two of the authors of this meta-analysis independently extracted all relevant data. Disagreement was resolved by discussion with a third investigator. The following data were extracted: (i) the participants' demographic data; (ii) indication for THA; (iii) the outcome measure of the number of acetabular cups implanted outside the desired range; (iv) functional outcome; (v) operative time; and (vi) any other outcomes mentioned in individual studies were considered for inclusion. When data were incomplete or unclear, attempts were made to contact the investigators for clarification.

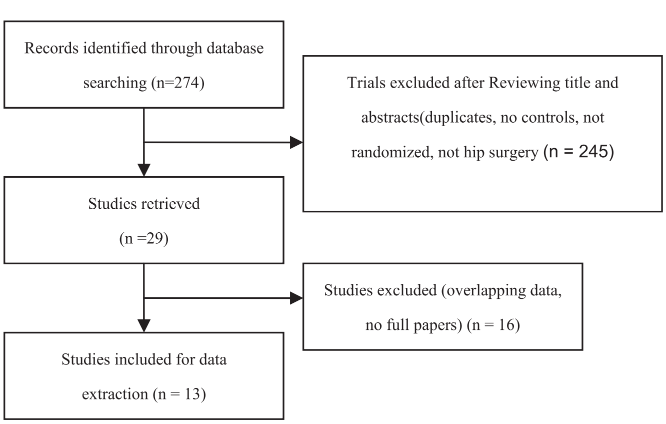

Fig. 1. Flow chart of the study selection and inclusion process.

2.4. Data analysis and statistical methods

This meta-analysis was undertaken using RevMan 5.0 for Windows (Cochrane Collaboration, Oxford, UK). We assessed the statistical heterogeneity for each study using a standard chi-square test (statistical heterogeneity was considered to be present at $P = 0.1$) and the I^2 statistic [11]; I^2 values of 50% were considered to indicate substantial heterogeneity. When comparing trials exhibiting heterogeneity, pooled data were meta-analyzed using a random effects model [12]; otherwise, a fixed effects model was used [13]. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for dichotomous outcomes and mean differences (MDs) and 95% CIs for continuous outcomes.

3. Result

3.1. Search results

There were 274 potentially relevant papers. By screening titles and reading the abstracts and entire articles, 13 studies of 1071 hips (546 in the navigated group and 525 in the conventional group) were included in the final meta-analysis. Twelve of these RCTs were published in English and one in Chinese [14]. The sample sizes ranged from 26 to 141 hips. Most of the studies had clear inclusion or exclusion criteria. Kalteis et al. used both imageless and CT-based navigation [15], eight studies used an imageless system [6,14,16–21] and five used CT-based navigation. Most indicated that the surgeons involved had experience in conventional THA before the study, to avoid learning curve bias. Choice of implant and fixation technique, when reported, varied between studies. Table 1 summarizes the key characteristics of the included RCTs.

3.2. Quality assessment

The methodologic quality of the 13 included studies was variable. The reported methods of generating allocation sequences were adequate in three RCTs [19,20,22] and only two trials [19,20] reported allocation concealment. Surgeon blinding would have been inappropriate in all of the included studies; three of the RCTs blinded their assessors to the patient groups. The methodologic quality of the studies is presented in Fig. 2. Judgments about each risk of bias item are presented as percentages for all of the included studies in Fig. 3.

3.3. Meta-analysis results

3.3.1. Cup inclination

We obtained usable data on cup inclination from eight trials including 512 hips [6,14,15,17–21]. As depicted in Fig. 4A, there was significant heterogeneity ($\chi^2 = 57.35$, df $= 7$, $I^2 = 88\%$, $P < 0.00001$). Using a random effects model, the pooled results indicated that there was no significant difference between the groups in terms of cup inclination (MD $= -0.93°$, 95% CI -3.88 to 2.02, $P = 0.54$).

3.3.2. Cup anteversion

Cup anteversion was mentioned in eight trials [6,14,15,17–21]. The pooled results show significant heterogeneity (χ^2 = 44.03,