Minimally invasive hip arthroplasty: a quantitative review of the literature

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Purpose: To perform a comprehensive quantitative review of the published literature and to assess the methodology of studies comparing the surgical outcomes in minimally invasive hip arthroplasty (MIHA).

Methods: We conducted a comprehensive literature search using Medline, Embase, Cochrane, CINAHL and Google Scholar. The bibliographies of papers were also examined. All relevant articles in peer-reviewed journals were retrieved except those not mentioning outcomes, case reports, review of literature and letters to editors. Two authors independently scored the quality of the studies using a modified Coleman Methodology Score with 10 criteria which allow critical analysis of the design and implementation of a particular study. The results are recorded as a final score between 0 and 100. We collected data for year of publication, type of study, patient numbers, surgical method, follow-up, complications and patient satisfaction.

Results: Thirty-six studies met our inclusion criteria giving details of 6434 HAs, 78.5% (4031) of which were implanted using MIHA techniques. The only statistically significant outcome was a reduction in length of hospital stay ($P = 0.02$). With no significant difference noted between the two groups with respect to operating time, blood loss, dislocation and revision rates, neurological injury and incidence of peri-operative fracture, patient selection and surgeons' experience may have had a significant effect on outcome. For instance, studies reporting outcomes on an average patient age of 48 years had significantly different results to one reporting on patients with a mean age of over 70 years. Scores were predominantly low for quality of the studies, with patient number, follow-up time and validated outcome measures being the weakest areas.

Conclusion: At present, there is still a lack of quality evidence to advocate the expansion of MIHA. The better designed studies suggest that it should even be limited further to recognized expert centres. The complication rates and learning curve may be altered by changes in training and adapting surgical techniques. We emphasize the need for meticulous design in future studies comparing the outcomes of these two procedures.

Keywords: Hip arthroplasty/minimally invasive/two-incision/MIS/review
Introduction

Over the past two decades, minimally invasive operative procedures have become increasingly popular. Minimally invasive surgery (MIS), including total hip arthroplasty (THA), has become relatively widespread, after initially only being practised by a few centres. The belief is that a smaller incision should lead to limited tissue trauma and is therefore associated with reduced patient morbidity, lower blood loss, a decreased cost of care, better scar cosmesis and improved functional recovery.\(^1\)\(^–\)\(^6\) On the other hand, potential disadvantages include reduced visualization contributing to a possible increased risk of iatrogenic injury and component malpositioning.

The concept of minimally invasive hip arthroplasty (MIHA) has been advertised and marketed to patients before appropriate peer review. These techniques are being promoted without sound clinical evidence to support their safety and efficacy.\(^7\)

Small incisions in the hands of less skilled surgeons who perform fewer procedures may not necessarily minimize tissue trauma or operating time, and they could increase the rate of potential intra-operative complications and the risk of infection.\(^8\)\(^–\)\(^12\) The orthopaedic literature is deficient in well-designed scientific studies to support the idea that MIHA provides superior outcomes compared with THA performed through standard incisions (SIs).\(^7\)\(^,\)\(^8\)\(^,\)\(^13\)\(^,\)\(^14\)

We performed a comprehensive quantitative review of the published literature on MIHA to assess the methodology of those studies and analyse the reported surgical outcomes.

Materials and methods

We conducted a comprehensive literature search of Medline, Cochrane, Embase and CINAHL databases. All articles relevant to subject were retrieved and their bibliographies searched for further references. We also examined the guidance issued by the United Kingdoms National Institute of Clinical Excellence (NICE, www.nice.org.uk). The search was limited to English literature and articles published in peer-reviewed journals. From a total of 48 articles, we excluded case reports, literature reviews, letters to editors and articles not specifically reporting outcomes. This left us with a total of 36 articles, all of which included outcomes of MIHA.

From each article, two investigators (A.M. and M.S.Z.) independently extracted the year of publication, type of study (randomized control trial, prospective trial or retrospective case series), the approach
used, total number of patients, follow-up, the outcome measures used, the amount of blood loss, the operating time, the duration of hospital stay, the radiographic acetabular and femoral indices, the revision rate and the complications and their rates. The major complications were divided into following categories:

- dislocation
- infection
- fracture
- nerve injury
- thrombosis
- revision

The raw data were converted into percentages of the number of cases per management group.

**Methodological assessment**

Ten criteria were used to assess the methodology of the studies reviewed. The Coleman methodology score, which was originally developed for and used to grade clinical studies on cartilage repair and patellar or Achilles tendinopathy,\(^{15-17}\) assesses methodology using the 10 criteria, giving a total score between 0 and 100. A score approaching 100 indicates that the study has a robust design and largely avoids chance, various biases or confounding factors. The subsections which compose the Coleman methodology score are based on the subsections of the CONSORT statement (for randomized controlled trials), but are modified to allow for other trial designs.

**Statistical methods**

Regression analysis was used to assess the extent of agreement between the Coleman scores of the two investigators, each of whom had performed the scoring independently of the other. The same method was used to assess correlation between the year of publication and the Coleman score.

Comparisons between the various mean demographic characteristics and mean reported procedure outcome data for the mini incision, and SI methods were made using Mann–Whitney and Wilcoxon tests (Table 1). Table 2 shows the summaries from these tests as the medians of the reported means for the MIHA and THA methods along with the associated \(P\)-values. Analysis was performed using Minitab (Minitab Inc.) statistics software.
Results

The 36 studies reported on 6626 hip arthroplasties (HAs) in 6098 patients; 79.8% (5285) of these HA had been performed using one of the MIHA procedures. The remaining 1341 HA (1300 patients) had a procedure through one of the SI techniques. For the purposes of this paper, we pooled the results of various MIHA approaches together. Only three of the studies were randomized controlled trials.\textsuperscript{8,18,19} The remaining studies were prospective (six comparative and eight single-cohort studies), retrospective comparative (nine) and retrospective case series (10).

The mean age of patients was 62.2 years (range 48–73.4) for the MIHA group and 63.3 years (range 49–69) for the SI group (Fig. 1). The mean body mass index (BMI) recorded in the 25 studies was 26.7 for the MIHA group and 28.2 for the SI group (Table 1).

The average follow-up time for all the studies was 65.1 weeks (range 4–260 weeks). Pipino\textsuperscript{20} mentions a follow-up period of between 1 and 7 years, but it is not specified how many patients were seen at what interval, so the lowest figure was considered as the follow-up time.

Sixteen studies used uncemented components, and eight used a hybrid system with the acetabulum uncemented. Two studies routinely cemented their components. Ten studies did not clarify the bone–prosthetic
interface that was used. In six studies, intra-operative fluoroscopy was used with uncemented prostheses.

There was no statistical evidence of a significant reduction in average blood loss recorded in 18 (50%) of the 36 studies. Only two studies recorded the requirement for transfusion beyond a single unit.

The mean operating time was 80.4 min (range 37.5–148 min) for MIHA and 86.5 min (range 54–166 min) for SI. This was not statistically significant (NS).

The average inpatient stay for MIHA was 3.69 days (range 1–6 days) and 4.98 (range 3–6 days) for SI. There was a broad range, with some centres discharging patients within 24 h following a specialist rehabilitation protocol. This was a statistically significant reduction in length of stay (Fig. 2).

Complications

Infection and dislocation were reported in 28 studies as a post-operative complication (Table 2). Nerve injury was mentioned in 25 studies. Neither showed a statistical significant difference.

Table 1 Demographic characteristics and procedure data.

<table>
<thead>
<tr>
<th></th>
<th>Mini incision</th>
<th>Standard incision</th>
<th>P-value (Mann–Whitney)</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62.17</td>
<td>63.03</td>
<td>0.464</td>
<td>–3.99 to 1.8</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.70</td>
<td>28.22</td>
<td>0.063</td>
<td>–3.49 to 0.1</td>
</tr>
<tr>
<td>Inpatient stay (days)</td>
<td>3.69</td>
<td>4.98</td>
<td>0.024</td>
<td>–0.5 to 0.9</td>
</tr>
<tr>
<td>Blood loss (ml)</td>
<td>400.16</td>
<td>455.94</td>
<td>0.468</td>
<td>–208.1 to 112.1</td>
</tr>
<tr>
<td>Blood transfusion</td>
<td>0.67</td>
<td>0.70</td>
<td>0.893</td>
<td>–0.60 to 0.54</td>
</tr>
<tr>
<td>Operating time (min)</td>
<td>80.4</td>
<td>86.52</td>
<td>0.520</td>
<td>–21.0 to 11.01</td>
</tr>
<tr>
<td>Acetabular index* (%)</td>
<td>97</td>
<td>96.28</td>
<td>0.671</td>
<td>–4.0 to 3.0</td>
</tr>
<tr>
<td>Femoral alignment* (%)</td>
<td>97.1</td>
<td>98.7</td>
<td>0.337</td>
<td>–3.0 to 0.0</td>
</tr>
<tr>
<td>Improvement in Harris hip score</td>
<td>40</td>
<td>42</td>
<td>1.00</td>
<td>–13.5 to 13.4</td>
</tr>
</tbody>
</table>

*Within satisfactory range.

Table 2 Complications

<table>
<thead>
<tr>
<th></th>
<th>Mini incision (%)</th>
<th>Standard incision (%)</th>
<th>P-value (Mann–Whitney)</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wound infection</td>
<td>0.60</td>
<td>1.63</td>
<td>0.676</td>
<td>–2.0 to 0.1</td>
</tr>
<tr>
<td>Dislocation</td>
<td>0.96</td>
<td>0.52</td>
<td>0.900</td>
<td>–0.3 to 0.8</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>1.28</td>
<td>1.56</td>
<td>0.711</td>
<td>–1.1 to 1.4</td>
</tr>
<tr>
<td>Early revision</td>
<td>1.03</td>
<td>1.00</td>
<td>0.252</td>
<td>–1.2 to 1.0</td>
</tr>
<tr>
<td>Intra-operative fracture</td>
<td>1.94</td>
<td>1.54</td>
<td>0.824</td>
<td>–1.0 to 0.99</td>
</tr>
<tr>
<td>Transient nerve injury</td>
<td>1.74</td>
<td>0.43</td>
<td>0.711</td>
<td>–0.5 to 0.9</td>
</tr>
</tbody>
</table>
Fracture related to the operative procedure was reported in 28 studies, with no significant difference between MIHA and SI groups; 20 studies report thrombosis as a post-operative complication (NS). However, the distinction between DVT and PE was not made.

The overall femoral alignment and acetabular index measurements showed acceptable prosthesis placement for both groups (Table 1). More than 95% of stems were in less than 5° of varus or valgus, with an average acetabular index of 43.1° for MIHA hips and 42.6° for SI (NS).

Revision surgery from malpositioning of components and early loosening was mentioned in 22 studies. There was no statistically significant difference in early revision requirements.

Twelve studies used the Harris hip score (HHS) as an outcome measure. The SF12 score and Oxford hip score were used by four studies. There was no statistically significant difference between MIHA and SI in the post-operative improvement in HHS (Table 1).

**Methodological assessment**

The average Coleman score was 48.2 out of a possible 100 (range 27–82). Overall, the study design was weak. Methodological deficiencies were found with respect to five criteria: the type of study, description of the rehabilitation protocol, outcome criteria, outcome assessment and subject selection process. The methodology score generally appeared to improve with the year of publication (Fig. 3). There was a high correlation shown between the two independent scorers, \( r = 0.99 \) (Fig. 1).
Discussion

THA is successful in relieving the pain and improving the quality of life for patients suffering from degenerative joint disease. MIHA, a still controversial procedure, is readily embraced by some orthopaedic centres and has been promoted to patients as the next big thing without reliable clinical evidence.\(^7\)\(^,\)\(^8\)\(^,\)\(^21\) There seem to be two reasons for this. First, emphasis in health care provision on greater cost effectiveness, and secondly, patients’ choice. It seems that the latter was in fact the primary reason for the early development of the technique by some of its initiators.\(^19\) In addition, implant manufacturers are rushing to design and aggressively market specialized surgical instruments for these procedures.

There is still a degree of ambiguity with regard to the definition of MIHA. Most surgeons used a wound of \(\leq 10\) cm for MIHA. In addition, it is also agreed that modification of surgical access should reduce the tissue trauma associated with hip replacement (www.exeter-hip.co.uk/ex_pag_mini-incision.htm).

Goldstein et al.\(^22\) highlight the fact to their patients that the difference between MIHA and SI may be purely cosmetic. However, Mow et al.\(^23\) in their independent blinded study of scar cosmesis found that MIHA scars were inferior to SI. This can be explained by skin and soft tissue damage produced by high retractor pressures needed for exposure using a limited skin incision.

The number of investigations reviewed in our study is the largest to date for MIHA. We identified five categories of major methodological deficiencies:
(1) type of study; (2) subject selection; (3) outcome criteria; (4) outcome assessment tools and (5) reporting of a post-operative rehabilitation protocol and patient compliance with rehabilitation.

Only five studies scored more than 65 points on the Coleman methodology assessment score, indicating serious methodological deficiencies in the published literature regarding MIHA.\textsuperscript{5,8,18,24,25} There were only three randomized control trials with a short follow-up period. Most studies were prospective comparative (10, 28\%) or retrospective case series (9, 25\%). We regarded prospective studies as those with clear pre-operative goals, assessment and multiple post-surgical follow-ups. Another major problem noted while assessing these articles was the lack of consistency in the design of studies, especially when reporting outcomes. Reliable hip outcome scores were used in only 14 studies (39\%).

We found an overwhelming bias for studies to report the outcome of MIHA rather than comparing with an SI procedure. Just 21 (58\%) of the articles retrieved compared the outcome of MIHA with an SI approach. This publication bias negatively influences the reliability of any clinical evidence, which can be deduced from some of these studies.

Despite the availability of a substantial number of outcome measures to assess the efficacy of management for hip diseases, less than half (44\%) of the studies used reliable or validated scores to measure the outcome of the procedure. The inconsistency in the use of validated outcome tools seriously limited the reliability of the studies to prove the superiority of MIHA. It is not clear in most studies who assessed the outcome, whether written assessment was used and whether assessment was recorded from the subject’s responses or surgeons’ files. This is a potential source of bias.

Our study has also highlighted an increasing number of quality articles being published in the last 2–3 years, indicating growing interest and development in this field.

Subject selection was inadequately reported in most studies, which may have contributed to a substantial amount of bias. The patients in the MIHA group generally had a relatively lower mean BMI than patients in the standard THA group, although this did not quite prove to be statistically significant (Table 1). In addition, patients having co-morbidities such as a history of inflammatory arthritis, coagulation disorders, and with complicated hip problems such as dysplasia or protrusio acetabuli and revision surgery were excluded from many of the MIHA studies. This makes it difficult to draw conclusions about differences in safety and efficacy outcomes such as intra-operative blood loss and operative time between the two groups.
There was a non-significant reduction in blood loss reported with MIHA \((P = 0.468)\), with similar post-operative transfusion requirements. Autologous transfusions were used in both groups, and the transfusion threshold was the same in both groups. One study showed that a low pre-operative haemoglobin level is a useful indicator of duration of hospital stay and post-operative transfusion requirement.\(^8\)

Operative times were not significantly different between the two groups overall, but the range was very broad. There is bound to be variation between the various MIHA techniques, with the two-incision being described as the most time consuming and the posterolateral and anterolateral as the most time efficient.\(^26\) Many of the studies did not use specialized instrumentation and the effect of this on operating time is not clear.

Dislocation and revision surgery rates were also very similar and showed no statistical significance \((P = 0.900)\) and \((P = 0.252)\). Data regarding the exact timing of diagnosis of dislocation and actual revision were often not elucidated upon.

Transient nerve injury and intra-operative fractures were slightly more common with the minimally invasive procedures. On the other hand, post-operative thrombosis (DVT/PE) and infection were slightly more prevalent in the SI group. However, the differences were not statistically significant between the two groups. Regarding transient nerve injury, reporting is variable and it is often not clear how many of these became permanent, as the follow-up period was often short.

A statistically significant difference was noted in the MIHA group, only in terms of reduced length of hospital stay \((P = 0.024)\). However, the effects of various variables such as patient education, pain management and rehabilitation protocols on overall patient recovery have not been clarified. Nearly 70\% (25) studies did not mention post-operative rehabilitation or patient compliance to that protocol. Some of the studies showed that a rapid rehabilitation protocol could be implemented and was safe in early discharge of patients having MIHA.\(^2,5,27–30\) Furthermore, Lawlor et al.\(^31\) reported that there was no significant benefit with MIHA in terms of the rate or ability of patients to mobilize and perform functional tasks when standardized physiotherapy assessment and treatment were used for the two groups. The same centre reported no difference for SI versus MIHA in gait kinematics at either 2 days or 6 weeks post-operatively.\(^32\) There is significant scope for further research to independently assess the effects of these numerous variables.

Radiographically, there was no difference in acetabular index, and >96\% of implants in both groups were within normal range. Also, >97\% of femoral implants were normally aligned, irrespective of the technique used. One study reported that a significantly higher
percentage of cementless stems in their MIHA group were graded as having poor fit and fill.\textsuperscript{12}

We are aware of limitations in our study. Our research was limited to English literature. The comparisons of the outcomes were being made simplistically between the reported means from studies of widely varying quality. Only inpatient stay shows a particularly low \( P \)-value. In this case, the confidence interval, around the difference between the medians for the two methods (\(-2.30 \text{ to } -0.27\)), does not enclose zero and so perhaps suggests that this outcome differs between surgical methods. However, with this comparison, there were 24 reports that included means of inpatient stays for MIHA but only 17 reports about mean inpatient stay with the SI use. Thus, even here one should be wary about claims of real differences in this particular reported outcome.

MIHA is technically more demanding than standard THA and has a significant learning curve. Archibeck and White\textsuperscript{33} demonstrated a significant decrease in operative time in the first 10 cases but no reduction in complication rates. We have mentioned that most studies are reporting early outcomes as this is still for many a recent technique. Future reports of longer term follow-up in the next few years will give us a more accurate reflection of complication and revision rates.

In conclusion, current knowledge of some surgeons and patients regarding MIHA is inadequate.\textsuperscript{34} Some of the quality studies have made a common point that HA through minimally invasive techniques is safe and reproducible in the hands of a highly experienced surgeon who has selected the appropriate patient. However, currently there is no strong published evidence that it offers any significant benefit in terms of clinical outcome and cost effectiveness compared with procedures performed through SIs.

References


