Prospective and comparative study of minimally invasive posterior approach versus standard posterior approach in total hip replacement

Étude prospective comparant la voie postérieure minimale invasive versus voie postérieure standard sur prothèse totale de hanche de première intention


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RÉSUMÉ

Nous avons réalisé une étude prospective, continue et comparative afin de rechercher l'intérêt d'une voie postérieure mini-male versus une voie postéro-latérale « standard » dans les arthroplasties totales de hanche.

Cent-seize arthroplasties réparties en deux groupes d'efficacité égal et comparables en préopératoire ont été incluses. Nous avons exclu les troubles architecturaux majeurs et les arthroplasties de reprise. Les deux voies ont été réalisées avec une instrumentation classique et le même type d'implant. Nous avons étudié la durée opératoire, le saignement opératoire (calculé grâce à l'hématocrite pré et postopératoire et aux transfusions sanguines), la douleur postopératoire et le positionnement des implants. Les résultats cliniques fonctionnels ont été évalués (score de Harris modifié et Womac permettant une auto-évaluation) à 6 semaines, 3 et 6 mois. Le seuil de significativité retenu était p < 0.05.

La longueur moyenne de l'incision était de 8,5 cm versus 15,1 cm. Les pertes globulaires moyennes calculées étaient significativement plus faibles dans le groupe mini-voie (p = 0.027) ainsi que la douleur postopératoire confirmée par une moindre consommation d'antalgiques morphiniques (p = 0.006). Les autres paramètres opératoires et le positionnement des implants étaient comparables. Aucune complication majeure n'a été relevée dans le groupe mini-voie. Dans l'autre groupe, une parésie du nerf fibulaire commun, deux luxations et deux fractures sur prothèse lors de chute ont été observées. L'index de Womac était meilleur après mini-abord à 6 semaines et 3 mois (p < 0.05), le score de Harris modifié était meilleur à 6 semaines seulement. Par la suite, les résultats fonctionnels devenaient comparables.

Mots clés : Voie postérieure, chirurgie mini-invasive, arthroplastie totale de hanche, étude prospective, comparative.

ABSTRACT

Purpose of the study

There have been few prospective studies comparing minimally invasive approaches for total hip replacement. We sought to ascertain the contribution of the minimally invasive posterior approach in comparison with the standard posterolateral approach in terms of early outcome.

Materials and methods

This study investigated a prospective, comparative, consecutive series of patients. Patients with major architectural problems or undergoing revision arthroplasty were excluded. One hundred ten patients (116 hips) were divided into two groups that were comparable for the number of patients, gender, age, body mass index, indication for surgery, and preoperative function scores. The preoperative ASA score was lower in the minimally invasive group (p = 0.04). The patients were in the lateral reclining position for both approaches and classical instrumentation using the same implants (stems and cemented or noncemented cups) was used. We noted operative time and blood loss (using the Brecher method based on the hematocrit
INTRODUCTION

The appearance of the first publications [Berger (1), Goldstein et al. (2), Wenz et al. (3), Wright et al. (4)] asserting the merits of the so-called minimally invasive approaches to total hip replacement sparked a lively debate that still has not been settled [Berry et al. (5)]. The minimally invasive approaches are defined by a short, 10-cm skin incision [Hartzband (6), Howell et al. (7), Woolson et al. (8)] and particularly by minimal damage to the muscles and capsules [Chiron et al. (9)]. The defenders of these minincision methods [DiGioia et al. (10), Chung et al. (11), Chimento et al. (12), Sculco et al. (13)] claim that this type of incision provides simpler operative follow-up and quicker functional recuperation with an equivalent complication rate to incisions using conventional approaches. On the other hand, the critics [Wright et al. (4), Woolson et al. (8)] note that reduced visibility can only increase the risk of immediate complications, which also makes implant positioning more haphazard. There have been few prospective and comparative publications to date [DiGioia III et al. (10), Chung et al. (11), Chimento et al. (12), Ogonda et al. (14), Nakamura et al. (15)]. Therefore, it is currently difficult to objectively prove the contribution of the minimally invasive approach compared to the conventional approach in hip surgery, but also to compare the different minimally invasive anterior [Kennon et al. (16), Sigui er et al. (17), Matta et al. (18)], anterolateral [Chiron et al. (19), Bertin et al. (20), Berger (21)], posterior [Chiron et al. (9), Goldstein et Branson (22)], and dual-incision approaches [Berger (1)].

We report the results of a comparative and prospective study on a series of patients operated on via the conventional posterior approach and a series of patients operated on using a minimally invasive approach.

PATIENTS AND METHODS

Patients

We conducted a prospective, comparative, and continuous study. The exclusion criteria were total hip arthroplasty (THA) revision surgery, cases requiring removal of osteosynthesis material before implantation, and those with major architectural problems. No other selection was made other than selection based on these criteria, with obesity notably not a factor for exclusion. We included 116 consecutive total hip arthroplasty procedures in 68 men and 48 women, with a mean age of 57.3 years (range, 21-86 years) divided into two equal groups: a minimally invasive approach group and a standard approach group. Each of the study’s groups comprised 58 consecutive patients operated on by a single surgeon experienced in the approach used (minimally invasive posterior or standard posterior). There was no randomization. The diagnoses requiring THA were for the most part primary osteoarthritis and osteonecrosis (fig. 1a and fig. 1b).

Surgical technique

The following describes the minimally invasive posterior approach [Chiron et al. (9)]. No specific instrumentation was used for this approach. Height was the only consideration in the choice of retractors (Charnley retractors, Holmman double-bent retractors bent at the handle). The patient was in the strict lateral decubitus position and maintained firmly with supports. The incision measured 8 cm, beginning three finger widths under the peak of the greater trochanter, opposite the trochanteric crest, toward the posterior superior iliac spine to place the axis of the scar along the gluteus maximus fibers and the femur neck fibers (fig. 2). The subcutaneous adipose tissue and the gluteal aponoeurosis were incised along the skin incision, then the gluteus maximus fibers...
were dissected. The trochanteric bursa was reflected to expose the muscles of the gluteal region. The sciatic nerve was systematically checked in the bursa/trochanter muscle plane. The posteromedial circumflex vessel was ligated within the fibers of the quadratus femoris to reduce intraoperative bleeding [Chiron et al. (9)]. The hip was placed in internal rotation. A double-bent retractor placed at the lower part of the capsule retracted the pyramidal muscle. Another double-bent retractor placed in the lower part of the capsule retracted the obturator externus and the quadratus femoris muscles. Only the tendon of the obturator internus and the gemelli remained behind the capsule and were cut at the extremity of the intertrochanteric line without opening the capsule (fig. 3). The tendon of the obturator internus was pulled back and then stretched over suture so as to protect the sciatic nerve. The arthrotomy was performed with an H-shaped incision, a T-shaped incision, or a periacetabular incision, with a pedicle flap on the trochanter area (fig. 4). The capsular flaps were suspended on sutures to prevent any later interposition during cup placement (fig. 5). The hip was then luxated in internal flexion-adduction-rotation with compression along the femur axis. The capsule under the femur neck was released to reposition the two double-bent retractors on either side of the neck. The neck was then sectioned using an oscillating saw along a line passing through the trochanteric fossa, perpendicular to the neck’s long axis. The upper part of the femur was then presented facing the incision, while still in internal flexion-adduction-rotation by pushing the gluteus medius laterally using a retractor. Using the chisel gouge, we hollowed out the anterolateral part of the trochanter; the diaphyseal axis was identified using an auger. The different broaches were inserted until they
reached maximum stability, notably in torsion, while protecting the skin during this phase to prevent superficial skin lesions. The acetabulum was exposed using a large double-bent retractor pushing against its anterior wall and pushing the femur forward. The labrum was excised to prevent any interposition between the bone and the metal-back. The socket was prepared using motorized reamers, preventing any nonhemispheric reaming caused by the distal part of the incision acting as a lever on the handle. The following prostheses were implanted: the Atlas™ (Fournitures Hospitalières, Heimsbrunn, France) or Shuster™ (formerly Centerpulse, now Zimmer, Winterthur, Switzerland) cup for the socket — with the implants screwed in if necessary — or cemented polyethylene. For the femur, an Omnicase™ (formerly Centerpulse, now Zimmer, Winterthur, Switzerland) stem was implanted: an identically shaped anatomic stem for both the cemented or cementless stems. A cementless or cemented pivot was chosen depending on the quality of the bone and the primary stability of the implant. No bone graft was required. After reduction, the joint capsule was sutured and then the obturator internus muscle’s tendon was sutured to its stump. A drain was set up in the sciatic nerve plane; the trochanteric bursa and the aponeurosis of the gluteus maximus were sutured.

The standard posterior approach was a standard approach. The incision comprised two parts: the short distal part in the femur axis and the second, longer part was oblique from outside to inside and from bottom to top. The intersection point was located roughly at the level of the intertrochanteric crest, approximately three finger widths above the top of the greater trochanter. The upper part of the incision was directed from the greater trochanter toward the posterior superior iliac spine for 10-15 cm. The lower part of the incision followed the axis of the femur for approximately 5 cm. The pyramidal, gemelli, obturator internus and externus, and quadratus femoris muscles were sectioned. Only the tendon of the obturator internus muscle was reinserted. The same type of implant was placed using this approach. No bone graft was required.

Analysis

All patients were examined before surgery to evaluate their pain level on a scale from 0 to 10 [Gagliese et al. (23)] and function was assessed using the the Postel and Merle d’Aubigné (24) (PMA) scores, the modified Harris Hip Score [Mahomed et al. (25)], the WOMAC index (the Western Ontario and McMaster University Osteoarthritis Index) [Bellamy et al. (26)], and the Charnley classification. The ASA (American Society of Anesthesiologist) score was also noted.

For all patients, the postoperative protocol included follow-up frontal x-ray of the pelvis immediately after surgery, biology (hemoglobin and hematocrit counts) at day 1 and day 5, low-molecular-weight heparin antithrombotic treatment at an isocoagulant dose, first dressing at day 2 with drainage and standardized analgesic treatment discontinued. No morphine delivered by syringe pump was used; level III analgesics were administered subcutaneously on demand depending on the patient’s pain. The parameters related to surgery were noted: size of the skin incision at the end of surgery, duration of the operation from skin incision to skin closure, and intraoperative complications. Blood loss secondary to the surgery was estimated using two different methods. Overall bleeding was estimated as the sum of intraoperative bleeding (produced from suction) and postoperative bleeding (produced from the drains). However, the overall red blood cell loss during hospitalization was also calculated using a standardized and validated method [Brecher et al. (27)]. We noted the number of red blood cell
units transfused. Patients were visited daily at the same
time and pain was noted on a scale from 0 to 10 [Gagliese
et al. (23)], as was the total consumption of morphine
(in milligrams) for the first 5 days after surgery. Early post-
operative complications during hospitalization were listed.
The length of the hospital stay as well as the type of care
after discharge (in a rehabilitation center or at home) were
specified. Postoperative x-rays were used to analyze the
centering of the femoral stem on a frontal hip x-ray, cup
inclination according to the Sutherland method (28), cup tilt
using the Dorr and Wan method (29), and cup centering
with the method devised by Pierchon et al. (30). Centering
was considered satisfactory when the distance between the
theoretical position and the position measured was less than
5 mm. All the radiographic, clinical, and biological data
were analyzed by a single observer who was not one of the
operators (JML).

Early postoperative assessment was done at 6 weeks,
3 months, and 6 months using questionnaires sent by post
to the patients’ home. These questionnaires included sev-
eral items: pain evaluated on a numerical scale from 0 to 10
[Gagliese et al. (23)], the WOMAC index, the modified
Harris Hip Score [Mahomed et al. (25)] for self-evaluation,
and the patient’s level of satisfaction measured on a numer-
ical scale from 0 (very dissatisfied) to 10 (very satisfied).

The statistical data were analyzed using the Statview®
software. Pre- and postoperative continuous variables were
compared using the bilateral paired Student t test when
values showed a normal distribution; otherwise, the nonpara-
metric Wilcoxon test was used. The continuous variables
between the two groups were compared using the bilateral
nonpaired Student t test or the Mann-Whitney U test. We
used the chi square test for the nominal variables and a
Fisher exact test when the theoretical numbers were less
than 5. Significance was set at $p < 0.05$.

RESULTS

The two groups were comparable before surgery except
for the significantly lower ASA score ($p = 0.04$) in the
minimal-incision group. The data are summarized in table I.
The mean length of the incision was 8.5 cm (range,
6-10 cm) in the minimally invasive approach group versus
15 cm (range, 11–25 cm) ($p < 0.0001$). We found no signifi-
cant difference in the duration of the operation, which was
74.4 min (range, 45–150 min) in the minimally invasive
approach group versus 72.6 min (range, 45–125 min) in the standard
approach group ($p = 0.65$). Implant positioning was satis-
factory in both groups. We observed one intraoperative frac-
ture in each group. These data are summarized in table II.

We observed significantly lower immediate postopera-
tive pain in the minimally invasive approach group at day 2
($p < 0.001$) and day 4 ($p = 0.004$). Beginning the 6th day,
this difference was no longer significant. These data were
confirmed by a significantly lower level III analgesic con-
sumption during the first 5 days after surgery: $15 \pm 12.4$ mg

| Table I. – Preoperative data. |
|-------------------------------|-----------------|-----------------|---|
|                               | Minimally invasive approach | Standard approach | $P$ |
| Number of hips                | 58               | 58              |   |
| Sex (M/F)                     | 35/23            | 33/25           |   |
| Age (years)                   | 55 (23–80)       | 59.7 (21–86)    | 0.1 |
| Body mass index               | 25 ± 3           | 26.2 ± 4.5      | 0.21 |
| ASA score                     |                 |                 |   |
| Classes 1/2/3                 | 37/16/5          | 20/35/3         | 0.01 |
| Mean ASA score                | 1.46 ± 0.65      | 1.71 ± 0.56     | 0.04 |
| Charnley classes A/B/C        | 27/26/5          | 28/27/3         | 0.77 |
| Preoperative pain (0–10 scale)| 5.99 ± 2.29      | 6.07 ± 1.94     | 0.99 |
| Preoperative functional scores|                 |                 |   |
| Harris Hip Score              | 47.7 ± 16.6      | 44.2 ± 15.8     | 0.30 |
| PMA score                     | 11.9 ± 3.1       | 11.7 ± 3.1      | 0.85 |
| WOMAC index                   | 57 ± 19.1        | 49.4 ± 16       | 0.06 |

Abbreviations: M, male; F, female; ASA, American Society of Anesthesiology; PMA, Postel and Merle d’Aubigné.
(range, 0–45 mg) for the minimally invasive approach group versus 22.8 ± 17.3 mg (range, 0–90 mg) for the standard approach (p = 0.01). The hemoglobin concentration (g/dl) and the hematocrit rate (%) were comparable in the two groups before surgery. The estimated intraoperative mean blood loss as well as the estimated total blood loss and the calculated total red blood cell loss [Brecher et al. (27)] were significantly lower in the minimally invasive approach group (p < 0.0001, p = 0.009, and p = 0.027, respectively), whereas the biological parameters at day 1 and day 5 were comparable. It should be noted that, considering a 40% hematocrit rate, the red cell blood loss of 509.4 ± 188.7 ml for the minimally invasive operations versus 614.5 ± 300.2 ml for the standard approach operations may correspond to total blood loss of 1270 ± 470 ml and 1535 ± 750 ml, respectively. After surgery, there was no significant difference in the blood transfusion parameters. These data are summarized in table III.

During the patients’ hospital stay, we counted six complications in the minimally invasive posterior approach group (one case of uncomplicated venous thrombosis and five hematomas that did not warrant surgical revision) and seven complications in the standard posterior approach group (one uncomplicated deep venous thrombosis, three hematomas, one paralysis in the common peroneal nerve area, one periprosthetic femoral fracture during a fall that required reoperation, and one luxation reduced orthopedically with no recurrence after a fall caused by dizziness). There was a significant difference in terms of length of hospital stay, with 9.9 ± 2.4 days (range, 7-20 days) for the first group versus 11.4 ± 3.1 days (range, 7-22 days) for the second (p = 0.003). At discharge, 35% of the patients who had had the minimally invasive operation returned home versus 17.2% in the standard approach group (p = 0.04). If the influence of age and comorbidities are considered for the entire population, 34% of the ASA1 subjects (with no comorbidities) returned home versus 18% of the ASA2 or ASA3 subjects. This difference is significant (p = 0.04). Similarly, the subjects returning home were significantly younger (51.3 ± 14.3 ans) than those discharged to a rehabilitation center (59.4 ± 14.8 years) (p = 0.02).

We found no complications over 6 months of follow-up in the minimal-incision group. In the other group, we found two recurring luxations that required a dual-mobility socket at 1 and 5 months after surgery. Two cases of periprosthetic fracture of the femur occurring after a fall were revised surgically. One patient presented persistent postoperative pain caused by poor metal-back support, which disappeared after the implant was changed. No infection was diagnosed during follow-up.

There was no significant difference at 6 weeks, 3 months, and 6 months in terms of pain. Significantly fewer patients from the minimally invasive group required walking aids at 6 weeks (p = 0.006) and 3 months (p = 0.02), but not at 6 months. The WOMAC index was significantly better in the minimally invasive approach group at 6 weeks, 3 months, and 6 months (p = 0.005, p = 0.02, and p = 0.01, respectively), but for the modified Harris Hip Score, there was no longer a difference beginning at the 3rd month after surgery. Overall, the patients were satisfied with their surgery and there was little difference between the groups. These data are summarized in table IV.

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**Table II. – Postoperative x-ray results for both groups.**

<table>
<thead>
<tr>
<th>Type of implant</th>
<th>Minimally invasive approach</th>
<th>Standard approach</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementless/cemented stem</td>
<td>56/2</td>
<td>56/2</td>
<td>NS</td>
</tr>
<tr>
<td>Cementless/cemented cotyle</td>
<td>56/2</td>
<td>58/0</td>
<td>NS</td>
</tr>
<tr>
<td>Orientation in degrees (min–max)</td>
<td>-0.07° (-5° to 5°)</td>
<td>-0.68° (-6° to -3°)</td>
<td>0.10</td>
</tr>
<tr>
<td>Number of hips with varus &gt; 5° or valgus &lt; -5°</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Table III. – Intraoperative complications.**

<table>
<thead>
<tr>
<th>Intraoperative complications</th>
<th>Minimally invasive approach</th>
<th>Standard approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>One lateral cortex fracture</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

This study was a continuous, prospective, and comparative study. Although there was no randomization, we were careful to keep patients unaware of their group assignment to eliminate any potential bias from the presupposed results of the minimally invasive approach. Other than the exclusion criteria retained, no patient was selected, in contrast to other series where there was a recruitment bias: exclusion of obese patients (BMI > 30) [Woolson et al. (8), Chimento

**TABLE III. – Preoperative and postoperative biological and transfusional data.**

<table>
<thead>
<tr>
<th></th>
<th>Minimally invasive approach</th>
<th>Standard approach</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin concentration (g/ml)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>13.8 ± 1.3 (11-16.6)</td>
<td>13.8 ± 1.4 (10.4-16.8)</td>
<td>0.97</td>
</tr>
<tr>
<td>Postoperative day 1</td>
<td>10.75 ± 1.5 (6.8-13.3)</td>
<td>10.52 ± 1.35 (8-13.5)</td>
<td>0.44</td>
</tr>
<tr>
<td>Postoperative day 5</td>
<td>10.46 ± 1.4 (6.8-13.2)</td>
<td>10.16 ± 1.4 (7.1-13.7)</td>
<td>0.39</td>
</tr>
<tr>
<td>Hematocrit rate (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>41.6 ± 3.4 (33.7-49.1)</td>
<td>41.2 ± 3.5 (30.8-47.9)</td>
<td>0.55</td>
</tr>
<tr>
<td>Postoperative day 1</td>
<td>31.9 ± 4.3 (20.3-40.8)</td>
<td>31.2 ± 3.8 (24.4-39.3)</td>
<td>0.44</td>
</tr>
<tr>
<td>Postoperative day 5</td>
<td>31.4 ± 3.7 (23.5-40.8)</td>
<td>30.1 ± 4.3 (20.3-39.3)</td>
<td>0.21</td>
</tr>
<tr>
<td>Estimated blood loss (ml)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraoperative</td>
<td>290 (100-1000)</td>
<td>495 (150-1400)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Total (intra- and postoperative)</td>
<td>581 (140-1150)</td>
<td>746 (245-1600)</td>
<td>0.009</td>
</tr>
<tr>
<td>Total calculated red cell blood loss during hospital stay (ml)</td>
<td>509.4 ± 188.7 (198.4-937.7)</td>
<td>614.5 ± 300.2 (220.1-1750.9)</td>
<td>0.27</td>
</tr>
<tr>
<td>Number of units of red blood cells transfused postoperatively</td>
<td>0.43 ± 0.91 (0 -3)</td>
<td>0.69 ± 1.44 (0 -8)</td>
<td>0.26</td>
</tr>
<tr>
<td>Percentage of patients receiving transfusion</td>
<td>18.9%</td>
<td>26.8%</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± standard deviation (minimum–maximum).

**TABLE IV. – Progression of functional parameters depending on approach and postoperative follow-up at 6 weeks, 3months, and 6 months**

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>6 weeks</th>
<th>3 months</th>
<th>6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mini-</td>
<td>Standard</td>
<td>P</td>
<td>Mini-</td>
</tr>
<tr>
<td></td>
<td>incision</td>
<td>incision</td>
<td></td>
<td>incision</td>
</tr>
<tr>
<td>Pain*</td>
<td>5.99 ± 2.3</td>
<td>6.07 ± 1.97</td>
<td>0.99</td>
<td>2.24 ± 1.79</td>
</tr>
<tr>
<td>WOMAC</td>
<td>57 ± 19.4</td>
<td>49.4 ± 16.1</td>
<td>0.06</td>
<td>81.8 ± 12.8</td>
</tr>
<tr>
<td>Modified Harris Hip</td>
<td>47.7 ± 16.8</td>
<td>44.2 ± 16</td>
<td>0.17</td>
<td>80.7 ± 16.2</td>
</tr>
<tr>
<td>Score</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>73%</td>
</tr>
<tr>
<td>Walking aid (%)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>73%</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>8.55 ± 1.4</td>
</tr>
</tbody>
</table>

* Numerical scale.
et al. (12)] or selection depending on the patient’s morphotype [Goldstein et al. (2), Woolson et al. (8), Chung et al. (11)]. Moreover, the series in the literature are sometimes difficult to compare because of the ethnic characteristics of the patients: Asian patients for Nakamura et al. (15), who were less overweight and smaller than the North American patients studied by Goldstein et al. (2). We used a self-assessment questionnaire sent to the patients’ home. The evaluation scores retained were the modified Harris Hip Score [Mahomed et al. (25)], which showed excellent correlation with the original Harris Hip Score and the WOMAC index [Bellamy et al. (26)]. This allowed us to remove any bias caused by subjectivity on the part of the operators in the evaluation of their own results. This evaluation did not analyze joint range of movement, which is part of the Postel and Merle d’Aubigné score (24) and the original Harris Hip Score (31). To analyze postoperative pain, a numerical scale from 0 (very dissatisfied) to 10 (very satisfied) was used because it was easily understood by the patient.

Agreeing on a scar length less than 10 cm to define a mini-incision approach seems very arbitrary and debatable. Some surgeons use the mobile window technique [DiGioia et al. (10), Chung et al. (11), Sculco et al. (13), Wright et al. (32)]: the skin incision measures only 6-8 cm but the subcutaneous dissection is lengthened by 3-5 cm proximally and distally. The dissection of the deep levels is therefore identical to the dissection via the conventional posterior approach. This tends to create a subcutaneous detachment with the risk of hematoma and delayed healing [Goldstein and Branson (22)]. In addition, incisions that are too small (< 6 cm) expose the patient to skin complications (reaming lesions, edges contused from excessive traction or burns from contact with the electrocautery knife), causing lesions that are possible sources of infection. Respect of the periarticular structures should be the preponderant criterion for defining the minimally invasive approaches; incision length only is insufficient. These less extensive dissections tend to reduce scarring fibrosis, which is also an advantage if there is later revision surgery.

Greater respect of the periarticular structures can result in what appears to be a longer, more meticulous dissection with more delicate exposure. However, the length of the operation, between 45 and 100 min, is not significantly increased [Goldstein et al. (2), Woolson et al. (8), Chimento et al. (12)]. Intraoperative bleeding seems to be significantly reduced [Ogonda et al. (14), Nakamura et al. (15)]; all the other series do not show the same results [Goldstein et al. (2), Woolson et al. (8)]. We do not give much credit to estimating operative bleeding by evaluating suction product and weighing compresses. This in no way reflects overall bleeding, which must account for intraoperative blood loss as well as visible postoperative blood loss (produced from drains) and occult blood loss [Sehat et al. (33)]. Our study is the only one to have confirmed this lesser bleeding using a standardized calculation of the overall red blood cell loss [Brecher et al. (27)]. This information contrasts, however, with the transfusion parameters: only two studies [Wenz et al. (3), DiGioia et al. (10)] have demonstrated lower transfusion rates in their minimally invasive approaches. Nevertheless, the morbidity of allogenic blood transfusion during the postoperative period must be emphasized [Bierbaum et al. (34)] as well as the cost of autotransfusion programs.

Early postoperative pain has not been reported much in the literature; certain authors [Chung et al. (11), Chimento et al. (12), Ogonda et al. (14)] consider its subjective assessment insufficiently reliable and prefer an objective parameter to evaluate it: the quantity of level III analgesic consumed or the duration of level III analgesic use. However, only pump syringe morphine use [Chimento et al. (12), Ogonda et al. (14)] can provide precise evaluation of the consumption of these analgesics. The quantity of morphine consumed subcutaneously or orally remains dependent on a number of factors (product availability and healthcare personnel availability, resorption speed during subcutaneous administration or oral absorption, etc.). We continue to evaluate pain using a reproducible numerical scale that reflects the patient’s experience. In this study, we found early postoperative pain assessed subjectively and objectively to be significantly lower in the mini-incision group. This participates, as does lower intraoperative bleeding [Bierbaum et al. (34)], in the patient’s early, rapid, and high-quality recovery and rehabilitation. Like Chung et al. (11) we found that the subjects operated via the mini-incision approach presented a shorter hospital stay and more often returned home upon discharge. Ogonda et al. (14) showed that returning home within the first 3 days was more a factor of young age and a high hemoglobin count than the type of surgery. The influence of these two factors [Salido et al. (35)] and comorbidities [Jain et al. (36)] has already been proved. The present study shows similar results to these last two authors: the population in the minimally invasive group was younger in our study (although not significantly) and presented fewer comorbidities. This can have an influence in terms of returning home and a shorter hospital stay. Similarly, the early clinical results (Harris Hip Score, limping, etc.) seem better at 6 weeks and 3 months [DiGioia et al. (10), Chimento et al. (12), Sculco et al. (13)], but these rapidly become similar between the two groups between 3 and 6 months after surgery. There is no difference at the medium term [DiGioia et al. (10), Chung et al. (11), Chimento et al. (12), Sculco et al. (13), Nakamura et al. (15)], where only Wright et al. (32) found a moderate advantage for the minimally invasive approach. Other studies [Woolson et al. (8), Ogonda et al. (14)] found no significant advantage to the minimally invasive posterior approach in terms of early clinical results.

Although some authors [Fehring and Mason (37), Bal et al. (38)] have recently reported complications during
minimally invasive procedures, these for the most part involve the dual-incision technique. The intraoperative complication rate is not increased during posterior minimal-incision approaches [Chung et al. (11), Ogonda et al. (14), Nakamura et al. (15), Wright et al. (32)]. Exposure during minimal-incision approaches can be more delicate, with less visibility. However, the literature has not shown a difference in implant positioning between the two approaches. Only Woolson et al. (8) found more malpositioned socket implants, varus stems, or a poor cement mantle in the mini-incision approaches. In a study with a 5-year follow-up, Wright et al. (32) found no significant difference in terms of radiographic results. The other, later complications (infections, luxations, etc.) did not seem more frequent [Sculco et al. (13), but the small number of cases and the short follow-up time preclude any conclusions.

To compare the different minimally invasive approaches, specifications must be established for comparison. Thus, when a minimal-incision technique is performed, it is preferable that fluoroscopy, orthopedic table, or specific ancillary equipment not be required. Verifying bleeding and the sciatic nerve must be possible at all steps of the procedure. One must be able to extend easily toward the femur or the pelvis at any time if need be. It is also necessary to be able to cement the femoral stem and/or the cup if the bone quality requires it while having direct visibility at all times. Muscle damage should be minimal, notably for the gluteus medius. Having to select patients should be avoided so as not to multiply the techniques. Finally, the ideal approach is an approach with a progressive learning curve that provides sufficient experience to guarantee reliability.

Despite the excellent results in terms of the muscles involved, the mini-Heuter anterior minimally invasive approach [Siguier et al. (17)] requires an orthopedic table and a sometimes lengthy learning curve for the surgeon and operating room personnel. The modified Watson-Jones anterolateral minimally invasive approach [Bertin and Röttinger (20)] also provides excellent muscle outcome; it is done without an orthopedic table but has a long learning curve, and there has not yet been a study providing comparative results. The mini-Harding purely lateral minimal approach [Berger (21)] requires partial disinsertion of the gluteus medius, which contradicts the minimally invasive concept. Finally, the dual-incision approach [Berger and Duwellius (39)] presents too many disadvantages: no direct visibility, reliable stem cementing impossible and extension to the femur difficult, the need for specific ancillary equipment, as well as a long learning curve [Archibeck et al. (40)] that is punctuated by complications [Bal et al. (38)]. Moreover, Mardones et al. (41) showed that during this approach, there were lesions to the gluteus medius as well as to the external rotator muscles, whereas the muscle outcome of this approach were initially presented as excellent [Berger (1)].

Only the anterior and anterolateral approaches provide excellent muscle results and only these approaches, associated with the posterior approach most often leave the gluteus medius totally intact. However, the minimally invasive posterior approach is the only approach that responds to all of our criteria. At any time during the procedure, the sciatic nerve can be checked and the opening enlarged if necessary toward the femur or the pelvis. The learning curve is also progressive by gradually reducing the incision size, as shown by the incisions in our standard approach: 15 cm (range, 11-25 cm).

**CONCLUSION**

The posterior mini-incision approach is a reliable minimally invasive approach. Satisfactory and reproducible implant positioning is provided. Extensions are possible at all steps of the procedure and the complication rate is not increased. Its advantages are reduced bleeding and faster initial recuperation. Learning the procedure is rapid and progressive. The effect on muscles favors the anterior and anterolateral mini-incision approaches that respect the gluteus muscles and the posterior tendons and capsule pieces. The luxation rate for these two approaches is low, but the learning curve is long. Conversion to an open enlarged conventional posterior approach remains possible at any time in case of complication or to accommodate an unexpected complementary procedure. The contraindications of mini-incision approaches must be respected: highly obese patients, associated osteotomy, congenital dislocation of the hip at the luxation stage, a history of acetabular and/or femur osteotomy, and amyloidosis. These more complex indications require wider exposure. This study shows an advantage over the short term related to the choice of a minimally invasive approach compared to the conventional approach, but few advantages over the long term.

**References**