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REVIEW

Posterior single-incision approach to minimally invasive total hip arthroplasty

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Abstract Enhanced surgical techniques and instrumentation enable surgeons to perform total hip arthroplasties through minimally invasive approaches. Using incisions typically less than 10 cm in length, surgeons can achieve adequate visualization of the surgical site while minimizing trauma to deep soft tissues. Associated reductions in morbidity should allow for improved rehabilitation and recovery. Although these techniques have been met with some controversy, a number of recent studies appear to attest to their safety and efficacy. Many of these studies have concentrated on a posterior single-incision technique for total hip arthroplasty. Favorable results for such outcomes as operative times, complication rates, pain, functional recovery, and blood loss have been reported, and patient satisfaction has been high. If surgeons and their patients are to achieve maximum benefit from minimally invasive total hip arthroplasties, it will be necessary to design effective educational tools that address the learning curve associated with these approaches.

Introduction

Over the last two decades, innovations in surgical technique and instrumentation have enabled surgeons to obtain adequate visualization through smaller and smaller incisions. So-called "minimally invasive" total hip arthroplasties (THAs) utilize these technologies to reduce necessary surgical incisions substantially and minimize transection of muscle and tendons, potentially leading to decreased surgical time, blood loss, infection, pain, and discomfort. Associated reductions in postoperative pain and intraoperative complications and morbidity should facilitate enhanced functional recovery and less rehabilitation time. Current techniques for minimally invasive THAs include single small-incision anterior, anterolateral, direct lateral, and posterior approaches, as well as two-incision techniques using direct visualization or fluoroscopy.

Although select surgeons have had more than 20 years experience with minimally invasive THAs [20], it is only recently that this technique has become more commonplace in orthopaedic practice. This development has been met with a certain amount of controversy. In recent years, however, a growing number of studies have presented convincing data that the use of smaller incisions potentially improves upon standard THAs [4, 5, 8, 10, 16, 18, 20, 21, 25, 30, 32, 34, 35, 37]. The current review aims to provide an overview of these studies, with a particular emphasis on those investigating the posterior single-incision approach to minimally invasive THAs.

Anterior and anterolateral approaches

The first minimally invasive THAs were conducted more than 25 years ago by Light and Keggi [20], who were able to attain successful visualization using a *direct anterior approach* via a curved transverse skin incision. In an analysis of the initial 104 procedures carried out during a 3-year study period, they reported encouraging outcomes in terms of surgery time, blood loss and transfusion, and hospital stay. As this procedure did not require dissection of the abductor muscles, superior levels of patient comfort and recovery of muscle tone were also achieved.

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A retrospective analysis of 2,132 consecutive primary anterior THAs using both cemented and noncemented implants conducted by Kennon, Keggi, and associates provided further indication of the success of this procedure [18]. After a minimum of 6-months follow-up, there was a low rate of intraoperative and perioperative complications, as well as reduced operative times and a low rate of blood loss.

Recent reviews of minimally invasive *anterior approaches* have reported favorable results in terms of component positioning and leg-length restoration without an increase in hip dislocations [21]. In a study of 1,037 hip replacements, Siguier reported a dislocation rate of only 0.96% (10 of 1,037 hips) at 2 weeks to 8 months after surgery [30]. However, this approach classically requires the use of a special traction table to allow reproducible visualization of the proximal femur [17].

The *anterolateral (Watson-Jones) approach* utilizes an interval anterior to the abductors and posterior to the tensor fascia lata, in which abductor muscle function is maintained and the posterior capsule is left intact [36]. Bertin and Röttinger developed a modified mini-incision anterolateral approach and reported decreased muscle damage in more than 300 patients, but experienced some difficulty with femoral exposure and obtaining consistent acetabular component positioning [7]. In a separate analysis, Berger found blood loss, length of stay, and the transfer rate to a rehabilitation facility to all be reduced with minimally invasive anterolateral THA [5].

In the *direct lateral (Hardinge) approach* for THA, a dissection deep to the fascia lata is employed whereby the anterior 1/3 to 1/2 of the gluteus medius muscle is released from the greater trochanter [12]. A minimally invasive direct lateral approach was performed for 34 THAs by O'Brien and Rorabeck and compared with a standard-incision [25]. Blood loss and the rate of complications were similar between the groups, though length of stay and discharge to home instead of a rehabilitation facility favored those receiving mini-incisions. In additional studies, the minimally invasive direct lateral approach failed to show significant improvements beyond slight reductions in hospital stay [9, 13].

Double-incision approach

Success with double-incision approaches has been noted in the literature [4, 16], yet the challenges inherent in these procedures make them a less feasible option than current single-incision minimally invasive THAs.

Utilizing a double-incision technique for THA without fluoroscopy, an adaptation of the posterior Moore [22] and anterior Smith-Petersen [31] approaches, Irving was able to limit soft tissue trauma resulting in favorable rehabilitation [16].

A more commonly practiced two-incision minimally invasive approach has been described by Berger [4]. This fluoroscopy-assisted approach requires a variety of specialized instruments and uses an anterior incision to facilitate osteotomy of the femoral head and proper placement of the acetabular component, as well as a posterolateral incision for introduction of the femoral stem. A report of the first 100 cases of this two-incision approach indicated a 1% complication rate, although with no instances of dislocation, failure of biologic fixation, or reoperations. Patients experienced rapid recovery and an 85% rate of same-day discharge.

Practitioners of this two-incision approach often note the demanding nature of this surgical technique and the need for specialized training to ensure the success of this procedure. Berger reported that he had undertaken substantial preclinical study involving experimental procedures in more than 40 cadavers prior to conducting his first such procedure [4].

Recent data provide little to recommend the use of this approach at this time. In an analysis of surgeons being trained in the two-incision technique, only 19 of the first 89 receiving this training completed 10 or more two-incision THAs throughout the 1-year study period. The prevalence of key complications was not related to either the prior experience of the surgeon or the number of dual-incision procedures performed during initial training. Notable complication rates included 8.0% for femoral fracture, 1.4% for nerve palsy, and 1.2% each for dislocation and infection [1].

Bal et al. compared 89 consecutive primary THAs using the fluoroscopy-guided two-incision approach with data from a historical control series of 96 direct lateral mini-incision THAs performed by the same surgeon [3]. They reported a substantial rate of complications, repeat surgery, and radiographic malpositioning of components with the two-incision approach. Surgical experience proved highly significant, as the rate of complications associated with the two-incision approach decreased from 55% after the initial 40 procedures to 31% for the subsequent 49 procedures ($p=0.0202$).

A comparison of 80 consecutive patients undergoing two-incision THAs with retrospective data from the same surgeon's previous 120 standard open posterior THAs by Pagnano et al. also reported an increased rate of complications with the minimally invasive approach [27]. The difficulty inherent in the two-incision approach was reflected in the longer mean operative times required when compared with the standard posterior approach (68 minutes vs. 54 minutes, respectively).

Posterior single-incision approach

The posterior approach is considered a relatively simple technique for performing standard THAs. Rate of postop-

erative limp resulting from gluteal nerve injury or postsurgical avulsion of the gluteal muscles, return to normal abductor strength, and time to ambulation are also considerably better in patients undergoing posterior THAs [37]. These benefits presumably could be obtained with the minimally invasive version of this procedure as well.

Sculco has performed the modified posterior approach since 1996, and has reported no increased risk for intraoperative or postoperative complications and no problems with component malposition [28]. Chimento and Sculco conducted a randomized trial in which 28 patients underwent posterior THAs through an 8-cm incision and 32 with a 15-cm incision [8]. Both intraoperative ($p<0.003$) and total blood loss ($p<0.009$) were significantly reduced in the 8-cm incision cohort.

In Waldman's account of his early experience with 32 patients undergoing this procedure, there were no reported sciatic nerve palsies, dislocations, or presence of significant limp after a mean 13-month follow-up period. Patients experienced ambulation of 10 feet or more on postoperative day 1 as well as shorter hospital stays [34]. Waldman further reported no increase in complications and favorable ambulation and hospitalization time in a comparison of 30 hip replacements performed via a minimally invasive approach compared to 91 via a standard incision [35]. A similar study of conventional and mini-incision procedures performed via the posterior approach demonstrated significant improvements in limp, stair climbing, and ambulation distance at 3- and 6-month follow-up for those in the mini-incision cohort [10].

Wenz et al. compared a minimally invasive posterior approach to THA with a standard direct lateral approach (≥25 cm incisions) [37]. Postoperative data revealed a significant decrease in transfusion requirements, shorter operative times, quicker time to ambulation, and improvements in discharge disposition and functional recovery during physical therapy for those undergoing minimally invasive THAs (124 procedures) compared with those who received standard THAs (65 procedures). It has been hypothesized that posterior incisions may result in an increased risk of wound infection [14], yet Wenz et al. discovered no significant difference in the rate of either superficial or deep wound infections between the study cohorts.

Longer-term clinical experience

More extensive follow-up data for minimally invasive posterior, single-incision THAs were provided by the author in a recent analysis of 1,000 consecutive procedures in 759 patients (mean age of 62.3 years), none of whom were excluded due to weight or body mass index (BMI) [32].

All patients received a tapered, titanium femoral component as well as a hemispherical, press-fit, acetabular component. The surgical technique employed by the author utilized an incision starting 2 cm posterior to the tip of the greater trochanter, and oriented approximately 20° to the shaft of the femur. The mean incision length was 8.8 cm, with a range of 6 to 16 cm. Patient body mass indices ranged from 14.3 to 56.5 kg/cm^2. During a mean operative time of 61.2 minutes, the average blood loss was 317 ml, and 43.6% of patients required a blood transfusion. The average hospital stay was 3.7 days.

After a mean follow-up period of 37 months, patients experienced an improvement in Harris hip scores from 34 prior to undergoing surgery to 92 postoperatively. The complication rate compared favorably to historical controls, with 30 dislocations (3.0%), three deep wound infections (0.3%), 5 superficial wound infections (0.5%), and 10 patients (1.0%) with delayed wound healing. There were 21 revisions (2.1%) required for such reasons as dislocation, loosening, deep infection, and periprosthetic femoral shaft fractures after patients fell in the early postoperative period. Of note, high offset femoral components were not used at the time of this study, which could partially explain a dislocation rate higher than that reported in other series of standard posterior approach THAs. Dislocations were not believed to be due to component malpositioning. Radiographic follow-up evaluation revealed acceptable component positioning for 95.3% of the patients. None of the femoral components exhibiting radiolucencies were progressive, and all were radiographically osseointegrated and clinically stable.

The evolution of minimally invasive THAs

Although the initial goal of minimally invasive total hip replacement was merely reducing the length of the scar, any advantages of this objective alone have not been borne out [2, 9, 11, 26, 39]. Most proponents now believe the advantages of minimally invasive THA derive from multiple factors. Reducing soft tissue trauma is thought by the majority to be the most significant factor in reducing blood loss, decreasing pain, and hastening recovery. Indeed, incisions which are too small increase trauma to the skin and subcutaneous tissues [23]. Additionally, lack of visualization may lead to an unacceptable complication rate [1, 3, 27].

The author now routinely uses only a modest posterior capsulotomy for exposure, maintaining the piriformis and quadratus femoris attachments. Capsulectomy is never performed, and selective circumferential capsulotomy is performed only for contractures. The posterior capsule is repaired in a semi-anatomic method to reconstruct the posterior

restraint resisting dislocation. The fascia lata is not disturbed, and the gluteus maximus tendon is never released.

Full visualization of the deep structures is always attained by following several basic principles. Incision placement and length are critical. Knowledge of anatomy and use of specialized instruments and retractors facilitates deep exposure. Proper limb positioning during each part of the procedure helps to make the essential anatomy visible. Gentle handling of soft tissues is of particular importance, and dissection should only be performed to the extent necessary to perform the procedure safely. Additionally, improvements in pain and nausea management have allowed accelerated rehabilitation programs that facilitate quicker recoveries with or without a minimally invasive approach [6, 15].

Learning curve

Since 1997, the author has performed over 2,000 hip replacements via a single posterior mini-incision. The favorable results observed during these procedures were no doubt heavily influenced by the increasing level of experience. Wound healing problems, component malpositioning, nerve palsies, and other complications all improved with experience, and the dislocation rate was reduced to less than 1% for the last 500 THAs performed [32]. In its current state, the surgical technique used by the author provides acceptable visualization while maintaining the gluteus maximus, piriformis, and quadratus femoris insertions, resulting in significant reductions in soft tissue trauma. Additionally, the author now reconstructs the posterior capsule in a manner that re-creates the tension band effect of the hip by tightening and advancing the posterior capsule on itself, further reducing the incidence of posterior dislocations ("capsular noose procedure") [33].

Postoperative mortality, infection, revisions, and other serious complications have been shown to be higher for patients undergoing THAs at low-volume practices [19], and one of the challenges facing minimally invasive THAs is ensuring a sufficient level of experience before a surgeon performs these operations.

The impact of physician experience is possibly evident in a retrospective analysis by Woolson et al. [38]. Primary posterior THAs were performed on 50 patients using a mini-incision and 85 patients with a standard incision. Wound complications, acetabular component malpositioning, and femoral component varus and malsizing were all significantly higher in the mini-incision cohort. It is important to note, however, that the participating surgeons had no experience with minimally invasive THAs prior to the initiation of the study, the potential impact of which was not adequately addressed by the study's authors.

It is also essential to remember that minimally invasive techniques have garnered successful results not due to reductions in incision length, but rather to improvements in deep dissection and soft tissue trauma. Several studies in which only the length of the incision was altered, not the deep operative technique, have failed establish a clear benefit for mini-incision THAs [2, 9, 26] With the increasing attention minimally invasive THAs have received of late, it is hoped that there will also be a corresponding drive toward providing interested surgeons with suitable educational tools to prepare them for performing these procedures despite reduced visualization of anatomic landmarks. Cadaveric courses, increased residency training, and mentoring programs with a trained surgeon are effective measures for addressing this steep learning curve.

Obese patients (BMI >30) and those with enhanced musculature in the thigh and buttock region present surgeons with a greater difficulty in obtaining adequate visualization through excessively short incisions [29]. The author has found BMI divided by 3 to be a good approximate equation for determining incision length in centimeters.

Surgeons with little direct experience with minimally invasive THAs should seek out patients with characteristics more conducive to proper visualization during their initial procedures and increase the length of the incision when necessary. Long-term results should never be sacrificed for short-term gains.

Conclusions

The body of knowledge regarding the posterior, single-incision technique for THA has grown considerably in recent years. A significant portion of the studies known to the author have reported short-term advantages to this approach, with improvements in pain, discomfort, blood loss, and surgical time that are indicative of the benefits of minimizing soft-tissue trauma. By successfully addressing the morbidity found with standard THAs, minimally invasive strategies should speed patients' postoperative rehabilitation, with a resulting improvement in functional self-sufficiency at a lower economic cost to the healthcare system [24].

As with all new surgical techniques, the success of minimally invasive THAs has proven highly commensurate with the individual surgeon's level of comfort and experience in performing the procedure. Effective training efforts must be undertaken if surgeons newly initiated in these approaches hope to minimize the potential for complications.

Conflicts of interest statement The author was a consultant for Plus Orthopedics and Smith & Nephew Orthopaedics during the study.

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