A Review Paper

The Application of Minimally Invasive Surgical Techniques. Part I: Total Hip Arthroplasty

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Abstract

Traditional surgical approaches often involve making large skin incisions and extensively dissecting healthy tissue to access diseased anatomy. Obviously more desirable is to make smaller incisions and more focused dissections and achieve the same postsurgical outcomes. Minimally invasive surgery (MIS) is gaining popularity in many orthopedic fields, but MIS techniques are not without risk. Continued use of these techniques is a topic of debate. If alignment is satisfactory with MIS, and if the complication rates of MIS are similar to those of traditional approaches, it seems sensible to consider the less invasive approaches to enable earlier patient recovery and improve cosmesis. Skeptics claim that there is no advantage in using MIS over time-tested approaches and are concerned that MIS approaches are being implemented before being properly subjected to peer review.

Traditional surgical approaches often involve making large skin incisions and extensively dissecting healthy tissue to access diseased anatomy. Such approaches are associated with a risk for nerve and blood vessel injury, wound infection, loss of function of surrounding muscles, and an unattractive scar. Obviously more desirable is to make smaller incisions and more focused dissections and achieve the same postsurgical outcomes. Minimally invasive surgery (MIS), which has been in development for many years and is still being refined, is based on 5 broad principles for decreasing surgical morbidity and recovery time[1,2]:

- Smaller incisions (<10 cm; actual dimension is debated).
- Development of mobile surgical window.
- Restricted dissection of soft-tissue structures.
- Modified and/or new instrumentation to enhance visualization.
- Accelerated recovery.

MIS is gaining popularity in many orthopedic fields, such as arthroplasty, fracture fixation, and spine surgery.[1,2] With improved instrumentation and surgical experience, these approaches can be further streamlined to limit deep soft-tissue dissection and shorten the incision.[3] However, these techniques are not without risk. During preoperative counseling, it is important to emphasize the risks of MIS to the patient and to explain that an MIS approach may be extended if deemed necessary during surgery. Continued use of these novel techniques is a topic of debate. Skeptics claim that there is no advantage in using MIS over time-tested approaches and are concerned that MIS approaches are being implemented before being properly subjected to peer review.

Background

Total hip arthroplasty (THA) is considered one of the most successful orthopedic procedures; patients are able to return to ambulation quickly and experience a remarkable reduction in pain. Implants have a 10-year survivorship of approximately 95%.[4] Furthermore, retrospective analysis of component survival using a Charnley low-friction arthroplasty through a conventional transtrochanteric approach demonstrated a component survivorship of 88% with a minimum 30-year follow-up.[5] Serious complications in these operations are relatively rare and occur in approximately 2% of cases. With the well-known aforementioned data, many surgeons feel that there is little room for improvement in THA and that any major changes should be carefully scrutinized and thoroughly investigated before being implemented.

Proponents of MIS-THA claim that, in addition to a more appealing scar, MIS reduces perioperative blood loss, soft tissue trauma, postoperative pain, duration

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of hospital stay, and time to return to normal function while maintaining the impressive longevity of the implant.[6-10] Critics disagree with most of those points and argue that skin trauma, infection rates, and neurovascular injuries are increased, that cosmesis is given preference at the expense of accurate positioning of the implants, and that length of hospital stay is an arbitrary outcome dictated by rehabilitation protocol rather than surgical approach.[1,11] This is currently a hotly debated subject and there have been many papers published in recent years investigating these issues.

Surgical Approaches

Among the first alternatives to the earliest transtrochanteric approaches to gain favor were the conventional posterior and lateral approaches.[12] These alternative approaches sought to limit disturbance to osseous and soft tissue anatomy, thereby avoiding unnecessary complications such as trochanteric nonunion.[13,14] The posterior and lateral approaches were nevertheless reported to be associated with gluteal nerve injuries, among other complications.[15] With the idea of limiting soft tissue dissection and avoiding healthy surrounding structure damage, MIS-THA was born. Beginning in the 1990s, steps were taken to modify the conventional surgical technique and therefore reduce intraoperative trauma and facilitate quicker rehabilitation.

The MIS approaches to THA can be divided into 2 groups:

- Single mini-incision (<10 cm) approaches, including posterior,[1] anterior,[1,16] posterolateral,[10] lateral,[17,18] and anterolateral.[19]
- Multiple small-incision (each within 2.5-5 cm), with[20] or without[21] the use of fluoroscopy.

The posterior approach is currently the most commonly used for conventional THA.[12] The mini-posterior approach uses the same plane of dissection as the conventional posterior approach, but unnecessary soft tissue dissection is avoided.[20,22] The gluteus maximus split should be kept to a minimum, and release of the gluteus maximus tendon insertion should be avoided if possible. An anterior capsular release is critical. Releasing the anterior capsule facilitates femoral mobilization and easy delivery of the femur into a small wound.[9] Lastly, a meticulous posterior capsular closure with short rotator reattachment is critical to the mini-posterior and conventional posterior approaches, because it reduces the risk of postoperative dislocation risk from 3% to 0.85%, as seen from a retrospective study of 945 hips.[23]

The anterior approach uses the internervous plane between femoral nerve (ie, lateral border of the sartorius and rectus femoris muscles) and superior gluteal nerve (ie, medial border of the tensor fascia latae and gluteus medius muscles). Since there is no major muscle to split, or tendon to cut, it represents the optimal MIS approach. The indirect or capsular head of the rectus femoris muscle is released from its insertion to expose the hip capsule, and the short external rotators (ie, piriformis, obturator internus, superior gemellus, inferior gemellus, and quadratus femoris muscles) may be injured during posterior capsular release. In a study of cadaveric MIS-THA, the gluteus medius was completely preserved in 4 of 5 hips, compared with 2 of 5 from a posterior approach, and 0 of 5 from the other 3 MIS approaches.[24] A retrospective review of 1037 THAs using an anterior approach demonstrated satisfactory outcomes and few complications, including 10 dislocations, 2 recurrent dislocations, 3 deep infections, and 3 aseptic loosenings.[16]

The other types of single mini-incision approaches are posterolateral, lateral, and anterolateral. For the posterolateral approach, an incision is made over the posterior aspect of the greater trochanter, and the gluteus medius and minimus are elevated off of the capsule.[25] For the lateral approach, the skin incision runs from 2 cm proximal to the greater trochanter to 5 to 8 cm distally along a line parallel to the long axis of the femur. After incising the tensor fasciae latae, the gluteus medius fibers are cut to expose the joint capsule.[18] The skin incision for the anterolateral approach goes from the anterior tubercle of the greater trochanter and angles towards the anterior superior iliac spine. Like the Watson-Jones approach, it uses the interval between the gluteus medius and tensor fasciae latae and usually only requires elevating the anterior one-third of the gluteus medius.[19,25] A possible downside was shown in a cadaveric study when the superior gluteal nerve was transected in 4 of 5 cases using this approach.[24] These approaches are much less commonly used and, therefore, have limited data. Most of the articles reviewed used the single anterior or mini-incision posterior approaches, or the 2 incision approach, and thus, the other single mini-incision approaches are not described in full detail here.

The 2 incision approach consists of a 5 cm anterior incision directly over the femoral neck used for accessing the acetabulum and inserting the cup and a 3 cm posterior incision in line with the femoral canal used for the femoral preparation. The anterior approach uses the internervous plane between the femoral and superior gluteal nerves, and the posterior approach uses the plane between the abductor tendons anteriorly and the piriformis posteriorly.[1] Some authors recommend using fluoroscopy to verify the correct location of the skin incisions,[20] while others feel like this extra equipment is not necessary.[21] Problems with increased complication rates, such as those seen with proximal femoral fractures in 2.8% of cases, have made some authors suggest that this minimally invasive technique is more challenging than the others and requires more extensive training.[1,26]

Specialized Instrumentation and Techniques

Mini-incisions may require modification of conventional instrumentation and possibly additional equipment

(ie, fiber optic light cables, cutaway reamers, Hohmann retractors with light sources, flexible acetabular reamers).[9,19,20] Using particular operating room tables make certain MIS approaches more accessible and may be required to provide requisite traction and permit rotation of the lower extremity. A Judet orthopedic table (Tasserit, Sens, France) or a PROfx fracture table (Mizuho OSI, Union City, California) can be used with an anterior approach, and the Jupiter Table (Trumpf Medical Systems Inc, Charleston, South Carolina) with the anterolateral approach.[16,19,27] The femoral neck may need to be osteotomized in situ instead of after dislocating the hip. In addition, the femoral head may need to be removed piecemeal instead of en bloc.[19,28]

Another unique aspect of MIS-THA is that preoperative templating can guide not only component size, but also the size of the incision. For example, a 10 cm incision would be appropriate for inserting a size 56 acetabular component while avoiding contact between the prosthesis and skin or subcutaneous fat.[29]

Outcome Studies

A retrospective study reported that the 2 major benefits of MIS-THA are incision cosmesis and psychological satisfaction.[29] There was also a significant decrease in blood loss, a decrease in postoperative limp, and decreased need for postoperative ambulatory walking aids. A prospective study compared the posterolateral mini-incision THA to a matched cohort using the standard posterolateral approach. Apart from improved cosmetic appeal, the postoperative pain and function assessment, as measured by the Harris Hip Score (HHS), was statistically significant, but unlikely to be clinically relevant.[30] Pre- and postoperative gait analysis on 10 patients after mini-posterior THA demonstrated 85% recovery of gait velocity, a 90% recovery of single leg stance time, a 90% recovery of cadence, and a 70% return of stride length, as well as less dependence on walking aids.[1]

Prospective comparison of 50 MIS-THAs with 57 conventional THAs via a direct lateral approach demonstrated that MIS-THA required slightly more operative time, but resulted in a statistically significant decrease in hospital stay (mean of 4.4 days vs 5.7 days).[31] Retrospective evaluation of the first 100 patients with the 2-incision THA had a decreased length of hospital stay, with 85% of patients discharged within 23 hours of the procedure.[32] Moreover, 97% of their patient cohort were able to attain standard physical therapy goals, including transferring in and out of bed from standing, rising from a chair to standing, moving from standing to sitting, walking 30.5 m, and negotiating a full flight of stairs within 1 day of surgery.[28]

In contrast, a retrospective study comparing 85 standard to 50 MIS-THAs via the posterior approach, found no differences in transfusion rates, estimated blood loss, operative time, or length of hospital stay.[11] Moreover, a 30% incidence of acetabular component malposition and a 6% rate of local wound complications, both of which were significant increases when compared to conventional approaches, were reported for MIS-THA.[11] Component malposition leads to increased polyethylene wear and osteolysis for polyethylene bearings, metallosis for metal-on-metal articulations, and audible component noise for ceramic-on-ceramic articulations, and liner fracture in all bearings. In addition, a case-controlled series of 30 patients undergoing THA using a MIS or conventional direct lateral approach found no significant differences in operative time, pain control, postoperative blood loss, complications, length of hospital stay, or HHS.[17]

A more recent prospective randomized study performed by a single experienced surgeon compared 109 mini-posterior to 110 standard posterior THAs and found no significant differences in postoperative hematocrit, rate of blood transfusion, pain score, analgesic use, length of hospital stay, functional outcome, component position, or cement mantle grade. In addition, gait analysis of 100 patients in this study found no difference in stride length, cadence, or walking speed.[33]

Case-controlled evaluation of 42 mini-posterior THA and 42 conventional THA reported improved cosmesis, patient satisfaction, and psychological recovery that in turn accelerated patient recovery.[9,34] In addition, case-controlled evaluation of 50 anterolateral THA and 72 conventional THA reported decreased operative time, blood loss, and length of hospital stay.[31] When appropriate patient analgesia protocols are followed, patients with the anterolateral and 2-incision approaches can often be discharged home within 24 to 48 hours postoperatively.[28,31,32] A consecutive case series of 506 MIS-THAs treated using a fluoroscopic-assisted anterior mini-incision approach and the PROfx fracture table demonstrated a median length of hospital stay of 4 days, with a mean of 10 days to walking without external support. There were only 5 complications in this series: 1 infection, 2 anterior dislocations, 1 posterior dislocation, and 1 temporary femoral nerve palsy; the mean leg length discrepancy was 3 mm.[35]

A double-blinded randomized controlled trial compared 60 MIS-THAs to 60 conventional THAs using either an anterolateral or posterolateral approach in patients under the age of 75 years and with a body mass index (BMI) no greater than 30. They found that there was a significant increase in HHS at 6 weeks and 1 year postoperatively in the MIS group, but they felt like this improvement was not clinically significant. In addition, there was no statistical increase in complication rate with MIS-THA. However, if only the complications of the first 60 hips were analyzed, there was a significantly increased doubling of the risk with the MIS-THA, but this difference did not exist with the last 60 hips. Also, operating time was increased by 10 minutes in the MIS group. This data gives some idea of a learning curve associated with MIS-THA.[36]

An analysis of 1205 hips from 12 randomized or

quasi-randomized controlled trials comparing MIS-THA to conventional THA showed that there was no statistical difference in complication rates or HHS, but there was a significant reduction in operating time by approximately 5 minutes and in intraoperative blood loss by almost 50 mL with the posterior and posterolateral MIS approaches. They also noticed that acetabular cup anteversion was almost 3 times more likely to be outside the acceptable range with the MIS approaches.[37] A recent meta-analysis reviewed 18 articles looking at various aspects of MIS-THA. They found that there was strong evidence that MIS produced a decrease in operating time, a decrease in intraoperative blood loss, and no change in complication rates or acetabular positioning. There was moderate to strong evidence that there is no difference in physical functioning at 6 weeks and 6 months after surgery. Moderate evidence exists that patients undergoing MIS-THA have a shorter length of hospital stay, and there was no evidence that pain is less 3 and 6 months after surgery.[38] A different meta-analysis of 26 articles and 2849 hips compared all of the single incision MIS approaches to the conventional THA. Except for an increased incidence of nerve palsy from MIS-THA, there was no clinically significant difference in other complications, blood loss, hospital stay, pain scores, or hip scores.[39] Overall, even though MIS-THA appears to have similar short-term results, there is a dearth of quality literature regarding MIS-THA outcomes. More prospective evidence needs to be reported before MIS-THA is seen as an improvement over the conventional techniques.

Complications and Limitations

Patient selection is one of the most important factors in predicting the success of MIS, and therefore, one of the major limitations of MIS-THA. Most authors recommend that the patient's BMI be less than 30 and that the patient not be exceedingly muscular. However, the distribution of the excess tissue is the more important issue to consider. Other contraindications are severe bony dysplasia, especially superior femoral head migration, revision surgeries, and severe muscle contracture around the hip.[1,31,34] Critics argue that patient selection clouds the ability of unmatched outcome studies to be unbiased because this type of patient (ie, BMI<30) tends to experience fewer complications and have a decreased hospital stay irrespective of the nature of the surgery.[11]

Several studies have shown an increase in local wound complications, and this is theorized to be secondary to increased soft tissue trauma from the retractors, from stretching of the skin, and from reamers abrading the skin. One study used a Doppler flow meter to investigate the effect of aggressive skin retraction on intraoperative skin blood flow. If showed that skin blood flow was reduced by approximately 32% with MIS-THA techniques, but there were no significant changes seen with conventional THA.[40] An increased wound complication rate of 6% has been reported, however, 2 recent meta-analyses showed this increase is not statistically significant.[11,38,39] One study compared the scar appearances from MIS to conventional THA at 2 years postoperatively, and found that plastic surgeons rated 6 of 20 MIS scars as poor and only 1 of 14 conventional scars as poor. Thirty of 31 of those same patients also revealed that at 2 years after surgery, pain relief and implant longevity were more important than scar cosmesis.[41]

Damage to surrounding structures, especially nerves, is one of the main concerns of detractors to MIS-THA. As mentioned previously, the anterolateral approach places the superior gluteal nerve at significant risk as 4 of 5 were cut during a cadaveric study.[24] Regarding the lateral femoral cutaneous nerve (LFCN), another cadaveric study showed that the MIS anterolateral approach conserved a significant amount of more branches of the LFCN, compared with the MIS posterior and standard lateral approaches.[42] However, a recent meta-analysis showed a five-fold increase in the risk of LFCN palsy after MIS-THA, as well as a statistically significant increased risk for any nerve palsy.[39]

Despite sufficient soft tissue mobilization in properly selected patients, limited surgical visualization may necessitate conversion of the MIS incision into a more conventional approach in less than 10% of patients.[18] Surgical complications include proximal femoral fracture (2.8% for 2-incision approach), hematoma (2% from 1 study), acetabular component malposition (abduction angle <35° or >50° was seen in 4% and 11%, respectively, using the posterolateral approach), and varus femoral component malposition (14% using the posterior approach).[1,10,11,31] Since the posterior approach is associated with increased risk of posterior dislocation, it is reasonable to continue to expect this as a potential complication. However, one study of 1000 hips using the mini-posterior technique reported a posterior dislocation rate of 1.2%, which is less than the value of 5.8% reported using the standard approach.[34,43]

The 2-incision approach has its own set of problems, because it uses unique dissection planes. As a result, 2-incision approaches have a significant learning curve resulting in a higher than expected complication rate while, in general, mini-incision approaches have similar learning curves to conventional approaches.[44] The rate of complications did not decrease over a surgeon's first 10 cases, suggesting that there is a longer learning curve than expected.[45] The 2-incision THA has been suggested to spare cutting muscles and tendons, although cadaveric studies of 10 hips showed that in every case, the abductors, external rotators, or both were injured.[46] Moreover, unlike standard mini-incision approaches to the hip, which use large dissection planes, the 2-incisions have limited extensibility

because the dissection planes are much smaller. As a result of the increased level of skill and experience required to perform this approach safely and correctly, many surgeons feel that this approach is best performed by high volume surgeons who receive specialized training.[1]

Perspectives on MIS Approaches to the Hip

The potential advantages of MIS techniques in hip arthroplasty include decreased operative blood loss, ease of surgical closure, decreased postoperative pain, reduced hospital stay, more rapid postoperative recovery, and increased cosmetic appeal.[47] However, possible problems with the surgical technique include:

- Steep surgical learning curve,
- Increased operative time,
- Compromised surgical exposure,
- Technical errors (eg, fractures, component malposition), and
- Neurovascular injury.

Critics of MIS-THA claim that the long-term outcomes would not be superior to the well-established approaches and that marketing schemes directed at patients paint a picture that is not supported by current literature. Some of the reported benefits including duration hospital stay for MIS approaches may be clouded by aggressive and innovative pain control protocols aimed at early rehabilitation of patients. Moreover, the benefits of MIS may be offset and overshadowed by the potential for wound complications and component misalignment. Patients are more likely to accept a larger incision if it minimizes their chances of a second revision operation.

Initial studies on MIS-THA procedures have, not unexpectedly, contained conflicting data. If satisfactory alignment with similar complication rates can be realistically achieved, it would seem sensible to consider the less invasive approaches to enable earlier patient recovery and improve cosmesis. Since many implants begin to show wear approximately 10 years after their implantation, surgeons are waiting to see if the revision rate for minimally invasive surgeries is higher than what is currently seen for components inserted via conventional approaches. MIS is probably best suited for specifically trained high volume surgeons.

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