7.5

Posterior Approach for MIS with Image-Free Computer-Assisted Navigation

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Introduction

This chapter will describe the technique of the posterior mini-incision of average 8 cm length. Sixty percent or more of total hip replacements in the United States are performed through the posterior approach. Therefore, it only makes sense that the majority of surgeons will need to initially learn to perform MIS THR through a posterior approach. Most will not go beyond this approach to an intermuscular one because the posterior mini-incision operation satisfies the needs of most patients. Gait studies have always shown better function post-operatively, at least in the first 6 months, in patients with a posterior rather than an anterior approach [1].

In this chapter the use and benefits of image-free computer navigation will also be described. The advantage of the computer is the precision it provides the surgeon in decision-making during the operation. Most of the anxiety of the surgeon during a hip-replacement operation is whether or not the components are correctly placed and the biomechanical reconstruction (leg length and off-set) is optimal. The computer provides precise information to enable these decisions. With image-free computer navigation the additional operating time approximates 15 min.

The Process of Posterior MIS THR

The satisfaction of patients with MIS operations has been, in part, because of the improvement for the patient of the process of the entire surgical experience. Pre-operative education, anesthesia, and pain management, as well as post-operative rehabilitation combined with a less invasive operation have improved patient outcomes [2]. Patient interest has been fueled by the entire process and not just that their body image is less injured by a small incision.

The improved process of THR has permitted patients to go home easily within 48 h – and often the same day with the Berger two-incision operation and process [2]. Of greater importance than early hospital discharge is that this new process permits the patient to achieve part-time return to work within 7–10 days. It also minimizes the time off work for the spouse or family of the patient. Our patients, excluding those with laboring occupations, returned to some hours of work at one week post-operative. The necessity for a patient to go to a rehabilitation ward after the operation has almost disappeared with our incidence decreasing from 40% to 2%. The cost savings to medicine and to society can be appreciated.

The process of the operation begins with pre-operative education which is conducted as a pre-operative class. This class educates the patient and his/her family to the hospital course and expectations, the implants to be used, the physical therapy to be received, the anesthesia to be used, and the nursing protocols. Therefore, the patients “know the routine” prior to coming to the hospital, and they expect to go home within 48 h unless medically this is not safe. Of equal importance is that the families expect this also and prepare for this timing of discharge.

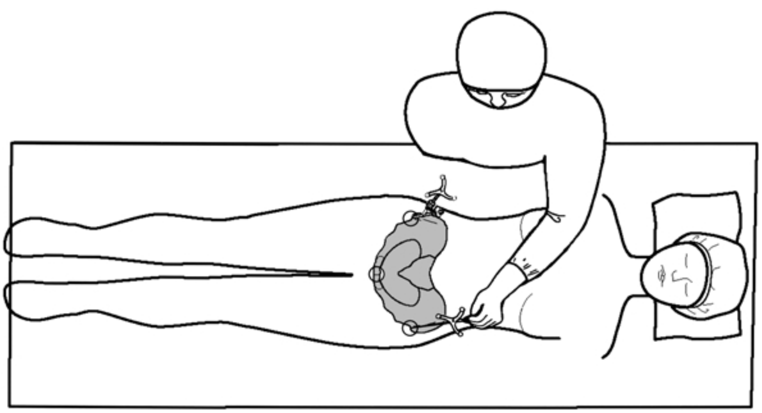
Anesthesia is best done by regional techniques of epidural or short-term spinal anesthesia [2]. We prefer epidural anesthesia to decrease the prevalence of spinal headache and permit maintenance of the epidural for 24 h in patients who have bilateral total hip replacements. The important fact is that *no* narcotics are used in the epidural or spinal. We use Ropivacaine (Astra Zeneca, Washington, DE) only. The avoidance of epidural narcotics and intravenous narcotics prevents post-operative nausea, dizziness, and emesis. This avoidance of intravenous narcotics may be the single most improvement in patient treatment for this operation because it prevents physical depression of the metabolism of the patient and the mental depression that then accompanies the physical symptoms of lethargy, dizziness, and emesis. The patient is unconscious during the operation by the infusion of propofol (Astra Zeneca, Wilmington, DE) which, when withdrawn, allows the patient to be wide awake in the post-anesthesia recovery room. This further allows the patient to be walking with physical therapy within 4 h of the operation. Oral anti-inflammatory and narcotic medications are administered one hour pre-operatively to the patient and the oral narcotics are given preemptively post-operatively [2]. By including the preemptive medications through the first two nights, the patients are able to sleep, which improves their performance with physical therapy, and their mental attitude, during the day or two of hospitalization.

Post-operative rehabilitation is simplified in this THR process. Patients are allowed to be full weight-bearing with a single crutch or cane, even when the implants are non-cemented, because implant stability and muscle function permit this. We use the anatomic porous replacement stem (APR, Zimmer, Warsaw, IN) which is anatomic and has inherent stability by design. Many other stems also permit immediate full weight-bearing post-operatively. Motivated patients with unilateral hip disease, and without medical comorbidities, can usually walk 1 mile within 2 weeks with a cane. The improvement for a patient is week by week during the first 3 months and then becomes month by month for the next 3–6 months.

Registration for Computer Navigation

Computer navigation requires data acquisition of the orientation of the pelvis in space so that this information is known while the operation is being performed. This is accomplished by registration of the anterior-posterior (AP plane) of the pelvis from which the computer software can determine the orientation of the acetabulum and acetabular component within the pelvis. The registration is done by first attaching a registration guide to the pelvis using of pins through the pelvic crest. With the infrared light-emitting diode markers (silver balls which will be called the light guide) positioned for the optical camera, the pelvis is registered by touching the pointing probe (probe) to the two anterior superior iliac spines (ASIS) and the pubis near the pubic tubercles (▣ Fig. 7.31). This registration is image-free which means that it does not require pre-operative CT scan or fluoroscopy.

After registration of the AP plane, the patient is positioned laterally and secured with thoracic and pelvic supports (▣ Fig. 7.32). The posterior supports are touched by the probe to register the position of the spine so that the software can measure the tilt of the pelvis. The pelvic tilt affects the anteversion of the cup and therefore the software will calculate the adjusted anteversion position of the cup based on the pelvic tilt. The



▣ **Fig. 7.31.** Pelvic tracking device in place and AP plane of pelvis registered by anterior superior iliac spines and pubis.

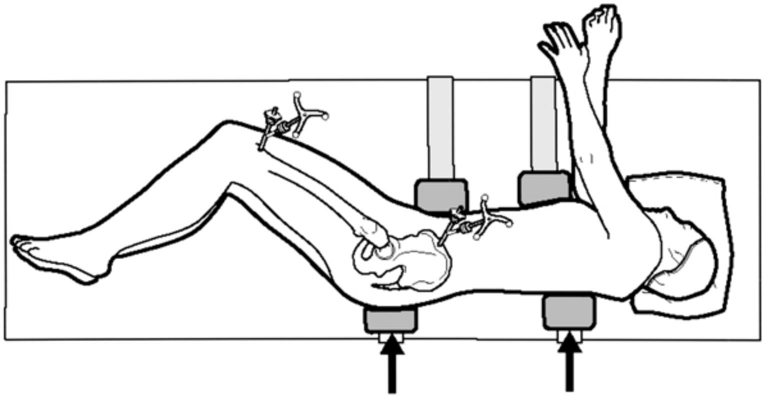


Fig. 7.32. Patient supported in lateral position with pelvis and femoral tracker in place. Posterior supports are used to register pelvic tilt (arrows)

pelvis is often tilted posteriorly when the patient is in the lateral position whereas it is tilted anteriorly when the patient is supine on the operating table. It is apparent that the knowledge of the tilt is critical to measuring the correct cup anteversion within the pelvis.

Once the skin preparation and draping has been completed, the femoral registration device is fixed. This is a 4.5 mm screw which is drilled into the distal lateral femur. A sleeve slides over the screw which has the light guide attached for registration of the femur (see Fig. 7.32). This sleeve is slotted so that it can be removed during the surgery and precisely replaced for measurements when they are performed. By registration of the femur, the computer will be able to tell the surgeon the anteversion of the femoral component, as well as the leg length and the off-set of the hip reconstruction.

This entire registration process of the pelvis and femur requires ten minutes of time in addition to the skin preparation and draping. However, the knowledge of component position and of the biomechanical reconstruction replaces several minutes of decision-making for the surgeon when using manual methods.

Technique

To accomplish this MIS operation with ease of technique and protection against excessive soft-tissue tension, specialized tools, including retractors, reamers, and implant holders, are needed. Several features are required for these instruments. Long handles are a necessity for the retractors to allow retraction with little soft-tissue tension, to keep the assistants' hands and bodies clear of the wound and the operating surgeon, and to allow the assistant to hold multiple retractors which minimizes the number of assistants needed.

The acetabular retractors are shown in Fig. 7.33 and are numbered in the order they are used at surgery, which is not the order in which they are presented in this descriptive explanation of the operation. A unique retractor (retractor #7) for the posterior capsule that has a long tip to engage the cortical bone of the cotyloid notch (just below the transverse acetabular ligament), and a paddle that sits on the ischial bone and protects

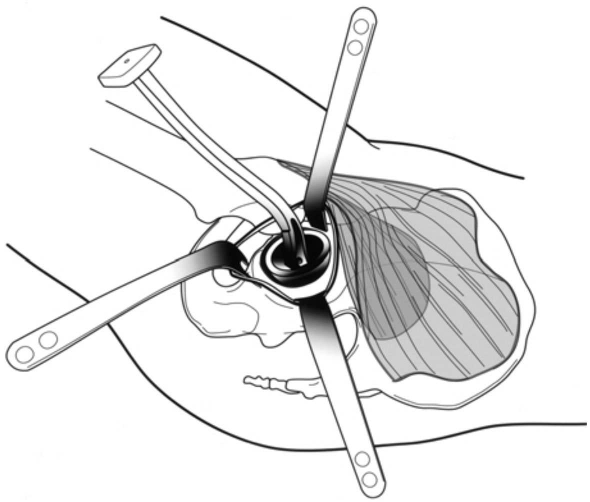


Fig 7.33. Acetabular exposure with retractor #5 at the top, retractor #4 at the lower right, and retractor #7 at the lower left. The curved reamer is placed into the acetabular cavity and it shows how the angle of the reamer permits reaming without the reaming impinging on the distal wound edge. The curved acetabular cup holder is shown during placement of the cup and illustrates how the curved holder allows the cup to be placed without the wound affecting the cup holder

the sciatic nerve as it retracts the posterior capsule, is key to complete exposure of the acetabulum. The retractor used to displace the femoral bone anterior to the acetabulum is named the "snake-retractor" (retractor #5) and was designed by Dr. Chit Ranawat (Lennox Hill Hospital, New York, NY). It has a point which is engaged on the anterior ilium, just lateral to the anterior-inferior spine, to give secure fixation for the retractor. It also has a radius of curvature which gives great leverage to retract the femur anteriorly without damage to the bone. By not placing an anterior retractor against the anterior wall of the acetabulum, both the wall is protected from breakage and the femoral nerve does not have tension on it. A posterior-superior retractor (retractor #4) has a point which can be pounded into the bone to stabilize it as it retracts the posterior-superior capsule and small external rotators.

The femoral retractors are also designed to maximize exposure of the cut surface of the femoral neck for preparation of the femur without excessive retraction force (Fig. 7.34). A new "jaws" retractor (retractor #8) was designed with a radius of curvature and a long handle which will effectively elevate the cut surface of the femoral neck into the wound by retracting the posterior-superior flap of the wound. The posterior-superior retractor for the acetabulum (retractor #4) is placed around the cut femoral neck under the quadratus femoris muscle to protect this muscle, and expose the medial cortex of the neck, during femoral preparation. The anterior skin and gluteus maximus muscle must be retracted from overhanging the greater trochanter. A trochanteric reamer (retractors #9 and #10) has two parts, which can be joined by a linking tool. Retractor #9 is for the overhanging gluteus maximus and skin, while retractor #10 is for the gluteus medius muscle. Both are not always necessary depending on the thickness of skin and fat and of the position of the gluteus medius and/or maximus muscles.

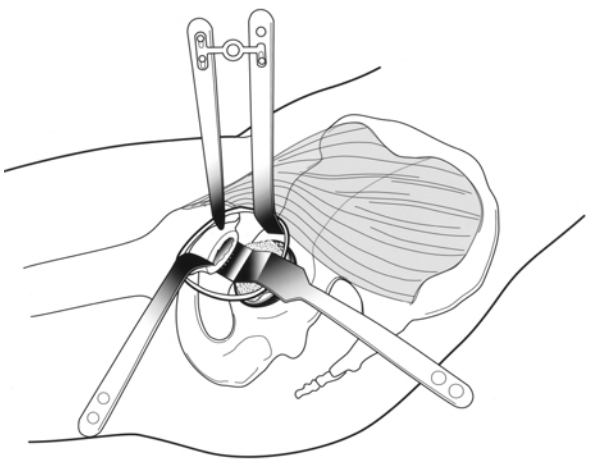


Fig 7.34. Femoral exposure with retractor #8 at the lower right, retractor #4 under the quadratus muscle, and around the medial neck at lower left, retractor #9 (more distal) and #10 (more cephalad) retracting the gluteus maximus and gluteus medius muscles. (These retractors can be joined by a link)

Soft-Tissue Exposure

The surgical technique being described is performed through an incision that is posterior to the greater trochanter (Fig. 7.35). The patient is in the lateral decubitus position and supported at the pelvis and at the chest so that there is complete stability of the body position (see Fig. 7.32). The site of the incision is absolutely critical. This incision must be on the posterior border of the trochanter, for if it is anterior to that, an extension of the incision will be necessary to provide completion of the operation. The length of the incision is proximally at the tip of the greater trochanter to distally at the level of the vastus tubercle of the femur. Therefore, the length of the incision can be changed according to the height of the patient. Very tall patients would have a longer length of their trochanter and therefore a longer incision. The best length of the skin incision is 8 cm which provides the best visual exposure for the surgeon and the assistants. An incision of 5–6 cm of the skin reduces the ability of the assistant to visualize the oper-

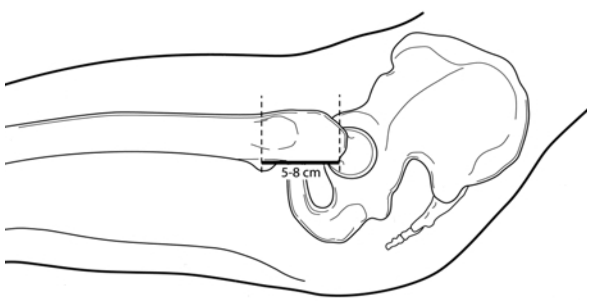


Fig. 7.35. The incision must be made along the posterior border of the greater trochanter

ation. Furthermore, this shorter skin incision does not give benefit to the patient. The length of the muscle incision, which can almost always be kept at 6 cm, is of greater importance to the function of the patient and does not change the attitude of the patient toward the cosmesis of the surgery.

The incision is made through the skin and the subcutaneous tissue and 6 cm of gluteus maximus muscle fibers adjacent to the posterior edge of the greater trochanter. Following the initial skin incision, the remainder of the exposure is done with an electrocautery Bovey. The leg is then turned into internal rotation with the knee kept in the center of the table (and on top of the lower leg). It is important *not* to let the knee drop over the side of the table because this puts too much tension on the soft-tissue structures in the posterior hip. With the leg in this position the separation between the gluteus medius muscle and the gluteus minimus muscle is divided with the surgeon's finger. This can easily be found by identifying the piriformis tendon and then sliding the finger under the gluteus medius and on top of the gluteus minimus. The gluteus medius muscle by retractor #2 is retracted from the gluteus minimus muscle. The gluteus minimus muscle is then incised to the pelvic bone beginning 3 cm superior to the attachment of the piriformis tendon because the superior edge of the acetabulum is 3 cm proximal to the piriformis tendon. The incision is continued as a single flap distally to the proximal edge of the quadratus muscle and then the capsule is divided beneath the quadratus muscle, leaving the quadratus muscle intact (Fig. 7.36). In some patients, the most superior attachment of the quadratus muscle to the trochanter must be released for 2–3 mm to relax the muscle enough that the capsule underneath it can be incised.

Once the hip is dislocated, a retractor (retractor #3) is placed around the femoral neck underneath the quadratus femoris muscle to both retract the quadratus femoris muscle from the femoral neck and to protect the sciatic nerve. The level of the femoral neck cut most often needed to recreate the off-set, and leg length for a patient is 2 cm below the distal edge of the femoral head. This can be determined by pre-operative templating, but has held to be true through our experience with hundreds of these hip replacements. Previously, we used the lesser trochanter to determine the level of femoral neck cut, but with retention of the quadratus femoris muscle this is not possible and this new technique has proved to

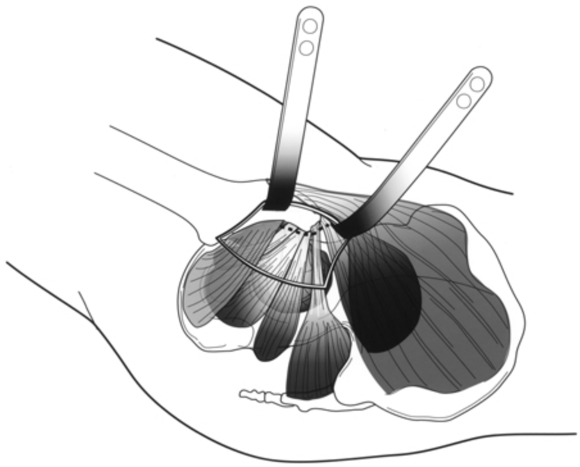


Fig. 7.36. The incision through the capsule and small external rotators is shown by the dotted line. The quadratus femoris is not incised. This flap is closed at the completion of the operation (see Fig. 7.41)

be predictable. Following removal of the femoral head, the acetabulum is able to be visualized and retractor #4 is then placed on the posterior superior acetabulum between the bone and the posterior superior capsule and external rotators. This allows excellent visualization of the superior acetabular labrum and the anterior superior capsule which overhangs the acetabulum with the femur in this position. The number #2 retractor is moved to a position behind this anterior superior capsule for ease of removal of this corner of capsule. This is the only capsule that is removed in this operation. This tissue excision relaxes the anterior capsule and the iliofemoral ligament and allows the snake retractor (#5) to be positioned on the ilium. The only other capsular incision is through the posterior medial capsule (which includes the ischiofemoral ligament). This capsular incision relaxes this contracted tissue which further allows the femur to be retracted anteriorly, as well as allowing the femur to be internally rotated and flexed. It also makes easier the placement of retractor #7 against the cortical bone of the cotyloid notch.

Computer Registration of the Acetabulum

When the acetabulum is exposed, it is registered in the computer so that subsequent reaming and component placement can be tracked. Registration is performed by touching the edge of the acetabular walls and the medial floor with the probe creating a cloud of points which outlines the geometry of the acetabulum (Fig. 7.37). A separate set of 6 points on the rim of the acetabulum allows the computer to measure the anatomic inclination and anteversion of the native acetabulum (see Fig. 7.38). In arthritic arthritic acetabulae these values are so variable that it is not prudent for the surgeon to match the acetabulum of the patient when placing the cup. These steps for registration of the acetabulum requires one minute of operative time.

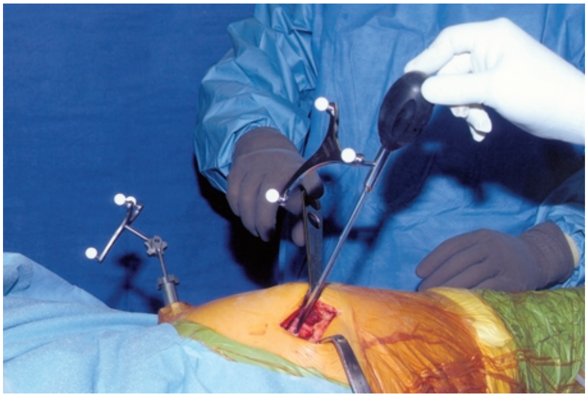


Fig. 7.37. Probe is used to map out the bony acetabulum

Reaming

Reaming is more dangerous when using a small incision because an error of reaming through an acetabular wall can occur. Reaming is significantly enhanced with the intra-operative computer. With any reamer the path of the reaming must be known by the surgeon, and the computer verifies this for the surgeon. The reamers have a light guide attached to them so that through the optical camera the computer can show the surgeon the position of the reamer in the bony acetabulum (Fig. 7.39). By approximating the reamer to the yellow dots, the surgeon knows that he/she has reamed through the acetabular ridge to the medial wall (and conversely is protected against reaming through the medial wall). Likewise, by keeping the reamer inside the red dots, the surgeon knows the reamer is inside the walls of the bony acetabulum.

Reaming is initiated by using a straight-handled reamer transversely into the acetabulum for the purpose of reaming the acetabular ridge to the level of the cortical bone of the cotyloid notch. Using "half reamers"

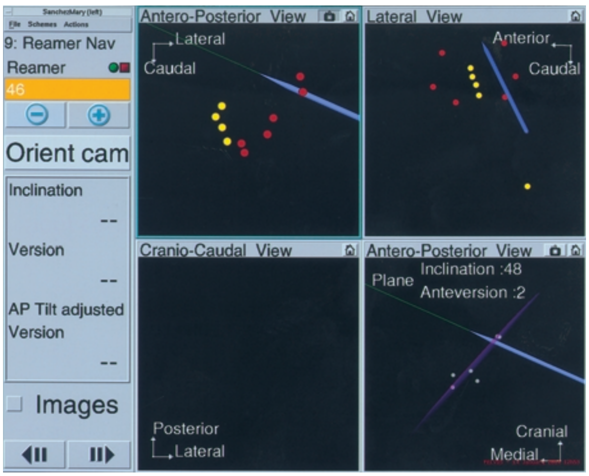


Fig. 7.38. The *red dots* are the cloud of points made to outline the acetabular wall, and the *yellow dots* the medial wall in the anteroposterior and lateral views (*top two quadrants*). In the *lower right quadrant* the cloud of points has enabled the software to calculate the inclination and anteversion of the native acetabulum

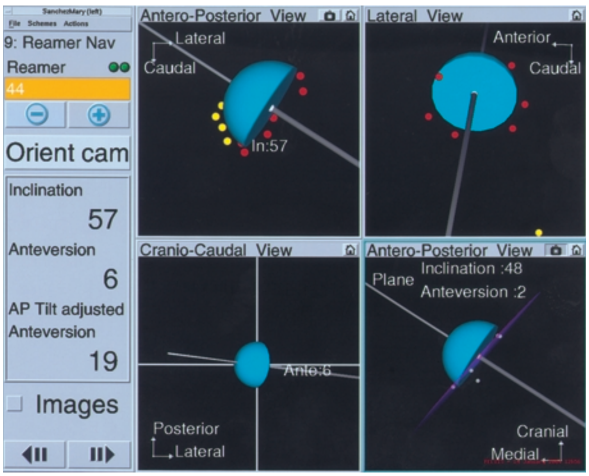


Fig. 7.39. The computer allows navigation of the reamer by tracking its path within the *red dots* and to the *yellow dots* (medial wall). The lateral view shows this reamer is slightly eccentric and reaming into the anterior wall. The *lower left quadrant* shows the anteversion of the cup relative to the plane of the pelvis without tilt. The adjusted anteversion on the *left column* indicates the adjusted anteversion is 19°. The *lower right quadrant* shows the inclination of the reamer relative to that of the native acetabulum

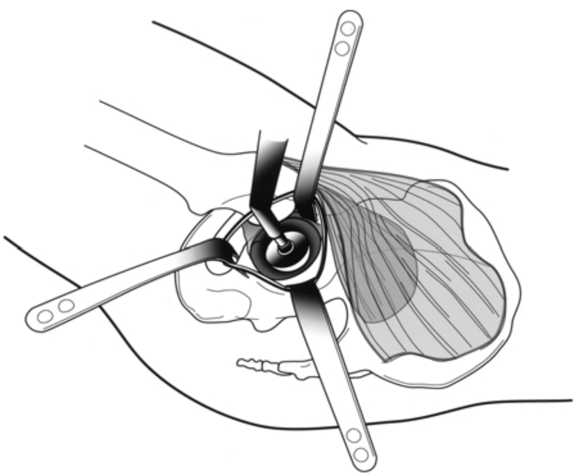
(Zimmer, Warsaw, IN) gives much better visual confirmation of the reamer position in the bony acetabulum. The anterior wall of the acetabulum is at risk for being overreamed with this preparation. The reamer must be transverse, but also anteverted between the anterior and posterior walls of the bony acetabulum so that the reamer is not pointed at the anterior wall (see ◘ Fig. 7.39). When this preparation is complete, there will be cancellous bone exposed beneath the now absent ridge, and the cortical bone of the medial wall will form the floor of the acetabulum.

Reaming is completed with the curved reamer (◘ Fig. 7.40) used to prepare a hemisphere by shaping the iliac bone of the acetabulum. If a curved reamer is not used, the superior wall of the acetabulum is at risk because a straight reamer can be levered into an adverse superior position by the handle of the reamer abutting the distal wound edge. When the surgeon becomes experienced with this reaming technique, the acetabular preparation can usually be done with two reaming steps – the use of the straight reamer once and the curved reamer once. This preparation with a curved reamer can be more precise (less reaming time) for a press-fit of the cup than was the singular use of straight reamers when a long incision was employed.

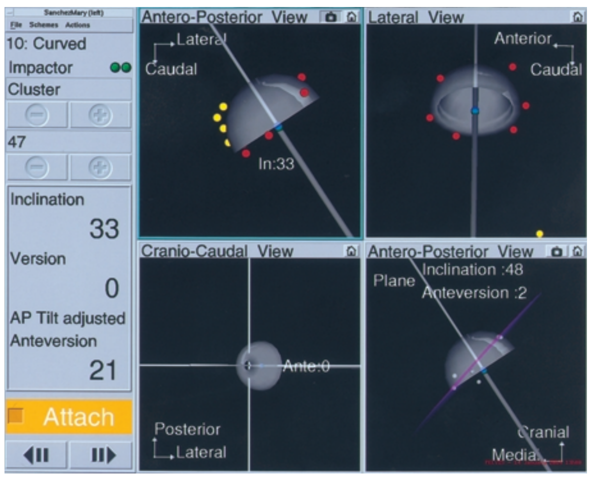
Acetabular Component Placement

A curved holder is necessary for ease and accuracy of cup position (see ◘ Fig. 7.33). Just as with a straight reamer, a straight implant holder can abut on the distal wound edge and promote malposition of both the inclination and anteversion of the cup. The cup position is most precisely implanted with the computer. The cup holder has a light guide so that the computer can measure the position of the cup relative to the pelvis. Because pelvic tilt influences particularly the anteversion of the cup, the computer provides both the absolute anteversion and the adjusted anteversion (◘ Fig. 7.41). Adjusted anteversion is the most accurate measure of the true anatomic anteversion as has been confirmed from postoperative CT scans of the pelvis. For avoidance of impingement of the femoral component on the acetabulum, the cup position of choice is 40±5° inclination and 20±5° adjusted anteversion. Acetabular position with the computer adds one minute to the surgical time (but eliminates the indecision of the surgeon as to the cup position!)

A trial acetabular component should be used for greatest accuracy of fit. Reaming the bony acetabulum 1 mm smaller than the actual implants gives even



◘ **Fig. 7.40.** The curved reamer when used can correctly shape the acetabulum into a hemisphere with the anteversion desired without the reamer impinging on the distal wound



◘ **Fig. 7.41.** The *upper two quadrants* show the cup position within the acetabular walls and to the medial wall. This patient had 21° of posterior tilt so that the importance of the adjusted anteversion is apparent. The inclination at 33° relative to the native acetabulum is shown in the *lower right quadrant*. With 33° inclination, the risk of impingement with the metal femoral neck during flexion is increased greater assurance that the fit will be secure without any adjunctive screws. A line-to-line fit with reaming is satisfactory if screws are to be used to fix the cup in every hip operation. To test the press-fit stability of the cup we try to lift the cup out of the bony acetabulum by pulling on the handle of the cup holder. If the cup moves, screws are required to provide immediate fixation stability. If manual evaluation of cup position is used, the medial edge of the cup should be level with the tear drop (the edge of the cortical bone of the cotyloid notch); the anterior edge should be about 5 mm below the pubic tubercle and preferably the metal edge of the cup is not proud above the anterior bony wall (so the iliopsoas tendon will not be irritated by the metal); superiorly, the metal edge of the cup should be below the anterior-superior acetabular bone to prevent impingement of the metal femoral neck against the metal edge of the cup in flexion; posterior superiorly there may be 5 mm of exposed metal which assures that the cup inclination does not exceed 45–50°.

Fig. 7.42. The correct leg position for internal rotation of the hip. The operated leg is placed on the lower leg in the center of the table and then internally rotated. This does not cause a stretch of the sciatic nerve. This maneuver may be necessary to allow the metal femoral neck of the stem to clear the retractors of the hip

Femoral Preparation and Implantation

Femoral preparation is performed with only the cut surface of the femoral neck as a bony reference. The quadratus femoris muscle obscures the femoral neck and lesser trochanter, although both can be felt. The use of a curved broach and implant holder will provide ease of broaching and implant placement. The computer can be used to verify the anteversion of the broach and the femoral component. The pointing probe is used to touch the surface of the metal neck and the light guides on the femoral registration device and the probe are aligned to measure the anteversion of the femoral component. This anteversion can be adjusted (or the cup position adjusted) to minimize any risk for impingement during range of motion of the hip.

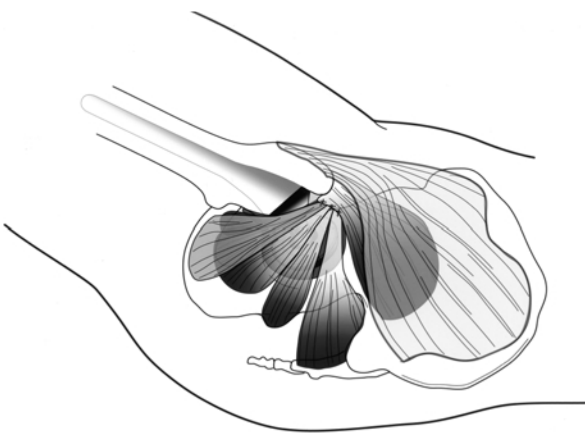
The preparation of the femoral bone can be done using either reamers and/or broaches as necessary, followed by insertion of the implant. Insertion of the implant sometimes results in the metal femoral neck impinging on the jaws retractor so that the leg will need to be internally rotated to avoid this impingement (Fig. 7.42). The internal rotation of the leg for this maneuver must be done with the leg on the table (resting on the lower leg). Internal rotation of the leg, when it is hanging over the side of the table, can stretch the sciatic nerve. In the future, the use of modular necks with the femoral component will avoid this particular technical problem. Following implantation of the femur, the femoral head is placed onto the femoral neck using a tool that allows this to be accomplished inside the small incision.

Soft-Tissue Tension and Prevention of Impingement

The correct soft-tissue tension for the hip, which includes the correct leg length and offset, and prevention of impingement of the metal femoral neck against the cup or the femur against the pelvis, must be established with the trial implants in place. The leg length and offset of the femur are measured with the computer. The desired change from the pre-operative position can be measured on the pre-operative X-ray. Almost always an increase in the leg length up to 5 mm is needed to compensate for the lost cartilage. The greater the pre-operative deformity the greater change that will occur. By using the light guide in the distal femur, the leg can be placed in the same position as the initial measurement so that any change is exact. The use of modular heads allows adjustment of the leg length and off-set to the optimal desired position.

Previously, the leg lengths were manually confirmed by the position of the lesser trochanter to the ischium inside the hip and by overlaying the leg and measuring the position of the patella and the foot of the upper leg to the lower leg. Satisfactory off-set can be manually determined by taking the hip through an entire range of motion and using the index finger of the free hand to check that the femur clears the pelvis in the maximum flexed and internally rotated position; the maximally abducted and externally rotated position; and that the lesser trochanter clears the ischium in the maximally extended and externally rotated position. This clearance should be just by one fingerbreadth. Two fingerbreadth clearance means the off-set is increased, and impingement of the bone against the bone means that the off-set is too small. When checking the clearance of the femoral bone from the pelvis, the index finger can also be used to insure that the metal femoral neck is not impinging against the metal edge of the acetabular cup.

Closure is done with the capsule and external rotators sutured to the cut edge of the gluteus minimus (▪ Fig. 7.43). This closure helps improve the function of the gluteus minimus muscle which is to contract against the femoral head and help hold it into position so that this closure gives further protection against dislocation. This closure also best eliminates any dead space between the closed capsule and external rotators and the metal femoral neck and head. A further help to reduce dead space in the closed hip is to use as large a femoral head as can be used in combination with the acetabular size. We have experienced that an additional benefit of the large femoral head will be improvement of the range of motion of the patient and further protection against impingement of either the metal femoral neck or the femoral bone.



▪ **Fig. 7.43.** The external rotators and capsule are repaired together to the cut edge of the gluteus minimus. This provides a closure without any dead space of the hip joint and also allows the gluteus minimus to improve its function which is to contract against the femoral head

Summary

Surgeons and patients must know that total hip replacement is predictable and reproducible with this posterior MIS operation or the mental and physical benefits for the patient are not of value. Studies have reported the same results with a posterior approach of 10 cm or less as have been reported with long incisions [3–5]. Our results have been summarized in two publications [2–6]. The publication of D'Gioia et al. [5] provides confirmation of the use of computer-assisted navigation for THR reconstruction. Their method used preoperative CT scans so that it is more expensive and time-consuming than our image-free method. Still, the principles remain the same.

Radiographic results showed that the average inclination angle of the acetabulum on X-ray was within 2° of that of the computer. While inclination remains the same, radiographic anteversion is, on average, 5° more than that of the computer and standing AP pelvis X-rays will measure, on average, 4 degrees more anteversion than the supine X-ray. These results demonstrate the influence of pelvic tilt in various body positions to the X-ray measurement of anteversion. The precision of the computer to provide an adjusted anteversion for the tilt of the pelvis on the operative table becomes very apparent. Our findings with these X-ray measurements compared to computer measurements are exactly the same as observed by Jaramaz et al. [7].

Since posterior MIS-THR surgery is reproducible and safe, surgeons must be aware of the desires of the patients and responsive to their needs. This is the art of medicine which heals many patients because patients get better more quickly and more easily when they are mentally confident.

The human goals of the patient must be considered in treatment decisions, and it has been observed that as orthopedic surgeons we now must make not just professional decisions, but value judgments based on human goals [8]. Because orthopedic surgeons have done so well with scientific improvements of hip replacement, we must respond to the increased social expectations of the patients who now know their lives can be improved and want that improvement with as little violation of their body as possible. The use of computer navigation permits precise reconstruction of the hip in combination with a minimally invasive operation.

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