Introduction

The recent surge in interest in minimally invasive approaches for total hip arthroplasty has captured the attention of both surgeon and patient and resulted in a proliferation of new surgical techniques. Simultaneously we are experiencing the introduction of computerized navigation systems for total hip arthroplasty that enables the surgeon to more accurately and reproducibly perform bone preparation and component insertion. Both of these new technologies are still in their infancy and will continue to evolve markedly over forthcoming years, with surgeon experience and most importantly the results of appropriately constructed and performed clinical trials directing their path. The use of computerized navigation in total hip replacement allows the advantages of minimally invasive surgery to be combined with the safety of anatomical and other information available to the surgeon previously only afforded by more invasive exposures.

Total hip arthroplasty has long been accepted as one of the most successful and cost-effective operations of the 20th century following its widespread introduction in the 1960s. Over recent decades, technological advances in this field have been directed towards aspects of component design, articular surface tribology and interface materials with little emphasis on the technique of implantation, soft-tissue handling and exact component positioning. Our assessment parameters have largely based outcomes and success upon Kaplan-Meyer survival graphs with revision or radiological failure as the end point [1].

Despite the overall success of total hip arthroplasty, one must not become complacent as there is always room for improvement. The eventual failure of the prosthesis-bone interface with aseptic loosening and articular interface wear remain ongoing long-term challenges. The short-term complications include infection, dislocation, leg-length discrepancy and impingement to name just a few [2-8].

Recently we have seen a strong push in two new areas not previously widely acknowledged in arthroplasty surgery: muscle-sparing (minimally invasive) surgery and computerized navigation techniques. The latter are able to aid the surgeon with the accurate placement of both acetabular and femoral components and provide precise leg-length measurements.

Minimally invasive surgery allows total joint arthroplasty to be performed through smaller incisions with potential early rehabilitation benefits to the patient. This trend goes against the grain of our conservative orthopedic education where we were taught that “wounds heal from side to side, not end to end” and the “big surgeon, big cut” philosophy. The reasoning behind these teachings was that a larger incision firstly allowed the surgeon to visually obtain more bony landmarks thus aiding with “eyeballing of the component position” and secondly to allow better inspection of the interfaces for component insertion, whether it be cemented or press-fit. Despite using accepted standard incisions, component position has been found to be extremely variable and poor positioning related to a decreased overall survival [9-11].

There has been a growing trend towards the implementation of minimally invasive surgical techniques throughout the western world, with wide publicity and patients frequently presenting to their surgeons, printed internet pages clutched in hand, requesting these new procedures. The factors involved with this type of introduction, namely in financed training centers and
significant printed and electronic media coverage have initially created a “market-driven demand” initially bypassing the scientific approach of publication in peer-reviewed journals. The published literature on the benefits and potential risks of these procedures has, to date, been conspicuous by its low volume [12–17] although many adequately designed prospective studies are currently underway. This I believe leaves many responsible surgeons in a difficult position with regards to when and if it is safe to employ these exciting new techniques.

The combination of minimally invasive surgery with navigation has been described as the “silver bullet” application with the minimally invasive total hip arthroplasty, providing the patient the benefits of early rehabilitation and the navigation ensuring the accuracy of component placement given the limitations of exposure [18,19]. In this chapter the practical aspects, advantages and limitations of using navigation with the double-incision and mini-posterior total hip arthroplasty are discussed.

### Computerized Navigation Units for THR

Although not yet routinely used, computerized navigation systems have become accepted in total knee arthroplasty with an increased accuracy of component placement and limb alignment being reported in the literature [20–22]. Following this initial success, a number of hip-navigation systems have been released to the market [19, 23–25]. The navigation systems all employ certain similar components:

1. **Patient trackers:** Individual trackers are fixed to the pelvis and femur. This allows the navigation unit to “see” the pelvis and femur and record dynamic movements and changes of position. The trackers may be infra-red optical or electromagnetic. The trackers may either be wired (connected by cable to the host computer), or wireless where they are battery-powered and actively transmit information via IR.

2. **Camera:** A stereoscopic camera is mounted in the operating theater within a functional range of the trackers and feeds information to the navigation computer. Newer generation machines are currently being developed with multiple cameras to provide a greater effective operating field.

3. **Navigation computer:** A laptop P4 notebook or similar computer controls the systems and provides output to the operating surgeon on a screen. The computer is usually docked into a housing station on the navigation machine, providing the interface to all components of the navigation unit.

The navigation systems differ in their need for pre-operative or intra-operative imaging. Image-based systems may either require a pre-operative CT scan with a 3-D reconstruction or intra-operative fluoroscopy for image acquisition. At our institution the time and expense of a routine pre-operative CT scan on each patient undergoing routine total hip arthroplasty was unjustifiable on a cost and resources basis and the use of intra-operative fluoroscopy was unappealing to the surgeon. Intra-operative fluoroscopy involves the use of a C arm in the operative field which may be cumbersome and requires the surgeon to wear a lead gown which is definitely undesirable!

At our institution we have chosen an imageless Stryker-Leibinger Navigation System running Hip Navigation V1.1 software module. This system requires no extra-imaging than that which the surgeon would routinely perform (routine pre-operative radiographs for diagnostic purposes). Using this system, the surgeon is required to register the frontal plane of the pelvis and sagittal plane of the femur by identifying a number of bony landmarks. This pelvic reference frame is calculated after the surgeon registers both anterior superior iliac spines and the pubic symphysis. The femoral reference frame is calculated following registration of the piriformis fossa, popliteal fossa and midpoint of the achilles tendon. A small number of ancillary anatomical points are then required to be registered throughout the procedure. The navigation system is then able to create two dynamic relational reference frames that give the surgeon anatomical information in the following:

- **Acetabular reaming:**
  - inclination and version of reamer,
  - depth to fovea.

- **Acetabular component ([Fig. 13.1]):**
  - inclination and version of component,
  - depth to fully seated.

- **Femoral broaching:**
  - predictive changes in leg length and offset not requiring trial reduction,
  - varus/valgus alignment of broaching.
Femoral stem insertion:
- predictive change in leg length and offset at the current position of the stem,
- varus/valgus alignment of stem,
- all permutations and combinations of head size and neck length.

Range of motion and stability:
- both at trial reduction and final reduction range of motion and stability are real-time 3-D modeled and recorded graphically with the graph turning red at areas of lift-off.

Surgical Technique: Minimally-Invasive Approaches for Navigated THR

The Double-Incision Approach with Navigation

As this surgical approach is covered elsewhere in this volume, only a brief summary is presented here as a reference for navigation. The Trident acetabular component (fully navigated) and the Accolade femoral stem have been chosen in our unit for double incision minimally invasive hip arthroplasties. The Accolade stem was chosen for its low profile and the suitability of instrumentation for this approach. Currently the loading of the geometric data from the Accolade stem into the navigation program is being completed. The full features of navigation of the broaching and femoral stem insertion are presently not available, but will have been released prior to publication of this book. In the following description of navigated double-incision MIS THR for broaching and femoral stem insertion the characteristics that the system will possess are outlined (as are currently available for the secure-fit femoral stem). Presently the navigation software provides complete information on acetabular cup insertion, overall leg length and femoral offset as well as joint stability and range of movement information. We currently continue to use the image intensifier for insertion of the femoral stem. In the next version of the software (Stryker Hip Navigation V1.2) the Accolade stem will be fully navigated and the use of intra-operative fluoroscopy will become obsolete.

The patient is placed on the operating table in a supine position with a one-liter sandbag on the ipsilateral side just above the buttock. The leg is routinely prepped and draped with the ipsilateral iliac crest exposed as well as the leg down to the level of the knee. A pelvic tracker is attached to the ipsilateral iliac crest and a femoral tracker fixed to the lateral femoral condyle. It is imperative that the trackers are placed in positions that are able to maintain good line of sight with the camera throughout the entire procedure. This applies especially to the femoral tracker as the leg will be flexed and externally rotated at various times in the operation (Fig. 13.2). Our recommended setup is to have the assistant standing on the ipsilateral side and the navigation unit and camera approximately 2 m away on the opposite side of the patient. The femoral tracker should be angled anteriorly, enabling it to be visible to the camera for the maximal amount of the procedure.

The first generation of trackers, apart from being large and cumbersome, were fixed to bone by threaded Steinmann pin-type devices. These usually required a 3–5 cm incision for direct application to the underlying bone. Especially at the level of the distal femur, this was seen to result in significant patient discomfort which may interfere with an otherwise rapid rehabilitation. Our current tracker design involves the use of small light-weight components fixed to the underlying bone percutaneously (Fig. 13.3). The percutaneous tripod base is applied in the position of maximal stability and then the tracker is attached by a universal elbow construct to allow optimum placement for the camera.

The anterior incision is a longitudinal incision beginning proximally at the level of the tip of the greater
Fig. 13.2. The patient is prepped and draped with pelvic and femoral trackers applied prior to the double-incision approach.

Fig. 13.3. Percutaneous tracker fixation enables minimal rigid fixation with minimal soft-tissue damage.

trochanter and extending distally for approximately 6 cm. The fascia is split at the same level and with careful blunt dissection a finger can be passed over vastus lateralis and gluteus medius and below rectus femoris directly onto the femoral neck. Specialized minimally invasive retractors and a fiberoptic light source are of great advantage at this stage in providing retraction and visibility.

At this stage, before resection of the femoral head, registration of the bony landmarks is performed. The pelvic reference plane is created by digitizing the two anterior superior iliac spines and a point on the pubic symphysis. The anterior superior iliac spines are usually easily palpable, even in the most obese patient as they are closely subcutaneous and under any abdominal adipose fold. The pubic symphysis digitization point may be more difficult in the obese patient due to the thickness of the subcutaneous fat layer directly over the symphysis. It is recommended to palpate inferiorly at the level of the suspensory ligament of the penis to obtain a more accurate point. Digitization of the pelvic reference frame is significantly easier with the patient in a supine position rather than a lateral decubitus position.

The next step involves resection of the femoral neck. This is performed through an anterior H capsulotomy and a 2-cm neck section is removed with the head left located, thus allowing the head to be removed with adequate space using a corkscrew. Through the anterior incision, good visualization of the entire acetabulum can be achieved. Further registration of the acetabular surface, the fovea and the acetabular rim can then be performed to provide additional information for the navigation system. The computer is then able to accurately calculate the diameter of the real acetabular surface, allowing the surgeon to introduce an appropriately sized reamer first up. This decreases the number of times reamers are required to be taken past the skin and soft tissues. The navigation unit also provides valuable real-time information to the surgeon about the depth of reaming with reference to the deepest point of the fovea (approximates to the medial wall).

Insertion of the acetabular shell is fully navigated, giving the surgeon information as to the inclination and version of the shell as well as telling the surgeon when the shell has been fully bottomed out to the depth of the reaming. Our preference is then to insert a non-lipped liner.

At this stage, the femoral reference plane has been registered by identifying the piriform fossa, midpoint of the popliteal fossa and mid-point of the tendo-achilles. The longitudinal axis of the femur is then calculated with a sagittal plane and a coronal plane calculated at right angles to this.

The superior incision (approximately 4 cm in length) is then made in line with the proximal femoral axis. This can be best performed by passing a large pair of dissecting scissors retrograde from the cut surface of the femoral neck through the gluteus medius and gluteal fascia. The skin incision can then be made directly over the palpable scissors. The femur can then be broached to the templated size. The navigated broach will provide information as to the varus/valgus alignment of the broach, the amount of anteversion and the predictive
change in leg length and offset if the hip were to be reduced with the broach at that level. The navigation system will then provide the same information to the surgeon for the insertion of the definitive femoral stem. The predictive information is able to decrease the amount of trialing required which may be difficult with double-incision procedures. It is likely with navigation of both the broaching and femoral stem insertion better control of version will be able to be obtained, thus decreasing the incidence of femoral calcar fracture.

The Mini-Posterior Approach

Once again as the operative techniques of the mini-posterior approach have been adequately covered elsewhere in this volume, it will not be covered in detail here, only in combination with navigation. The implants used in our mini-posterior navigated THR are the Trident acetabular component and the Secure-fit femoral stem. All components are currently fully navigated, allowing the software to provide “look ahead” predictive features, which are of benefit in limited approaches. Our unit also performs a cemented Exeter through a mini-posterior approach and will perform this navigated in the next version of the software when the Exeter data is also available in the navigation software.

For the mini-posterior navigated THR the patient is placed in a lateral position with both anterior and posterior supports. We currently leave the posterior support a little loose, allowing the patient to be rolled back slightly following prepping and draping. This allows for easier digitization of the contra-lateral ASIS as this may be difficult to accurately identify if covered by a brace. Other units have employed different techniques to overcome this, including insertion of the tracker and performing the registration process with the patient supine prior to prepping and draping. This technique requires re-prepping of the tracker pin and wound site when the patient has been turned and placed in the lateral decubitus position.

The second difference with the navigated mini-posterior approach is the placement of the distal femoral tracker. As the hip is dislocated into a posterior position with 90° of internal rotation of the femur, the tracker should be angled posterior to the sagittal plane to enable it to remain visible to the camera following internal rotation.

The Future of Navigation with Minimally Invasive Total Hip Arthroplasty

As with many other fields of surgery, the uptake of minimally invasive total hip arthroplasty has been rapid and led by patient demand. It is likely to have already made permanent changes to the ways in which we perform our surgery, the instruments we use and the expectations of our patients.

Already described as the “silver bullet application”, the combination of the two new technologies of minimally invasive surgery and navigation are mutually complimentary. Many early publications support the advantages of minimally invasive surgery while others report an increased incidence of complications. The introduction of navigation to the techniques of minimally invasive surgery first and foremost serve to provide increased safety for the procedure. The risks of minimally invasive surgery appear related to loss of visibility of the surgeon’s normal landmarks, and inability to adequately visualize the bone-prosthesis interface. Early work with navigation in both the double-incision- and mini-posterior approaches have shown this combination to result in superior surgery with better short-term and more reproducible results.

The future of both navigation and minimally invasive surgery will be directed by appropriately constructed prospective studies aimed at ensuring the safety of emerging surgical techniques and the clinical advantages of these techniques to the patient. We will continue to see as rapid developments in computerized navigation as we have witnessed in all aspects of the computer industry with increased accuracy and decreased size of the hardware components combined with more intuitive and smarter software.

References