Advances and Controversies in Total Hip Arthroplasty

John A Scanelli,¹ Anjan P Kaushik¹ and Quanjun Cui²

¹. Resident Physician; 2. Associate Professor and Attending Physician, Department of Orthopaedic Surgery, University of Virginia School of Medicine, Charlottesville, Virginia, US.

Abstract

Improvements in biological fixation, bearing surfaces, surgical technique and implant geometry have expanded the indications for total hip arthroplasty to younger as well as more active elderly patients, with potential to increase longevity of the implants. Managing bone loss in revision total hip arthroplasty remains one of the biggest challenges to improving outcomes. Even though considerable advances in technology have been made over the last 30 years, there is still no substitute for good surgical technique. Component malposition, polyethylene wear and infection can significantly increase the risk of failure and the need for expensive revision surgery.

Keywords

Total hip arthroplasty, revision, osteoarthritis, hip, adult reconstruction

Epidemiology

The demand for total hip arthroplasty (THA) will continue to grow as the size of a more active elderly population in the US increases and as younger patients with hip arthritis are being treated with THA. The obesity epidemic will also lead to an increased incidence of patients afflicted by hip osteoarthritis and the number of patients seeking THA. The rate of primary THA increased by 50% over a 13-year period between 1990 and 2002 in the US.¹ In 2005, 237,645 primary and 37,231 revision THA surgeries were performed in the US.² Regression analysis estimates that between 2005 and 2026, the need for revision THA will increase by roughly 150%.³ Access to THA in the US is likely to become more difficult for patients during this decade, due primarily to the anticipated retiring of senior arthroplasty surgeons and decreasing numbers of orthopaedic residents choosing to pursue careers in total joint arthroplasty.⁴

Modern Techniques in Primary Total Hip Arthroplasty

Surgical Approaches

The posterior approach to the hip joint is by far the most commonly performed exposure for THA.⁵ Lower rates of dislocation are reported with the anterolateral and lateral approaches to the hip joint compared to the traditional posterior approach. Surgeons and patients in the US are showing an increased interest in the direct anterior approach for THA because of its muscle-sparing technique. Hip precautions are not routinely necessary following the direct anterior approach. The direct anterior approach can be performed on a standard operating table or a specialised orthopaedic table. It requires the use of specialised instruments and is associated with a steep learning curve.⁶ Berend and colleagues showed a significant improvement in post-operative Harris hip scores at six weeks using the direct anterior approach compared to the direct lateral and minimally invasive lateral approach.⁷ Other studies show no difference in post-operative measures of recovery comparing the direct anterior approach to the direct lateral approach at two years.⁸ The ability of minimally invasive (MI), or minimal incision, THA to improve the clinical outcome of THA in the short and long term is controversial. Proponents of MI THA cite decreased blood loss, less post-operative pain, quicker rehabilitation and decreased length of hospital stay as potential advantages. Pour and colleagues found that improved pain management, increased pre-operative family and patient education, as well as an aggressive rehabilitation protocol made a more significant impact on patients’ recovery at six weeks after primary THA, regardless of the incision size.⁹

Navigation in Total Hip Arthroplasty

A recent meta-analysis by Gandhi and colleagues showed that computer navigation reduces the number of outliers from the ideal range of acetabular component position compared to the freehand technique.¹⁰ There is insufficient published data at present to demonstrate that computer navigation actually improves the long-term outcome of primary THA. Given the increased expense and operative time of computer navigation, it is not readily apparent that this technology is actually cost-effective and would reduce the revision burden in a way that would justify its use in routine primary THA.

Implant Design and Bearing Surfaces

Maximising the femoral head to neck ratio will minimise the risk of dislocation when the acetabular and femoral components are placed...
appropriately. Anteverision of the femoral component, neck length and femoral offset are factors controlled by the surgeon that affect the range of motion, stability, abductor tension and leg lengths of the patient. Tapered neck designs and larger diameter femoral heads (>32 mm) allow a larger arc of motion before impingement. Larger diameter femoral heads have an increased excursion distance and are associated with lower rates of dislocation. High offset stems allow the abductor mechanism to maintain adequate tension and function without over-lengthening the operative extremity. Most systems today offer increased modularity, which allows the surgeon to more closely restore the patient-specific anatomy of an arthritic hip.

Implants that rely on biological fixation have largely surpassed the use of cemented components in elective THA. Porous-coated or grit-blasted metallic surfaces provide surface area for bone ingrowth or ongrowth. Some implants are precoated with osteoconductive materials such as hydroxyapatite to further stimulate osseointegration. If either the femoral or acetabular component being used is dependent on biological fixation, it is imperative that immediate stability of the component be achieved before leaving the operating room to maximise the chance of osseointegration. When too much relative motion occurs at the implant-bone interface, fibrotic scar tissue forms instead of bony integration into or onto the prosthesis.

The ideal bearing surface has a low coefficient of friction, is resistant to third body damage and generates minimal wear debris. Although titanium has many applications for use in orthopaedic surgery, it is a poor bearing surface, scratches easily and generates significant wear debris. Alternative bearing surfaces such as ceramic-on-ceramic, metal-on-metal, and ceramic-on-metal were developed to avoid the complications of late polyethylene wear and to provide a durable solution for younger THA patients. These bearing surfaces are expensive and their use in elderly patients may not be justified compared to the traditional metal-on-polyethylene coupling. Bozic and colleagues used the Nationwide Inpatient Sample database to assess bearing surface use in primary THA between October 2005 to December 2006 and found 33 % of patients over 65 years of age received a hard-on-hard bearing couple. Overall, the breakdown of bearing surface use in the Medicare population they studied was 51 % metal-on-polyethylene, 35 % MOM and 14 % ceramic-on-ceramic.

Improvements in the manufacturing of ceramics and the design of the Morse taper have substantially decreased the risk of catastrophic fracture that was seen with earlier types of ceramic implants used in THA. Ceramic bearings generate relatively inert wear debris and are also highly scratch resistant. Squeaking is a rare complication of ceramic-on-ceramic bearings. Deep flexion or repeated microseparation between the femoral head and acetabular component during the swing phase of gait results in edge loading, which can produce stripe wear. This abnormal contact between the femoral head and acetabular component hinders the development of a fluid layer between the bearing surfaces, which can also result in early failure of the implants.

Metal-on-metal Total Hip Arthroplasty

MOM bearing surfaces have a 200-fold decrease in volumetric wear rate compared to conventional metal-on-polyethylene coupling. Metal wear debris is more abrasive and generates nanometre-sized particles that are ingested by lymphocytes compared to polyethylene debris, which are processed by macrophages. MOM bearing surfaces eliminate the problem of polyethylene debris and allow for larger head sizes, which confer more stability. However, concerns have recently been raised regarding the safety of MOM hip replacements. The ASR™ XL Acetabular System and the ASR™ Hip Resurfacing system (DePuy Orthopaedics, Inc., Warsaw, Indiana) have been voluntarily recalled because of unexpectedly high failure rates. In April 2010, the Medicines and Healthcare Products Regulatory Agency (MHRA) in the UK issued a medical device alert to notify public that there is a higher than expected rate of failure with some MOM hip replacements. There is no reliable method of determining which patients will develop hypersensitivity to metal wear debris at present.

The debris generated by MOM bearing couples can produce a local delayed-type hypersensitivity response, more commonly referred to as aseptic lymphocytic-vasculitis associated lesions (ALVAL), which is frequently found on histology sections surrounding loose MOM components. These pseudotumours (see Figure 1) are thought to represent either a hypersensitivity response to a normal quantity of wear debris, or a toxic reaction to a large amount of metal debris. Browne and colleagues retrospectively reviewed the cause of revision for MOM hip arthroplasties over a three-year period at a referral institution and found metal reaction (27 %), aseptic cup loosening (22 %) and infection (19 %) were the three most common reasons for MOM revision.

Although increased levels of systemic and urinary metal ion levels of cobalt and chromium have been found in patients with MOM hip arthroplasties, their risk of cancer is the same as the general population. Because the long-term effects of MOM bearings are not currently understood, MOM is not recommended for women of childbearing age or patients with renal insufficiency. Its current use has declined substantially in the US. Algorithms for monitoring patients with MOM hip replacements and factors that influence the need for revision continue to evolve.

Options in Revision Total Hip Arthroplasty

Acetabular Revision

The goals of acetabular reconstruction include minimising the amount of host bone reamed to maximise the amount of contact with the component, restoring the native hip centre if possible, ensuring the hip joint is stable and minimising any difference in leg lengths. Biological fixation is preferable over cemented components in most revision situations and requires >50 % contact of the porous-coated acetabular component with host bone.

The type of implant and reconstructive plan for acetabular revision depends largely on the amount and location of bone loss. Often the amount of bone loss encountered intra-operatively is more than was anticipated before surgery. Anticipating this and being prepared by having backup options available to manage this scenario cannot be overemphasised.

Extra-large uncemented hemispherical components or jumbo cups (diameter >62 mm in women and >66 mm in men) are frequently used in the surgical management of revision THA in the setting of significant bone loss in the US. There are good data to support use of these components in the short and midterm. Placement of a standard acetabular component with a high hip centre to maximise contact with host bone should be avoided. Disadvantages of a high hip centre include increased risk of impingement of the femur on the pelvis and decreased soft tissue tension; both factors contribute to an...
increased risk of dislocation. Restoring leg lengths is also more difficult to achieve when a component is placed with a high hip centre.

When there is deficient bone stock that precludes the use of biological fixation, morselised or structural bone grafts can be used to fill these defects and are protected with an antiprotrusio ring or reconstruction cage. These devices function to shield the bone graft from enough stress to allow them to incorporate with the host bone. The acetabular reinforcement ring, or roof ring, was initially designed as a solution for the superolateral acetabular deficiency frequently seen in developmental dysplasia of the hip. This has largely been replaced by the use of jumbo cups and metal augments. The bilobed or oblong cup is also another reconstruction option for superolateral acetabular deficiency.

Antiprotrusio reconstruction cages are capable of spanning larger defects than roof rings. The reconstruction cage must be malleable enough to contour intra-operatively; therefore it is dependent on mechanical fixation and is prone to fatigue fracture, which compromises the long-term survivorship of these constructs. A polyethylene liner is cemented into the cage with the appropriate anteverision and inclination. Although this technique is less expensive than many of the porous coated and trabecular metal shells, antiprotrusio cages have largely fallen out of favour in the US to implants capable of biological fixation when there is enough host bone to reliably achieve this. Failure of the bone graft to incorporate into the surrounding host bone, or late re-absorption of the bone graft, are complications of antiprotrusio cages.

Impaction grafting is another technique used to restore bone stock to a deficient acetabulum with a cavitary defect. After the defect is filled with cancellous bone graft, a polyethylene cup is cemented in place and weightbearing is restricted post-operatively for the first 6–12 weeks to allow the graft to incorporate.

Trabecular metal augments can be used to fill superior bone defects that would otherwise prevent the use of a porous coated uncemented hemispherical cup. The advent of the cup-cage construct is gaining increased popularity as a reconstruction option. It is designed to take advantage of the ability of trabecular metal to serve as a bone void filler and achieve biological fixation in situations where host bone is minimal. Trabecular metal cups and augments are protected by reconstruction cages, which are placed within the metal cup and secured to the pelvis with screws for immediate fixation.

Management of massive acetabular bone loss or pelvic discontinuity with a triflange cup provides several advantages for these difficult revision scenarios compared to other current implant options. The triflange cup is designed specifically for each individual patient modelled off a computed tomography (CT) scan of the affected hemipelvis. Because the surgeon does not need the flexibility of the anti-protrusio cages to bend the flanges to accommodate the specific defect intra-operatively, the component can be made of a more rigid metal that is suitable for biological fixation. The hip centre can also be more closely restored to normal because the component is custom-made. Disadvantages include an expensive implant that takes several weeks or months to produce. Christie and colleagues reported on their series of 67 revisions utilising the triflange cup in which no cups were removed at an average follow-up of 53 months and Harris hip scores improved from a mean pre-op 33 to 82 post-operatively. There was a 7.8 % revision rate for dislocation.
Over time, wear debris generated from the polyethylene bearing surface is absorbed by macrophages and results in activation of osteoclasts that re-absorb host bone surrounding the implants. This process results in aseptic loosening of the components, which is the most common cause of late failure in an otherwise successful primary THA. The use of bisphosphonates is currently being investigated as a way to reduce this host immune response that leads to bone resorption. Liner exchange without revision of the acetalubar metal shell can be performed if the acetalubar component at the time of surgery is well-positioned and fixed. Although liner exchange is technically straightforward, there is a high risk of dislocation associated with this procedure. Boucher and colleagues reported a 25 % dislocation rate for liner exchange in a patient series over a 4.5-year follow-up period. Some implant systems have deficient liner locking mechanisms that are thought to contribute to this increased dislocation rate.

**Femoral Component Revision**

For femoral components that require revision, deciding whether to replace bone loss with allograft or metal is an important step in the pre-operative plan. The American Academy of Orthopaedic Surgeons (AAOS) and Paprosky classification are helpful for guiding reconstructive strategies for managing femoral bone loss. Any loss of cortical bone is referred to as a segmental defect, which can be circumferential or non-circumferential. Cavitary defects involve variable degrees of cancellous bone loss with an intact femoral cortex. Combined defects, ecstasia or change in the shape of the femoral canal, malalignment, femoral stenosis or femoral discontinuity are also used to describe types of proximal femoral bone loss.

The Paprosky classification provides a treatment algorithm according to the type and amount of femoral bone loss encountered at the time of revision surgery. When there is minimal cancellous bone loss and an intact diaphysis, cemented or cementless implants can be used. For loss of metaphyseal bone, where cement fixation is questionable but is mechanically supportive, the authors recommend extensively porous coated stems that achieve diaphyseal fixations or a femoral implant that is capable of obtaining immediate stability in the metaphyseal region. For situations in which the metaphysis is not supportive and there is >4 cm of intact diaphyseal bone, longer implants or modular tapered revision femoral components (see Figure 2) that can achieve a scratch fit distally in the diaphysis are preferred.

Femoral component revision may require extensive exposure such as trochanteric osteotomy and specialised instruments for implant extraction. Proximal femoral bone loss from stress shielding or osteolysis makes it difficult to achieve durable implant fixation in this region of the femur at the time of revision surgery. Modern implant design now relies on diaphyseal fixation distally to overcome the torsional forces that frequently caused loosening of earlier revision femoral components in the setting of proximal femoral bone loss.

Slots or flutes created in the distal end of the femoral prosthesis decrease stem stiffness that theoretically reduces the risk of post-operative thigh pain that is seen with extensively porous coated stems. The slots produce a more flexible implant, which also reduces the risk of intra-operative fracture. Extensively porous-coated stems have a good track record in the revision setting; however, persistent thigh pain post-operatively and stress shielding can occur.

**Complications**

Katz and colleagues looked at Medicare claims data on patients who were treated with primary or revision THA over a one-year period and found an association between surgeon and hospital volume with rates of complications. These authors concluded that decreased surgeon volume, not hospital volume, was associated with increased mortality after revision arthroplasty, while a meta-analysis by
Orthopaedic Surgery  Hip

Figure 3: Anteroposterior Radiograph

Anteroposterior radiograph shows a loosened femoral stem with deficiency of femoral metaphyseal bone stock (A). The failed stem was revised and reconstructed using metal mesh, impaction graft, strut allograft and cemented stem (B). Radiograph was taken five years after revision surgery.

Shervin and colleagues found that high-volume THA hospitals were associated with lower rates of mortality and dislocation, but did not lower the incidence of infection or improve the functional status of patients post-operatively.28

In general, the rate of complications in revision THA is higher than in primary THA. The average length of inpatient hospitalisation is 6.2 days for revision THA and the average billed charges are US$54,553 in the US.30 One of the greatest risk factors for early failure of a primary THA is poor surgical technique resulting in inappropriate positioning of the components and inadequate soft tissue tension. This will lead to accelerated wear of the bearing surface and can also increase the risk of dislocation when early impingement of the femoral neck against the acetabulum or pelvis occurs within the patient’s functional range of motion.

The three most common causes of late failure in an otherwise successful primary THA are mechanical loosening, instability and infection. Neurovascular injury is dependent on the type of surgical approach, as well as the use and location of acetabular screws. Lengthening the operative leg more than 2 cm puts the sciatic nerve at increased risk for injury.

The reported rate of dislocation following primary THA is 1–3 % compared to 7 % for revision THA. Risk factors for dislocation include previous hip surgery, trochanteric nonunion and component malposition. The use of larger femoral heads has substantially reduced the rate of dislocation.

The rate of deep infection following primary THA in the US is 0.2 and 4–6 % for revision THA. A study by Bozic and colleagues found the cost of revision THA for infection is 2.8 times higher than revision THA for aseptic loosening and 4.8 times higher than primary THA.31

Peri-operative Care

Although the technical aspects of surgery are essential to a successful THA, the importance of pre-operative counselling for patients and family members and peri-operative management of medical co-morbidities are necessary to ensure an optimal outcome. The surgeon needs to develop strategies that focus on prevention of infection, pain control, DVT prophylaxis, physical therapy and management of medical co-morbidities. Enlisting the support of an internist in the peri-operative setting can help minimize the risk of medical complications including myocardial infarction, stroke, hypoxia and acute renal failure.

The use of peri-operative antibiotic prophylaxis reduces the risk of deep infection. The use of specialised operating theatres with positive pressure, laminar airflow and body exhaust suits are also designed to minimise the risk of infection. Longer operative times, transfusion of allogenic blood products and prolonged wound drainage are associated with increased risk of infection. The use of a post-operative drain and the indications for blood transfusion are still controversial.

The risk of DVT and PE after THA without prophylaxis ranges from 39–74 % for DVT and 0.19–3.4 % for pulmonary embolus.32,33 There is at present a lack of consensus amongst physicians about which form and duration of DVT prophylaxis best reduces the risk of blood clots while concurrently minimising the risk of developing bleeding after surgery. Many surgeons will utilise some form of chemoprophylaxis (aspirin, low molecular weight heparin, fondaparinux, or warfarin) and mechanical compression devices combined with early mobilisation.

Spinal or epidural anaesthesia can be used in conjunction with general anaesthesia. Many surgeons are utilising multi-modal treatment plans to limit the amount of post-operative pain and the side effects of narcotics. Regional anaesthesia, or lumbar plexus blocks, can provide a single dose or continuous dose of anaesthetic to help reduce the amount of acute post-operative pain. Some treatment regimens include pre-medicating with gabapentin and anti-inflammatory agents. A recent meta-analysis determined that there are not enough randomised controlled trials to determine the clinical effectiveness of regional anaesthesia on improving mortality, cardiovascular morbidity, or the incidence of DVT or PE.34

Early mobilisation and physical therapy are ideally started the day of or after primary THA. Physical therapy restrictions are usually determined by the surgical approach. No precautions are generally prescribed when the direct anterior approach is used. If a trochanteric osteotomy is performed, passive adduction of the operative leg past the midline and active abduction is also restricted. Standard hip precautions that accompany the posterior approach include limiting hip flexion beyond 90 degrees and restricting internal rotation and adduction.

Conclusion

Total hip arthroplasty continues to be one of the most effective operations addressing hip arthropathy. The demand for primary and revision THA will continue to grow. Improvements in surgical technique, biological fixation and bearing surfaces have expanded the indications for THA to younger as well as more active elderly patients, with potential to increase longevity of the implants.
Managing bone loss in revision THA remains one of the biggest challenges to improving outcomes. Even though considerable advances in technology have been made over the last 30 years, there is still no substitute for good surgical technique. Component malposition, material wear and infection can significantly increase the risk of failure and the need for expensive revision surgery.