Early release, published at www.cmaj.ca on October 21, 2013. Subject to revision.

Surgical management of hip osteoarthritis

Rajiv Gandhi MD MS, Anthony V. Perruccio PhD, Nizar N. Mahomed MD ScD

Osteoarthritis is a leading cause of pain, disability and health care use among adults. The hip is the second most common large joint affected by osteoarthritis.[1–3] Although research has advanced our knowledge of osteoarthritis, no therapies currently exist that halt progression of the disease. In many cases, the disease progresses to damage and destruction of the joint. Consequently, orthopedic surgery has a critical role in the management of osteoarthritis.

More than 30 000 hospital admissions for hip replacement and revision surgery were reported across Canada in 2008/09, a 63% 10-year increase.[4] Aging of the population; increased longevity, arthritis prevalence and rates of obesity; and expanding indications for hip surgery portend a continuing upward trend in demand for surgical management of hip osteoarthritis.

Although there have been many advances in surgical techniques and approaches for hip osteoarthritis, debate continues on the optimal management for the individual patient. In this review, we discuss indications for surgery, review surgical approaches and component materials, and suggest future directions. We reviewed randomized clinical trials, meta-analyses, and prognostic, observational and retrospective studies (Box 1).

When should patients be referred for surgical assessment?

Referral for surgical assessment should be considered for patients who experience hip symptoms (e.g., pain, restricted function and stiffness) that substantially affect quality of life and are unresponsive to pharmacologic and nonpharmacologic treatments.[5–7] Evidence suggests that early referral, before extensive functional limitation and pain, and early intervention are associated with better patient-reported pain and function following surgery (Table 1).[8–15]

Although patient-specific factors, including age, sex, obesity and comorbidities, may variably influence patient-reported outcomes after surgery (Table 2),[16–18] there is no suggestion that these factors should be barriers to referral, and these factors are not used for wait-list prioritization. Even if certain subgroups fare less well after joint replacement, this does not mean that, on average, they do not receive benefit.[18] Further, there is no consensus on the use of scoring tools or algorithms by which referral is based on a specific threshold being reached.

Glycemic control is critical because diabetes confers an increased risk of deep infection (relative risk 2.11, 95% confidence interval [CI] 1.41 to 3.17) after surgery.[19] Also, cessation of smoking for 6–8 weeks before intervention has been shown to decrease wound complications (absolute risk reduction of 26%).[20] Among patients taking newer-generation antiplatelet agents such as clopidogrel, it is recommended that these medications be stopped 7 days before surgery, particularly if spinal or epidural anesthesia is being considered.[21] Finally, hip replacement should be delayed 1 year after cardiac stent placement.[22] Individual risk–benefit evaluation is essential.[21,22]

Competing interests: Rajiv Gandhi has received speaker fees from Smith & Nephew and conducted research funded by Bayer. Nizar Mahomed has received speaker fees from Smith & Nephew, and his institution has received research funds from Smith & Nephew and Biomet. No competing interests declared by Anthony Perruccio.

This article has been peer reviewed.

Correspondence to: Nizar N. Mahomed, nizar.mahomed@uhn.ca

CMAJ 2013. DOI:10.1503/cmaj.121584

Box 1: Summary of literature review

We performed a literature search of PubMed (1980 to January 2013), Embase (1980 to January 2013) and MEDLINE (1950 to January 2013) databases. We used a combination of Medical Subject Headings, including "hip replacement," "hip arthroplasty," "hip resurfacing," "metal-on-metal," "ceramic hip," "minimally invasive hip surgery," "mini-incision hip surgery," "hip replacement outcomes," "metal-on-polyethylene hip replacement," "revision hip replacement" and "meta-analysis." Reference lists of selected articles were also reviewed for additional studies. Two of us abstracted and reviewed all data. We included the best evidence, including clinical trials, meta-analyses, prognostic studies, observational studies and retrospective studies, as available.

Key points

- Total hip replacement with a metal-on-polyethylene bearing surface remains the "gold standard" for the treatment of end-stage hip osteoarthritis, providing reliable improvement in pain and function with consistent implant longevity.
- Registry reports suggest an increased rate of revision for hip resurfacing compared with total hip replacement, particularly among female patients.
- A further registry report showed an increased failure rate of metal-on-metal bearing surfaces compared with ceramic and polyethylene at 7 years.
- The outcomes of revision total hip replacement are poorer than those of primary replacement, with patients reporting worse pain and poorer function at 5 years after revision surgery.

Table 1: Associations between early referral and postsurgical outcomes

Study	Design	Duration	Patients	Comparisons/ evaluations	Outcomes
Fortin et al.[8]	Observational; longitudinal	Preoperative to 6 mo after hip replacement	*n* = 116, undergoing total hip replacement for osteoarthritis	Compared 6-mo outcomes between those with "high" (better) and "low" (worse) function preoperatively	SF-36 physical function score,* WOMAC pain score,† WOMAC functional limitation score,‡ hip range of motion: mean difference (high–low) (95% CI) 16.4 (7.3 to 25.5), –1.9 (–3.0 to –0.7), –5.9 (–9.7 to –2.1), 12.8°, respectively (i.e., worse 6-mo status among those with worse function preoperatively).
Garbuz et al.[9]	Observational; longitudinal	From placement on waiting list to 1 yr after hip replacement	*n* = 147, undergoing total hip replacement for osteoarthritis	Examined probability of achieving better than expected outcome at 1 yr based on "long" (> 6 mo) v. "short" (≤ 6 mo) wait and by count of months on waiting list from decision to proceed with surgery to operation	Better than expected v. not better than expected WOMAC outcomes. 43% of patients with short waits v. 31% of those with long waits achieved better than expected functional outcome. Those with long waits had 50% decreased odds for achieving a better than expected outcome compared with those with short waits. Each additional month spent waiting was associated with an 8% decreased odds (adjusted OR 0.92, $p = 0.05$) of better than expected functional outcome. No evidence of negative effect of wait time found for WOMAC pain and stiffness domains.
Vergara et al.[10]	Observational; longitudinal	Preoperative to 6 mo after hip replacement	*n* = 527, undergoing total hip replacement for osteoarthritis	Examined predictors of change in WOMAC domains over 6 mo, and predictors of achieving minimal clinically important difference on WOMAC domains, including presurgery status and wait time	WOMAC pain score, WOMAC functional limitation score, WOMAC stiffness score.§ Change in function was poorer ($p = 0.025$) among those who waited > 6 mo for surgery. Progressive reduction in % of patients surpassing minimal clinically important difference with increasing wait time; 74% v. 68% v. 52% for those waiting < 3 mo, 3–6 mo and > 6 mo, respectively ($p < 0.001$). Likelihood of perceiving a gain greater than minimal clinically important difference was lower (OR 0.47, $p = 0.006$) with > 6 mo wait compared with < 3 mo wait. No effects on other WOMAC domains observed.
Hajat et al.[11]	Observational; longitudinal	Preoperative to 12 mo after hip replacement	*n* = 3600 at 12 mo, undergoing total hip replacement (87.8% had osteoarthritis as primary diagnosis)	Examined predictors of 12-mo Oxford Hip Score status, including presurgery status and wait time	Oxford Hip Score¶ (measure of severity of hip problems: pain, disability, loss of physical function). Trend of worse 12-mo status with worse presurgery status ($p < 0.001$), longer wait to first outpatient appointment ($p < 0.001$) and longer time on wait list ($p < 0.001$).
Fortin et al.[12]	Observational; longitudinal	Preoperative to 2 yr after hip replacement	*n* = 84, undergoing total hip replacement for osteoarthritis (subset of sample from Fortin et al.[8] who completed 2-yr survey)	Compared 6-mo outcomes between those with "high" (better) and "low" (worse) function preoperatively	SF-36 physical function score,* WOMAC pain score,† WOMAC functional limitation score‡: mean difference (high–low) (95% CI) 14.7 (2.6 to 26.8), –1.5 (–3.1 to 0.1), –6.6 (–11.8 to –1.4), respectively (i.e., worse 2-yr status among those with worse function preoperatively).

Note: CI = confidence interval, OR = odds ratio, SF-36 = 36-Item Short-Form Health Survey, WOMAC = Western Ontario and McMaster Universities Arthritis Index.
*The SF-36 physical function score ranges from 0 to 100: higher scores indicate better physical health, and a minimal clinically important difference is 20 points.
†The WOMAC pain score ranges from 0 to 20 and is standardized to a range of 0 to 100: 0 represents the best health status and 100 the worst health status, and the minimal clinically important difference is 29 points.
‡The WOMAC functional limitation score ranges from 0 to 68 and is standardized to a range of 0 to 100: 0 represents the best health status and 100 the worst health status, and the minimal clinically important difference is 26 points.
§The WOMAC stiffness score ranges from 0 to 8 and is standardized to a range of 0 to 100: 0 represents the best health status and 100 the worst health status, and the minimal clinically important difference is 25 points.
¶The Oxford Hip Score ranges from 0 to 48: 0 represents maximum disability and 48 no disability, and the minimal clinically important difference is between 4 and 6 points.

What surgical options are there?

In the early stages of osteoarthritis, joint-preserving procedures such as pelvic osteotomy (for insufficient acetabular coverage of the femur) or hip arthroscopy (for femoroacetabular impingement) may be considered depending on the patient's underlying diagnosis. These procedures are generally not recommended for patients with advanced degenerative changes. Patients with

Table 2: Patient-specific factors as predictors of patient-reported outcomes following total hip replacement

Study; variable	Outcomes (generally assessed between 3 and 24 mo after surgery)
Ethgen et al.[16]	
Age	• Age was not a factor in pain outcomes. • Results were mixed for physical function: either no effect or older age associated with somewhat worse scores. • Reported change in pain and function were similar across age groups, but status was generally worse with older age.
Sex	• Results were mixed: either no difference in change in pain and function, or men trended toward greater improvement in function and/or pain. • Status at follow-up trended toward better among men.
Ethnicity	• Black patients had less change in pain and function than white patients.
Obesity	• Higher BMI was generally associated with greater change in pain and function, but worse status.
Education	• Range of health-related quality-of-life outcomes: higher educational attainment was generally associated with greater improvement.
Comorbidity	• Greater levels of comorbidity were generally associated with less improvement in pain and function. • The influence appeared to be greater among older age groups.
Jones et al.[17]	
Age	• Older age at surgery was associated with greater satisfaction.
Obesity	• Results were inconsistent for health-related quality-of-life outcomes. • Generally, no influence was identified; some patients reported worse postoperative pain and functional status.
Mental well-being	• Preoperative psychological status explained some variation in postoperative pain and function. • High levels of anxiety or depression were associated with worse outcomes.
Comorbidity	• A greater number of comorbid conditions were associated with worse short-term pain and functional outcomes. • The overall impact appeared to be relatively small. • The influence of older age was believed to be mediated through number of conditions.
Santaguida et al.[18]	
Age	• Results were inconsistent for revision surgery; younger patients were at somewhat greater risk at 2–20 yr. • Older age was associated with greatest risk of death at 30–90 d. • Older age was associated with poorer function, though not when assessed using WOMAC. • Age was not associated with postoperative satisfaction, but older age was associated with less satisfaction after revision surgery.
Sex	• Results were inconsistent for revision surgery; men were at somewhat greater risk, particularly younger men. • Men were generally at greater risk of death at 30–90 d. • Women generally had poorer function, showed less functional improvement and showed less postoperative pain. • Sex was not associated with satisfaction following the primary procedure, but women reported less satisfaction following revision surgery.
Obesity	• Higher BMI was associated with poorer postoperative function. • Obesity status was not associated with postoperative satisfaction.

Note: BMI = body mass index, WOMAC = Western Ontario and McMaster Universities Arthritis Index.

advanced joint damage are best referred to a surgeon to consider the options of either hip resurfacing or total hip replacement.

In a traditional hip replacement, the femoral head and damaged acetabulum are both removed and replaced with metal, plastic or ceramic components (Figure 1). Cement may be used for fixation, but most hip replacements performed in Canada are now uncemented[23] owing to longer implant survival.[24–26] Although ethical concerns, and costs, preclude clinical trials for establishing the merits of hip replacement,[27] many observational studies have shown this procedure to be highly effective (and cost-effective) in minimizing pain and restoring function.[16,28–34] Because surgical techniques and the design of prostheses and materials have improved over several decades, the risks of complications and early revisions following replacement have diminished. Rates of complications occurring within 90 days after surgery were found to be 1.0% for mortality, 0.9% for pulmonary embolus, 0.2% for wound infection, 4.6% for hospital readmission and 3.1% for hip dislocation among the US Medicare population.[35] Ten-year revision rates after surgery can range from 5% to 20%, depending on age and fixation technique.[36]

Despite the overall success of hip replacement, studies have documented that 5% to 25% of patients who undergo this procedure report minimal improvement or dissatisfaction with their outcomes.[14,16–18,37–43]

In hip resurfacing, the femoral head is left in place but trimmed and capped with a metal covering. The damaged acetabulum cartilage is removed and replaced with a metal shell, similar to a traditional hip replacement. The proposed advantages of resurfacing include bone conservation among patients likely to outlive a traditional replacement (i.e., younger patients), improved hip range of motion and the potential for allowing younger patients an increased level of activity. Reported disadvantages include increased risk of femoral neck fracture, more bone loss on the acetabular side, a more difficult operation requiring larger incisions, and increased risk of systemic exposure to metal ions resulting from wear of the metal-on-metal bearing surface.[44–49]

Hip resurfacing is predominantly considered for the young active patient with end-stage osteoarthritis.[47] Early and mid-term follow-up generally has shown comparable results to those of standard replacement.[50–59] However, complications particular to this procedure have been identified (as stated previously), and emphasis is placed on patient selection, component selection and surgical technique to avoid poor and adverse outcomes and short-term failures.[44,47,60–70] Many surgeons avoid resurfacing in postmenopausal women because of an increased risk of femoral neck fracture, and in those with known renal insufficiency owing to the potential for metal ion accumulation.

Earlier generations of resurfacing devices frequently failed, often because of problems with excessive wear of the bearing surface materials. Since then, improvements in surgical technique and design have led to a renewed interest and use of hip resurfacing.

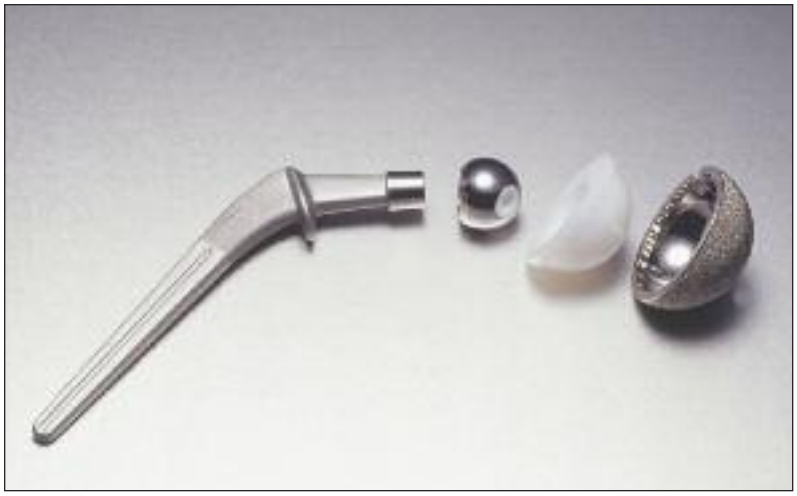

Figure 1: Components of traditional hip replacement.

Is hip replacement or is hip resurfacing the best approach?

Matched comparative studies and clinical trials have compared short- and long-term outcomes of hip resurfacing versus hip replacement (Table 3).[48,56,58,70–73] One of the larger matched studies with 5-year follow-up compared patients who had undergone hip resurfacing with those who had undergone traditional hip replacement.[56] The authors found that the hip resurfacing group were more active in running (58.5% v. 13.7%, $p < 0.001$), sports (73.6% v. 33.3%, $p < 0.001$) and manual labour (60.4% v. 39.2%, $p = 0.049$).[56]

The consensus from 3 clinical trials[70,71,74] is that hip resurfacing has no added advantage with respect to gait speed, stride length, stair climbing,[71] range of motion[74] or health-related quality of life.[70,71,74] One study found that a substantially higher number of patients who had undergone hip resurfacing returned to moderate or high activity levels 1 year after surgery (77%) compared with those who had undergone hip replacement (39%).[75] No published trial appears to be adequately powered to compare the complication rates of resurfacing versus replacement, however.

Limited to short-term follow-up, current trial evidence does not adequately address the differ-

ence in implant lifespan between resurfacing and replacement. Norwegian[73] and Australian[72] registry data showed increased rates of revision at 2 and 5 years, respectively, for resurfacing versus replacement. Longer-term follow-up periods for present resurfacing designs are needed. A recent UK-based registry study reported high revision rates among women who had undergone hip resurfacing (8.5% at 5 yr), and the authors advocated against resurfacing in female patients.[48]

Given the added expense of implants used in hip resurfacing, a cost–benefit analysis should be considered in future trials comparing this procedure with hip replacement.

Is mini-incision hip surgery preferable to conventional hip surgery?

The traditional approaches to hip replacement are the direct lateral and posterior approaches. The traditional incision is typically 15 cm or greater in length. Differences have not been shown for dislocation, limp or function between the 2 approaches.[76] Mini-incision hip surgery was developed with the goal of decreasing tissue injury and blood loss, and improving patient outcomes. Although there is no universally accepted definition of mini-incision, many define it as an incision less than 12 cm in length. Patients considered appropriate candidates should have a body mass index of 30 or less, or a thigh circumference of less than 50 cm.[77,78] Clinical trial evidence comparing mini-incision with conventional approaches is limited (Table 4[77,79,80]). For smaller incisions, findings suggest no difference for in-hospital morphine use (mean 42.9 ± 97.4 mg v. 45.0 ± 96.8 mg, p = 0.89), and reduced intraoperative blood loss (mean 314 ± 162 mL v. 366 ± 190 mL, p = 0.03) but no difference in transfusion rates (mean 0.42 ± 0.95 units v. 0.30 ± 0.66 units, p = 0.27).[77,79,80] Differences in patient function 3 months and 1 year after surgery were not found.[80,81]

Table 3: Selected studies comparing outcomes of total hip replacement and hip resurfacing

Study	Design	Final follow-up, yr	Sample size	Outcome	Findings at follow-up (total hip replacement v. hip resurfacing)
Garbuz et al.[70]	RCT	Mean 1.1 (range 0.8–2.2)	107	WOMAC score, mean	90.1 v. 90.4, p = 0.950
				SF-36 physical function score, mean	51.2 v. 51.2, p = 0.979
Lavigne et al.[71]	RCT	1	48	Gait speed, m/s	1.46 ± 0.18 v. 1.44 ± 0.19, p > 0.05
				Step length, m	0.68 ± 0.07 v. 0.67 ± 0.07, p > 0.05
Pollard et al.[56]	Retrospective, matched cohort	5–7	108	UCLA activity score	6.8 v. 8.4, p < 0.001
				EQ-5D score	0.78 v. 0.9, p = 0.003
Smith et al.[48]	UK registry	5	> 400 000	Implant failure	Total hip replacement: 2.8% (95% CI 2.7% to 2.9%)
					Hip resurfacing: Men: 3.6% (95% CI 3.3% to 3.9%) Women: 8.5% (95% CI 7.8% to 9.2%)
Corten and MacDonald[72]	Australian registry	5	> 135 000	Implant failure	Total hip replacement: 2.7%
					Hip resurfacing: 3.7%, p < 0.001
Johanson et al.[73]	Norwegian registry	2	> 170 000	Implant failure, cumulative revision rate	Total hip replacement: 1.2% (95% CI% 1.2 to 1.3%)
					Hip resurfacing: 3.3% (95% CI 2.2% to 4.3%), p < 0.001

Note: CI = confidence interval, EQ-5D = Euro-Qol 5-dimension, RCT = randomized controlled trial, SF-36 = 36-Item Short-Form Health Survey, UCLA = University of California Los Angeles, WOMAC = Western Ontario and McMaster Universities Arthritis Index.

What are the comparative benefits and risks of metal-on-metal versus other bearing surfaces?

Metal-on-metal and other "hard-on-hard" bearing surfaces such as ceramic have gained popularity in recent decades because of their potential for less wear and improved implant longevity over traditional polyethylene bearing surfaces. To date, trial evidence has not indicated any benefit of hard-on-hard bearing surfaces over polyethylene for implant survivorship (Table 5).[82–88] A recent UK-based registry report showed higher revision rates for metal-on-metal bearing surfaces (6.57%, 95% CI 5.10% to 8.43%) compared with ceramic (3.00%, 95% CI 2.45% to 3.68%) and polyethylene (2.03%, 95% CI 1.69% to 2.44%) at 7-year follow-up.[89] The concern with metal-on-metal implants is the accumulation of cobalt and chromium ions in the body, with a potential for cardiac toxicity, local soft-tissue erosions (pseudotumours, estimated incidence of 1% at 5 yr[90]) or neurologic complications.[45,91–93] A case series that reported on early failures (within 2–3 yr of surgery) cited implant loosening in 56% of these failures, and the remainder as soft-tissue reactions, pseudotumours and persistent pain.[94] These

Table 4: Selected studies comparing outcomes of minimally invasive and standard-incision total hip replacement

Study	Design	Final follow-up	Sample size	Primary outcome	Findings at follow-up (mini-incision v. standard incision)
Dorr et al.[80]	RCT	6 mo	60	Total blood loss, mL, mean	352.3 ± 145.5 v. 408.3 ± 158.3, $p = 0.12$
				Length of stay, h, mean	63.2 ± 13.3 v. 73.6 ± 23.5, $p = 0.04$
Ogonda et al.[77]	RCT	6 wk	219	10-m walk time, s, mean	54.4 ± 29.8 v. 54.5 ± 32.7, $p = 0.97$
				Stair climbing, s, mean	19.31 ± 8.78 v. 19.58 ± 9.38, $p = 0.83$
				Hematocrit level on discharge, mean	0.275 ± 0.04 v. 0.276 ± 0.04, $p = 0.75$
				36-h VAS pain score, mean	16.8 ± 20.3 v. 19.8 ± 21.2, $p = 0.29$
Chimento et al.[79]	Retrospective, matched cohort	1	60	Total blood loss, mL, mean	378 ± 151 v. 504 ± 205, $p < 0.009$
				6-wk limp	21.4% v. 46.8%, $p = 0.04$
				1-yr limp	None
				Hospital length of stay, d, mean (range)	5.8 (4–13) v. 5.5 (3–15), $p = 0.6$

Note: RCT= randomized controlled trial, VAS = visual analogue scale.

Table 5: Selected studies comparing outcomes of metal-on-metal and metal-on-polyethylene hip replacement

Study	Design	Final follow-up, yr	Sample size	Outcome	Mean difference (95% CI) (metal-on-metal v. metal-on-polyethylene)
Dahlstrand et al.[84]	RCT	2	54	Harris Hip score	3.1 (–2.0 to 8.2)
Engh et al.[85]	RCT	2	59	Harris Hip score	4.0 (–0.4 to 8.4)
Lombardi et al.[86]	RCT	5.7	99	Harris Hip score	1.2 (–1.9 to 4.3)
MacDonald et al.[87]	RCT	3.2	41	Harris Hip score	0.4 (–7.0 to 7.8)
Zijlstra et al.[88]	RCT	10	200	Harris Hip score	1.0 (–2.9 to 4.9)

Note: CI = confidence interval, RCT = randomized controlled trial.

implants have recently garnered substantial media attention owing to some companies removing their products from the market over concerns of early failures, and owing to safety advisories from the US Food and Drug Administration and Health Canada.[95,96] Metal-on-metal bearings should be avoided in women of childbearing age because of the risk of metal ion accumulation. Patients with metal-on-metal hip replacements without symptoms should have regular follow-up by their surgeon.

Ceramic implants have not shown improved longevity over polyethylene, and they have the potential risk of fracture.[97] Further, up to 10% of ceramic hips may have an audible "squeak," which is troubling enough that patients have required revision to change the bearing surface.[98] Clinical trial data and cost–benefit analyses, with a minimum 15–20 years of follow-up, are still needed to definitively address the issue of "best" bearing surface.

What management options exist when patients require revision?

Based on expert consensus, patients with implants should be followed biennially by an orthopedic surgeon, regardless of symptoms, for clinical and radiologic investigation of implant wear. Symptoms of implant wear or loosening may include groin or thigh pain, or symptoms of hip instability (i.e., a feeling of giving way).

Revision surgery, including multiple revisions, may be required for a diagnosis of aseptic loosening of 1 or both components, recurrent dislocation or infection. For recurrent dislocation, assuming adequate component alignment, the surgical options are revision to a larger femoral head or a hip-stabilizing (constrained) acetabular component. For aseptic loosening, revision options exist; however, bone grafting, cement or metallic augments may be needed to compensate for bony defects. For infection, the common procedure is a 2-stage revision, whereby the components are removed and a temporary implant is used to deliver local antibiotic therapy in addition to parenteral antibiotic therapy. Following infection eradication, new hip implants are inserted. Length of stay in acute care after revision is generally longer than for the primary operation (6.2 v. 4.0 d), and patients report worse pain and poorer function at 5 years following revision compared with the primary surgery.[99,100]

Future directions

More people are living longer and indications for hip surgery are expanding to include younger patients, which suggest a potentially greater future demand for revision surgery. To minimize this likelihood, continued improvement of design, materials and surgical techniques are key.[101]

As indicated, there are still gaps in our understanding of the benefits and disadvantages of hip resurfacing versus hip replacement, mini-incision versus conventional approaches, and optimal bearing surfaces. These areas require further research.

Efforts in tissue engineering and biologic therapies for osteoarthritis have focused on repair of cartilage defects. Methods have included bone marrow stimulation techniques, osteochondral grafting and chondrocyte implantation.[102,103] Although many are investigating stem cell use in cartilage regeneration, limited evidence is currently available to support routine use of this technique.

References

1. Arden N, Nevitt MC. Osteoarthritis: epidemiology. *Best Pract Res Clin Rheumatol* 2006;20:3-25.
2. Felson DT. An update on the pathogenesis and epidemiology of osteoarthritis. *Radiol Clin North Am* 2004;42:1-9.
3. Zhang Y, Jordan JM. Epidemiology of osteoarthritis. *Rheum Dis Clin North Am* 2008;34:515-29.
4. *Methodological notes: Canadian Joint Replacement Registry quick stats, September 2010, 2008–2009 data; overview of hip and knee replacements.* Ottawa (ON): Canadian Institute for Health Information; 2010.
5. Dougados M, Hochberg MC. Management of osteoarthritis. In: Hochberg MC, Silman AJ, Smolen JS, et al. editors. *Rheumatology*. Philadelphia (PA): Mosby/Elsevier; 2011:1793-9.
6. Hochberg MC, Altman RD, April KT, et al. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. *Arthritis Care Res (Hoboken)* 2012;64:465-74.
7. Zhang W, Doherty M, Arden N, et al. EULAR evidence based recommendations for the management of hip osteoarthritis: report of a task force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). *Ann Rheum Dis* 2005;64:669-81.
8. Fortin PR, Clarke AE, Joseph L, et al. Outcomes of total hip and knee replacement: preoperative functional status predicts outcomes at six months after surgery. *Arthritis Rheum* 1999;42:1722-8.
9. Garbuz DS, Xu M, Duncan CP, et al. Delays worsen quality of life outcome of primary total hip arthroplasty. *Clin Orthop Relat Res* 2006;447:79-84.
10. Vergara I, Bilbao A, Gonzalez N, et al. Factors and consequences of waiting times for total hip arthroplasty. *Clin Orthop Relat Res* 2011;469:1413-20.
11. Hajat S, Fitzpatrick R, Morris R, et al. Does waiting for total hip replacement matter? Prospective cohort study. *J Health Serv Res Policy* 2002;7:19-25.
12. Fortin PR, Penrod JR, Clarke AE, et al. Timing of total joint replacement affects clinical outcomes among patients with osteoarthritis of the hip or knee. *Arthritis Rheum* 2002;46:3327-30.
13. Lingard EA, Katz JN, Wright EA, et al. Predicting the outcome of total knee arthroplasty. *J Bone Joint Surg Am* 2004;86-A:2179-86.
14. Nilsdotter AK, Petersson IF, Roos EM, et al. Predictors of patient relevant outcome after total hip replacement for osteoarthritis: a prospective study. *Ann Rheum Dis* 2003;62:923-30.
15. Röder C, Staub LP, Eggli S, et al. Influence of preoperative functional status on outcome after total hip arthroplasty. *J Bone Joint Surg Am* 2007;89:11-7.
16. Ethgen O, Bruyere O, Richy F, et al. Health-related quality of life in total hip and total knee arthroplasty. A qualitative and systematic review of the literature. *J Bone Joint Surg Am* 2004;86-A:963-74.
17. Jones CA, Beaupre LA, Johnston DW, et al. Total joint arthroplasties: current concepts of patient outcomes after surgery. *Rheum Dis Clin North Am* 2007;33:71-86.
18. Santaguida PL, Hawker GA, Hudak PL, et al. Patient characteristics affecting the prognosis of total hip and knee joint arthroplasty: a systematic review. *Can J Surg* 2008;51:428-36.
19. Pedersen AB, Mehnert F, Johnsen SP, et al. Risk of revision of a total hip replacement in patients with diabetes mellitus: a population-based follow up study. *J Bone Joint Surg Br* 2010;92:929-34.

20. Møller AM, Villebro N, Pedersen T, et al. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. *Lancet* 2002;359:114-7.
21. Steele MJ, Fox JS, Fletcher JP, et al. Clopidogrel dilemma for orthopaedic surgeons. *ANZ J Surg* 2011;81:774-84.
22. Luckie M, Khattar RS, Fraser D. Non-cardiac surgery and antiplatelet therapy following coronary artery stenting. *Heart* 2009;95:1303-8.
23. *Hip and knee replacements in Canada — Canadian Joint Replacement Registry 2008–2009 annual report*. Ottawa (ON): Canadian Institute for Health Information; 2009.
24. Corten K, Bourne RB, Charron KD, et al. What works best, a cemented or cementless primary total hip arthroplasty?: minimum 17-year followup of a randomized controlled trial. *Clin Orthop Relat Res* 2011;469:209-17.
25. Mäkelä KT, Eskelinen A, Pulkkinen P, et al. Total hip arthroplasty for primary osteoarthritis in patients fifty-five years of age or older. An analysis of the Finnish arthroplasty registry. *J Bone Joint Surg Am* 2008;90:2160-70.
26. Rothman RH, Cohn JC. Cemented versus cementless total hip arthroplasty. A critical review. *Clin Orthop Relat Res* 1990;(254): 153-69.
27. Maloney WJ. National joint replacement registries: Has the time come? *J Bone Joint Surg Am* 2001;83-A:1582-5.
28. Bunker JP, Frazier HS, Mosteller F. Improving health: measuring effects of medical care. *Milbank Q* 1994;72:225-58.
29. Chang RW, Pellisier JM, Hazen GB. A cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. *JAMA* 1996;275:858-65.
30. Davis AM, Perruccio AV, Ibrahim S, et al. The trajectory of recovery and the inter-relationships of symptoms, activity and participation in the first year following total hip and knee replacement. *Osteoarthritis Cartilage* 2011;19:1413-21.
31. Gandhi R, Dhotar H, Davey JR, et al. Predicting the longer-term outcomes of total hip replacement. *J Rheumatol* 2010;37:2573-7.
32. Jones CA, Voaklander DC, Johnston DW, et al. Health related quality of life outcomes after total hip and knee arthroplasties in a community based population. *J Rheumatol* 2000;27:1745-52.
33. Mancuso CA, Salvati EA, Johanson NA, et al. Patients' expectations and satisfaction with total hip arthroplasty. *J Arthroplasty* 1997;12:387-96.
34. Perruccio AV, Davis AM, Hogg-Johnson S, et al. The importance of self-rated health and mental well-being in predicting health outcomes following total joint replacement surgery for osteoarthritis. *Arthritis Care Res (Hoboken)* 2011;63:973-81.
35. Mahomed NN, Barrett JA, Katz JN, et al. Rates and outcomes of primary and revision total hip replacement in the United States medicare population. *J Bone Joint Surg Am* 2003;85-A:27-32.
36. Corbett KL, Losina E, Nti AA, et al. Population-based rates of revision of primary total hip arthroplasty: a systematic review. *PLoS ONE* 2010;5:e13520.
37. *NHS 2010–2015: from good to great. Preventative, people-centred, productive*. London (UK): Department of Health; 2009:30-2.
38. Levy RN, Levy CM, Snyder J, et al. Outcome and long-term results following total hip replacement in elderly patients. *Clin Orthop Relat Res* 1995;(316):25-30.
39. Anakwe RE, Jenkins PJ, Moran M. Predicting dissatisfaction after total hip arthroplasty: a study of 850 patients. *J Arthroplasty* 2011;26:209-13.
40. Hulleberg G, Aamodt A, Espehaug B, et al. A clinical and radiographic 13-year follow-up study of 138 Charnley hip arthroplasties in patients 50–70 years old: comparison of university hospital data and registry data. *Acta Orthop* 2008;79:609-17.
41. Rolfson O, Dahlberg LE, Nilsson JA, et al. Variables determining outcome in total hip replacement surgery. *J Bone Joint Surg Br* 2009;91:157-61.
42. Rolfson O, Karrholm J, Dahlberg LE, et al. Patient-reported outcomes in the Swedish Hip Arthroplasty Register: results of a nationwide prospective observational study. *J Bone Joint Surg Br* 2011;93:867-75.
43. Baumann C, Rat AC, Osnowycz G, et al. Do clinical presentation and preoperative quality of life predict satisfaction with care after total hip or knee replacement? *J Bone Joint Surg Br* 2006;88: 366-73.
44. Amstutz HC, Le Duff MJ, Campbell PA, et al. Complications after metal-on-metal hip resurfacing arthroplasty. *Orthop Clin North Am* 2011;42:207-30.
45. Kwon YM, Glyn-Jones S, Simpson DJ, et al. Analysis of wear of retrieved metal-on-metal hip resurfacing implants revised due to pseudotumours. *J Bone Joint Surg Br* 2010;92:356-61.
46. Macpherson GJ, Breusch SJ. Metal-on-metal hip resurfacing: a critical review. *Arch Orthop Trauma Surg* 2011;131:101-10.
47. Shimmin A, Beaule PE, Campbell P. Metal-on-metal hip resurfacing arthroplasty. *J Bone Joint Surg Am* 2008;90:637-54.
48. Smith AJ, Dieppe P, Howard PW, et al. Failure rates of metal-on-metal hip resurfacings: analysis of data from the National Joint Registry for England and Wales. *Lancet* 2012;380:1759-66.
49. Smith TO, Nichols R, Donell ST, et al. The clinical and radiological outcomes of hip resurfacing versus total hip arthroplasty: a meta-analysis and systematic review. *Acta Orthop* 2010;81: 684-95.
50. Amstutz HC, Ball ST, Le Duff MJ, et al. Resurfacing THA for patients younger than 50 year: results of 2- to 9-year followup. *Clin Orthop Relat Res* 2007;460:159-64.
51. Heilpern GN, Shah NN, Fordyce MJ. Birmingham hip resurfacing arthroplasty: a series of 110 consecutive hips with a minimum five-year clinical and radiological follow-up. *J Bone Joint Surg Br* 2008;90:1137-42.
52. Hing CB, Back DL, Bailey M, et al. The results of primary Birmingham hip resurfacings at a mean of five years. An independent prospective review of the first 230 hips. *J Bone Joint Surg Br* 2007;89:1431-8.
53. Steffen RT, Pandit HP, Palan J, et al. The five-year results of the Birmingham Hip Resurfacing arthroplasty: an independent series. *J Bone Joint Surg Br* 2008;90:436-41.
54. Baker RP, Pollard TC, Eastaugh-Waring SJ, et al. A medium-term comparison of hybrid hip replacement and Birmingham hip resurfacing in active young patients. *J Bone Joint Surg Br* 2011;93: 158-63.
55. Mont MA, Marker DR, Smith JM, et al. Resurfacing is comparable to total hip arthroplasty at short-term follow-up. *Clin Orthop Relat Res* 2009;467:66-71.
56. Pollard TC, Baker RP, Eastaugh-Waring SJ, et al. Treatment of the young active patient with osteoarthritis of the hip. A five- to seven-year comparison of hybrid total hip arthroplasty and metal-on-metal resurfacing. *J Bone Joint Surg Br* 2006;88:592-600.
57. Stulberg BN, Fitts SM, Bowen AR, et al. Early return to function after hip resurfacing: Is it better than contemporary total hip arthroplasty? *J Arthroplasty* 2010;25:748-53.
58. Vail TP, Mina CA, Yergler JD, et al. Metal-on-metal hip resurfacing compares favorably with THA at 2 years followup. *Clin Orthop Relat Res* 2006; (453):123-31.
59. Vendittoli PA, Ganapathi M, Roy AG, et al. A comparison of clinical results of hip resurfacing arthroplasty and 28 mm metal on metal total hip arthroplasty: a randomised trial with 3–6 years follow-up. *Hip Int* 2010;20:1-13.
60. Beaulé PE, Dorey FJ, Le Duff MJ, et al. Risk factors affecting outcome of metal-on-metal surface arthroplasty of the hip. *Clin Orthop Relat Res* 2004; (418):87-93.
61. Hart AJ, Buddhdev P, Winship P, et al. Cup inclination angle of greater than 50 degrees increases whole blood concentrations of cobalt and chromium ions after metal-on-metal hip resurfacing. *Hip Int* 2008;18:212-9.
62. Treacy RB, McBryde CW, Shears E, et al. Birmingham hip resurfacing: a minimum follow-up of ten years. *J Bone Joint Surg Br* 2011;93:27-33.
63. O'Neill M, Beaule PE, Bin NA, et al. Canadian academic experience with metal-on-metal hip resurfacing. *Bull NYU Hosp Jt Dis* 2009;67:128-31.
64. Amstutz HC, Campbell PA, Le Duff MJ. Fracture of the neck of the femur after surface arthroplasty of the hip. *J Bone Joint Surg Am* 2004;86-A:1874-7.
65. Siebel T, Maubach S, Morlock MM. Lessons learned from early clinical experience and results of 300 ASR hip resurfacing implantations. *Proc Inst Mech Eng H* 2006;220:345-53.
66. van der Weegen W, Hoekstra HJ, Sijbesma T, et al. Survival of metal-on-metal hip resurfacing arthroplasty: a systematic review of the literature. *J Bone Joint Surg Br* 2011;93:298-306.
67. Heneghan C, Langton D, Thompson M. Ongoing problems with metal-on-metal hip implants. *BMJ* 2012;344:e1349.
68. Mont MA, Seyler TM, Ulrich SD, et al. Effect of changing indications and techniques on total hip resurfacing. *Clin Orthop Relat Res* 2007;465:63-70.
69. Prosser GH, Yates PJ, Wood DJ, et al. Outcome of primary resurfacing hip replacement: evaluation of risk factors for early revision. *Acta Orthop* 2010;81:66-71.
70. Garbuz DS, Tanzer M, Greidanus NV, et al. The John Charnley Award: Metal-on-metal hip resurfacing versus large-diameter head metal-on-metal total hip arthroplasty: a randomized clinical trial. *Clin Orthop Relat Res* 2010;468:318-25.
71. Lavigne M, Therrien M, Nantel J, et al. The John Charnley Award: The functional outcome of hip resurfacing and large-head THA is the same: a randomized, double-blind study. *Clin Orthop Relat Res* 2010;468:326-36.
72. Corten K, MacDonald SJ. Hip resurfacing data from national joint registries: What do they tell us? What do they not tell us? *Clin Orthop Relat Res* 2010;468:351-7.

73. Johanson PE, Fenstad AM, Furnes O, et al. Inferior outcome after hip resurfacing arthroplasty than after conventional arthroplasty. Evidence from the Nordic Arthroplasty Register Association (NARA) database, 1995 to 2007. *Acta Orthop* 2010;81:535-41.
74. Costa ML, Achten J, Parsons NR, et al. Total hip arthroplasty versus resurfacing arthroplasty in the treatment of patients with arthritis of the hip joint: single centre, parallel group, assessor blinded, randomised controlled trial. *BMJ* 2012;344:e2147.
75. Lavigne M, Masse V, Girard J, et al. [Return to sport after hip resurfacing or total hip arthroplasty: a randomized study] [article in French]. *Rev Chir Orthop Reparatrice Appar Mot* 2008;94:361-7.
76. Jolles BM, Bogoch ER. Posterior versus lateral surgical approach for total hip arthroplasty in adults with osteoarthritis. *Cochrane Database Syst Rev* 2006;(3):CD003828.
77. Ogonda L, Wilson R, Archbold P, et al. A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes. A prospective, randomized, controlled trial. *J Bone Joint Surg Am* 2005;87:701-10.
78. Sculco TP, Jordan LC, Walter WL. Minimally invasive total hip arthroplasty: the Hospital for Special Surgery experience. *Orthop Clin North Am* 2004;35:137-42.
79. Chimento GF, Pavone V, Sharrock N, et al. Minimally invasive total hip arthroplasty: a prospective randomized study. *J Arthroplasty* 2005;20:139-44.
80. Dorr LD, Maheshwari AV, Long WT, et al. Early pain relief and function after posterior minimally invasive and conventional total hip arthroplasty. A prospective, randomized, blinded study. *J Bone Joint Surg Am* 2007;89:1153-60.
81. Reininga IH, Zijlstra W, Wagenmakers R, et al. Minimally invasive and computer-navigated total hip arthroplasty: a qualitative and systematic review of the literature. *BMC Musculoskelet Disord* 2010;11:92.
82. Lewis PM, Al-Belooshi A, Olsen M, et al. Prospective randomized trial comparing alumina ceramic-on-ceramic with ceramic-on-conventional polyethylene bearings in total hip arthroplasty. *J Arthroplasty* 2010;25:392-7.
83. Qu X, Huang X, Dai K. Metal-on-metal or metal-on-polyethylene for total hip arthroplasty: a meta-analysis of prospective randomized studies. *Arch Orthop Trauma Surg* 2011;131:1573-83.
84. Dahlstrand H, Stark A, Anissian L, et al. Elevated serum concentrations of cobalt, chromium, nickel, and manganese after metal-on-metal alloarthroplasty of the hip: a prospective randomized study. *J Arthroplasty* 2009;24:837-45.
85. Engh CA Jr, MacDonald SJ, Sritulanondha S, et al. 2008 John Charnley award: metal ion levels after metal-on-metal total hip arthroplasty: a randomized trial. *Clin Orthop Relat Res* 2009;467:101-11.
86. Lombardi AV Jr, Mallory TH, Cuckler JM, et al. Mid-term results of a polyethylene-free metal-on-metal articulation. *J Arthroplasty* 2004;19(Suppl 2):42-7.
87. MacDonald SJ, McCalden RW, Chess DG, et al. Metal-on-metal versus polyethylene in hip arthroplasty: a randomized clinical trial. *Clin Orthop Relat Res* 2003;406:282-96.
88. Zijlstra WP, van Raay JJ, Bulstra SK, et al. No superiority of cemented metal-on-metal over metal-on-polyethylene THA in a randomized controlled trial at 10-year follow-up. *Orthopedics* 2010;33(3). doi: 10.3928/01477447-20100129-19
89. Smith AJ, Dieppe P, Vernon K, et al. Failure rates of stemmed metal-on-metal hip replacements: analysis of data from the National Joint Registry of England and Wales. *Lancet* 2012;379:1199-204.
90. Pandit H, Glyn-Jones S, Lardy-Smith P, et al. Pseudotumours associated with metal-on-metal hip resurfacings. *J Bone Joint Surg Br* 2008;90:847-51.
91. Frustaci A, Magnavita N, Chimenti C, et al. Marked elevation of myocardial trace elements in idiopathic dilated cardiomyopathy compared with secondary cardiac dysfunction. *J Am Coll Cardiol* 1999;33:1578-83.
92. Mao X, Wong AA, Crawford RW. Cobalt toxicity — An emerging clinical problem in patients with metal-on-metal hip prostheses? *Med J Aust* 2011;194:649-51.
93. Tower SS. Arthroprosthetic cobaltism: neurological and cardiac manifestations in two patients with metal-on-metal arthroplasty: a case report. *J Bone Joint Surg Am* 2010;92:2847-51.
94. Fabi D, Levine B, Paprosky W, et al. Metal-on-metal total hip arthroplasty: causes and high incidence of early failure. *Orthopedics* 2012;35:e1009-16.
95. *Important safety information for orthopaedic surgeons regarding patient management following metal-on-metal implant surgery*. Ottawa (ON): Health Canada; 2012.
96. US Food and Drug Administration. Medical devices: recalls. Washington (DC): US Department of Health and Human Services; 2012. Available: www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/ImplantsandProsthetics/MetalonMetalHipImplants/ucm241770.htm (accessed 2013 Oct. 15).
97. Koo KH, Ha YC, Jung WH, et al. Isolated fracture of the ceramic head after third-generation alumina-on-alumina total hip arthroplasty. *J Bone Joint Surg Am* 2008;90:329-36.
98. Jarrett CA, Ranawat AS, Bruzzone M, et al. The squeaking hip: a phenomenon of ceramic-on-ceramic total hip arthroplasty. *J Bone Joint Surg Am* 2009;91:1344-9.
99. Lübbeke A, Katz JN, Perneger TV, et al. Primary and revision hip arthroplasty: 5-year outcomes and influence of age and comorbidity. *J Rheumatol* 2007;34:394-400.
100. Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total hip arthroplasty in the United States. *J Bone Joint Surg Am* 2009;91:128-33.
101. Suter LG, Paltiel AD, Rome BN, et al. Medical device innovation — Is "better" good enough? *N Engl J Med* 2011;365:1464-6.
102. Minas T, Gomoll AH, Solhpour S, et al. Autologous chondrocyte implantation for joint preservation in patients with early osteoarthritis. *Clin Orthop Relat Res* 2010;468:147-57.
103. Punwar S, Khan WS. Mesenchymal stem cells and articular cartilage repair: clinical studies and future direction. *Open Orthop J* 2011;5(Suppl 2):296-301.

Affiliations: Division of Orthopedic Surgery, University of Toronto and University Health Network (Gandhi, Mahomed); and the Arthritis Program, University Health Network and the Institute of Health Policy, Management and Evaluation, University of Toronto (Perruccio), Toronto, Ont.

Contributors: All of the authors contributed to the conception and design, and drafting and revision of the article, and approved the final version submitted for publication.