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SPECIAL ARTICLE

Update on Hip and Knee Arthroplasty: Current State of Evidence

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Introduction

Total hip (THA) and total knee (TKA) arthroplasties are cost-effective interventions for reducing pain, improving function, and enhancing the quality of life in patients with arthritis of the hip and knee (1,2). More than 193,000 THA and 381,000 TKA procedures are performed in the US each year (3), and future projections indicate that by the year 2030, more than 750,000 of these procedures will be performed per year (4). Therefore, it is imperative for health care professionals to practice evidence-based medicine by integrating the scientific literature with their clinical expertise and the patients' preferences to select the most effective treatment interventions for enhancing patient recovery after joint replacement (5).

In response to this need, the Association of Rheumatology Health Professionals, a division of the American College of Rheumatology, assembled a multidisciplinary group of experts from the US and Canada in a conference to review the current evidence on hip and knee arthroplasty. The purpose of the conference was to provide state-of-the-art information for health care professionals on the surgical procedures, preoperative interventions, biomechanical considerations, rehabilitation strategies, outcomes assessment, and health disparities related to THA and TKA. We present the findings from that conference, which synthesizes the available evidence in each area, identifies the gaps in knowledge, and provides suggestions for future research.

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Surgical Advances in Hip and Knee Arthroplasty

Total hip arthroplasty. Long-term success of THA is dependent upon prosthetic component fixation and the amount of wear and debris generated by the bearing surface. Efforts to improve the function and survivorship of prostheses have focused on these important features of prosthetic design. Advances in both femoral cementing techniques and the design of cemented stems have resulted in near perfect (98%) survivorship at 10 years, and good survivorship (93%) at 25 years (6–9). Comparable survival rates have been reported using cementless techniques for the femoral component (10–14). In the acetabular component, 10-year survival rates are similar for cemented (95%) and cementless (95–100%) techniques; however, at 15 years, cementless technology supercedes cemented techniques (70–95% cemented versus 85–94% cementless) (6,7,10,11,15–17). Consequently, either cemented or cementless femoral stems could be considered the gold standard for long-term success; however, cementless techniques are now the preferred method for the vast majority of acetabular reconstructions.

Improvements in cementless, femoral component technology have included the use of circumferential porous coatings, a trend toward less stiff and more biologically inert metal alloys (away from cobalt-chromium alloys and toward titanium alloys), and a greater use of modularity to allow different leg-lengths, offset femoral head size options, and different bearing surface options with the femoral stems. These advances have given rise to a generation of femoral stems that are relatively biologically inert, have excellent bone ingrowth properties, are more similar to the modulus of elasticity of bone, and allow for many different femoral heads and bearing surfaces to be used in conjunction with the cementless implants.

Advances in metallurgy have resulted in the development of highly porous metal alloys (tantalum, trabecular metal) that are more characteristic of bone, are highly porous, and can be fashioned in a vast array of sizes and configurations for a number of different applications. These implants demonstrate tremendous bone and soft tissue ingrowth and are now being used in an expanding number of clinical indications for both primary and revisional hip surgery (18,19). There has also been experimentation with bioactive ceramic coatings such as hydroxyapatite or tricalcium phosphate that are amenable to bone healing (15,20,21). Radiographs have shown improvements in bone ingrowth with the bioactive coatings; however, there have been no demonstrated effects on survivorship of the implants.

Concerns about polyethylene wear debris and osteolysis associated with the traditional metal-on-polyethylene bearing surfaces have led to the emergence of alternative bearing surfaces that include metal on cross-linked polyethylene, metal-on-metal, and ceramic bearing surfaces. Cross-linked polyethylene has demonstrated greater wear resistance than standard polyethylene and is now the most frequently used polyethylene bearing surface in hip surgery in North America (22–24).

Ceramic-on-polyethylene articulations, using highly cross-linked polyethylene, produce less friction and fewer polyethylene particles (25). Studies have demonstrated almost no radiographically detectable wear of the polyethylene at 2 to 3 years (26); however, long-term studies are needed with data on wear at 10 to 15 years after surgery. A low-risk of ceramic bearing fracture has prevented this bearing option and the ceramic-on-ceramic bearings from becoming a more popular option in North America (27–29). Although one study has shown ceramic-on-ceramic articulations to be successful at 10-year followup (30).

Metal-on-metal bearing surfaces produce little friction and therefore have low wear rates. There is increasing use of this bearing surface in young, active patients in North America in recent years and 5 to 10-year followup studies demonstrate excellent clinical results (31–34). The long-term potential for carcinogenesis or organ problems due to the systemic absorption of metal particulate debris, however, is not known (35,36).

Canada, England, and Australia have witnessed the re-emergence of resurfacing hip arthroplasty, a procedure that preserves and resurfaces the arthritic femoral head and acetabular bearing surfaces. Resurfacing hip arthroplasty was performed more than 20 years ago; however, the rates of osteolysis and subsequent failure were high due to the cemented polyethylene cup in the acetabulum. The success of metal-on-metal bearings, as mentioned above, has hastened the development of this newer resurfacing hip arthroplasty technique. Current resurfacing techniques use metal-on-metal components (cobalt-chromium-molybdenum alloy) and involve minimal bone resection. Proponents suggest that the procedure will restore normal anatomy, maximize proprioception, minimize dislocation rates, and will be amenable to future revision/conversion to a THA system should it wear or fail in the future. Recent reports suggest excellent clinical results at short-term followup; however, long-term data are not available (34,37–42).

Advances in instrumentation have spurred the trend toward smaller surgical incisions. Minimally invasive surgery is a promising technique that may offer low complication rates, early mobility, and a shorter length of hospital stay as compared with traditional surgical approaches (43–46). The long-term survivorship of the implants, and whether the benefits of these procedures translate into detectable differences in function or in the duration of rehabilitation, however, are not known and warrant further research. Image-guided surgery may assist the surgeon in ensuring that the components are precisely located in the bone, which may facilitate further efforts in minimally invasive joint arthroplasty (47,48).

Total knee arthroplasty. Cemented TKA is the current gold standard with consistent long-term (10 to 14 year) survival rates of 94–98% (49,50). Although a few designs of cementless TKA have demonstrated good long-term success, the majority of cementless implants have not been able to reliably result in bone ingrowth (51).

Long-term survival rates and functional abilities are comparable in cruciate-retaining and cruciate-substituting (posterior stabilized) prostheses (52). To improve patient satisfaction and function, implants have been modified to permit an increased arc of flexion that may approach 150 degrees of knee flexion (53). The results of several randomized controlled trials (RCTs) investigating the role of this type of implant in improving functional performance are forthcoming.

Whether or not to resurface the patella during primary TKA has long been a debate within the orthopaedic community. Several RCTs reported similar outcomes with a resurfaced or unresurfaced patella; however, some of the trials had limited power due to small sample sizes. A recently published RCT demonstrated no differences in knee pain or patient satisfaction between those with and without patellar resurfacing (54). Recent literature syntheses and efforts at meta-analysis suggest that resurfacing the patella likely improves outcomes and long-term, patellar pain-free function (55–57).

Despite the advances in TKA technology, polyethylene wear and component loosening are major mechanisms of prosthetic failure (58). Therefore, there remains the need to enhance fixation and reduce wear to optimize long-term survival. The trabecular metal technology used in cementless THA also serves a role in enhancing fixation in cementless TKA (19). Tibial base plates made of tantalum are now available and are porous with high shear strength and low stiffness. In addition, efforts are currently underway to explore the merits of hydroxyapatite and other osteoinductive or osteoconductive materials to augment bone ingrowth and adherence to TKA prostheses.

The knee arthroplasty component with the lowest wear debris production in routine use appears to be a cobalt-chromium alloy femur articulating against a standard, polyethylene tibial surface. The role of ceramic-on-polyethylene designs is being explored, and a zirconium oxide–coated femoral implant is currently available for use against polyethylene tibial surfaces. Knee simulator studies suggest wear reduction by as much as 85% with this type of bearing (59).

Similar to THA, the use of cross-linked polyethylene in TKA reduces polyethylene wear; however, studies are needed to establish the long-term effectiveness of this technology (60,61). Additional efforts to reduce polyethylene stresses and wear debris include the use of the rotating platform or mobile-bearing knee implants. Most manufacturers now produce second-generation rotating platform implants; however, there are few studies with more than 10 years of followup data (62,63).

Minimally invasive TKA is rapidly gaining the attention of the orthopedic community. Limited, early published results suggest better range of motion, less blood loss, and a shorter length of stay with minimally invasive TKA as compared with standard TKA (64). Long-term results for these minimally invasive techniques are not available.

Although TKA is currently the so-called gold standard for knee joint replacement, unicompartmental arthroplasty has re-emerged as a suitable option for advanced medial compartment osteoarthritis with outcomes comparable with those for TKA. The procedure is generally performed using a minimally invasive approach and leads to a more rapid recovery, minimal bone loss, less pain, and early discharge as compared with TKA. The 10–15-year survival rates for unicompartmental knee arthroplasty are high, and range from 95 to 98% (65–67).

In summary, the emergence of new technology has led to advances in THA and TKA. Clinicians need to critically appraise the literature to determine if these technologic advances comply with the principles of evidence-based medicine. To further the field of joint replacement, it is imperative that RCTs and epidemiologic studies rigorously assess these new developments with regards to clinical effectiveness, cost-effectiveness, and the impact on patient quality of life and satisfaction.

The Role of Preoperative Education and Interventions

Multidisciplinary, preoperative education programs are generally available to prepare patients for the postoperative experience, with the goal of improving outcomes and subsequently decreasing the length of hospital stay. Outcome studies have been inconsistent, but have generally reported decreased postoperative pain (68), medication use (69), hospital length of stay (69), and fear/anxiety (70) in patients who participated in the educational programs as compared with those who did not. Thus, there is some evidence that preoperative educational programs positively impact postoperative outcomes; however, more research is needed in larger size samples to examine the most effective types of education, other potential venues for education (e.g., the internet or distance learning), and to develop targeted interventions for patients with varying physical and emotional needs.

Few studies have examined the effect of prearthroplasty exercise interventions on functional status. Despite the preponderance of evidence that exercise is beneficial for people with arthritis (71–74) and that self-reported, preoperative functional status is positively related to postoperative functional status (75), little data support the value of preoperative exercise interventions. Three controlled clinical trials (2 randomized) have been conducted to compare exercise interventions prior to TKA with a control group. There were significant improvements in impairments and function in the exercise groups prior to surgery, but no significant differences in the length of hospital stay, rate of complications, and impairments and function at 12 weeks postoperatively (76–78). These studies contained small sample sizes and various interventions that were not well defined (e.g., exercise intensity). Therefore, the current literature is inconclusive and does not provide clear evidence of efficacy for preoperative exercise in TKA.

A recent RCT of patients scheduled for THA involved a larger sample size and compared a progressive, preoperative and postoperative strength training intervention with a nonexercising control group (79). After completing the intervention, the exercise group demonstrated significant improvements in self-reported physical function and pain, hip strength, and hip range of motion as compared with the control group (79). At 12 and 24 weeks postoperatively, the exercise group had significantly higher strength and self-reported physical function than the control group (79). Therefore, there is some evidence that exercise before THA is beneficial to a person's recovery of function; however, more data are needed from large RCTs to determine the efficacy of preoperative exercise on the recovery from surgery and of function in this patient population. Moreover, questions remain about the optimal type and the amount of exercise and the timing of the preoperative intervention.

Biomechanical Considerations After Hip and Knee Arthroplasty

Biomechanical measurements of lower extremity kinematics (joint motion and alignment) and kinetics (joint and muscular loads or forces) have greatly contributed to our understanding of the impact that rehabilitation interventions and activities of daily living have on the hip and knee joints after arthroplasty. For example, in vivo pressure measurements with instrumented hip prostheses have challenged our assumptions about traditional therapeutic exercise and gait retraining approaches. Research has demonstrated that slow walking generates greater acetabular cartilage pressure than normal speed walking; non- or touchdown weightbearing during gait produces more pressure than full weightbearing; and hip exercises, such as straight leg raises, are more stressful than walking (80–82). More recent evidence indicates that descending stairs, getting out of a chair, and bending/lifting with the knees bent (versus straight) place the most stress on the hips and knees (83–86). Therefore, activities that have been thought to protect/strengthen the hip joint have been shown to produce higher levels of stress than expected.

Although these scientific data have furthered our knowledge in rehabilitation interventions, there is a paucity of information on the effectiveness of rehabilitation in eliminating impairments and improving function. Although patients may attain near perfect scores on traditional outcome measures, significant biomechanical impairments may remain after THA or TKA (87). How individuals compensate for these biomechanical impairments requires further investigation. According to McGibbon et al (88,89) some individuals may "functionally adapt" by allowing one joint to compensate for the reduced power in the hip or knee joint. Others may "neuromuscularly adapt" by transferring a load away from the affected hip or knee joint or by inhibiting movement at that joint (83,90). Whether these adaptations should be permitted or eliminated, and how best to measure and address them, warrants further investigation (91).

Evidence-Based Approach to Rehabilitation

The treatment approaches used after THA and TKA vary greatly among rehabilitation providers. Despite these inconsistencies, the goals of rehabilitation are similar. Rehabilitation in the acute care phase focuses on reducing pain, increasing mobility, restoring function, and identifying and preventing immediate postoperative complications (92). The early postoperative phase also includes patient education on weightbearing and positioning precautions, as well as an assessment of equipment needs and available resources at home (92).

In patient clinical pathways for joint replacement and more specifically, therapeutic exercise protocols, also vary among institutions. No RCTs have been conducted to determine the most efficacious protocol for rehabilitation after THA or TKA. The use of continuous passive motion devices after TKA has been investigated in a number of studies and were found to offer no long-term advantage over other forms of early mobility exercise (93–96).

In the post-acute home or inpatient rehabilitation phase, the efficacy of rehabilitative interventions has been studied even less frequently than in the acute care phase. Munin et al (97) demonstrated that early transfer from acute care to inpatient rehabilitation is associated with a more rapid attainment of goals; however, no studies have prospectively evaluated the benefit of inpatient rehabilitation after elective THA or TKA.

Weightbearing restrictions after surgery are typically based on individual surgeons' preferences and have been questioned after primary THA (98). Because full weightbearing transmits minimal forces through the hip and does not adversely affect bone ingrowth or prosthesis stability (99–101), full weightbearing is recommended for most patients following cemented or uncemented THA in the absence of other complicating factors.

Range of motion restrictions are routinely prescribed after THA; however, no specific data are available on the nature or duration of these precautions. Regardless of the surgical approach, once soft tissue healing is complete, it is generally accepted that the risk of hip dislocation is minimal. Despite this, range of motion, positioning, and activity restrictions are sometimes advised beyond 3 months postsurgery. It is assumed, but not well studied, that patients with connective tissue disease, history of dislocation, or revision surgery are at a higher risk for dislocation. It is also assumed that surgical approach and technique influence dislocation rate (e.g., anterior or minimally invasive surgical approaches are considered to disrupt capsular structures less and result in fewer dislocations). Therefore, restrictions should be prescribed on an individual basis.

Several studies have identified long-term impairments and disability following THA and TKA. Brander and colleagues (102) found that almost 1 of 8 patients reported significant pain that adversely affected function 1 year after TKA. Mizner et al (103) documented reduced quadriceps femoris activation after TKA. Others have reported poor postural stability, persistent muscle weakness, and difficulty squatting and climbing stairs as long as 2 years after THA or TKA (104–108). In elderly patients, persistent strength and balance deficits after joint replacement increases their risk of falls (107). Consequently, patients should be advised to continue their therapeutic exercise program for at least 1 year after surgery (106,107,109).

The efficacy of rehabilitation interventions in addressing these long-term impairments and functional limitations is not well understood. A limited number of prospective trials have examined the different approaches, timing, and frequency of specific rehabilitation interventions. In a prospective RCT, Moffet and colleagues (110) compared 12 outpatient physical therapy visits with a home exercise program in patients 2–4 months after TKA. Individuals who participated in the prolonged outpatient physical therapy experienced improvements in short and long-term function; the treatment effect was consistent yet fairly modest (110). Similarly, Binder et al (111) reported the results of an RCT of 6 months of physical therapy or home exercise in 90 patients following hip fracture. Extended outpatient therapy improved physical functioning, quality of life, and reduced overall disability (111). It has yet to be determined whether inpatient, outpatient, or home-based rehabilitation offers superior long-term results and patient satisfaction, although studies on these issues are beginning to emerge (112–114).

It is recognized that differing patient demographics, comorbidities, surgical procedures, perioperative complications, and social support systems will influence the discharge destination after surgery (113,114). Patients at risk for poor outcomes, such as those with severe pain, depression, or anxiety, should be identified before surgery, and treatment programs should be tailored to meet the needs of these subsets of patients (102).

The long-term impact of exercise and physical activity on implant longevity and patient quality of life is probably the least understood area of rehabilitation after joint replacement. Assumptions about prosthetic wear and failure are based on in vitro material testing, instrumented hip studies, indirect mathematical models, and retrospective studies using age as a proxy for activity. All of these methods have their limitations. At present, patients are routinely advised to avoid sporting activities that generate high compressive or rotary forces or place them at risk for injury to the replaced joint (115–119).

Outcomes Assessment in Hip and Knee Arthroplasty

There has been a shift in the measurement of outcomes after THA and TKA from the traditional surgeon-defined, impairment-based outcome measures to more patient-centered outcomes incorporating patient expectations and satisfaction. Historically, the outcome instruments selected for use after THA and TKA were based on surgeon perceptions of the relative importance of certain symptoms and impairments; were technically oriented (e.g., range of motion, radiographic findings, or survivorship); unvalidated; focused on impairments, especially pain; and did not measure function in a uniform manner. The most commonly used traditional outcome measures for TKA are the Hospital for Special Surgery Knee Score (120), the Knee Society Clinical Rating System (121), and the Harris Hip Score (122) for THA.

The emergence of the International Classification of Functioning, Disability, and Health (ICF) provides a conceptual model for selecting outcome measures after THA and TKA (123). Under the ICF, outcome measures can be selected to assess impairments of body function/structure (e.g., joint mobility), activity limitations (e.g., self care), and participation restrictions (e.g., occupational activities) after joint replacement. Instruments such as the Short-Form Health Survey (124), the Western Ontario and McMaster Universities Osteoarthritis Index (125), and the American Academy of Orthopaedic Surgeons Lower Limb Instruments (126) are being used more frequently after THA and TKA to measure impairments, activity limitations, and participation restrictions.

There is a greater emphasis now on measuring patient expectations and satisfaction after THA and TKA. Patients with higher expectations for pain relief and walking improvement have greater levels of satisfaction than those wanting to improve non-essential activities after surgery (127). Furthermore, patients with better outcomes after THA or TKA tend to have higher levels of satisfaction (127). Therefore, outcome measures should address patient expectations and satisfaction, but with the understanding that expectations can change over time (128).

The ultimate goal of outcomes research is to have clinically useful and valid data to feed back to patients and other health care providers, preferably in an interactive format with shared decision making by the patient and health care provider. Future steps toward achieving this goal include the use of electronic medical records and the consolidation of outcome instruments to minimize concerns about respondent burden and floor/ceiling effects.

Disparities in Hip and Knee Arthroplasty

Disparities in the rates of THA and TKA have been identified based on geographic and sociodemographic factors. A review of Medicare data identified a pattern of higher THA and TKA rates in Midwestern and Western states and lower rates in Southern states (129). States with lower rates of joint replacement had a higher proportion of African American patients per total population (129).

Studies have confirmed the finding that THA and TKA rates are lower in African Americans compared with whites, independent of access to health care, socioeconomic status, or comorbidities (113,130–133). Sex differences also exist in joint replacement, with women more likely to undergo surgery than men (133). Men, African Americans, and individuals with lower income levels have a greater risk of experiencing complications after joint replacement (133).

Studies have also addressed differences in access, attitudes, and beliefs related to joint replacement surgery. In one study, women were only half as likely as men to have ever discussed joint replacement with their physician, especially women with lower income levels (134). Women in higher socioeconomic categories had less access to joint replacement surgery than their male counterparts (134). Fewer African Americans than whites reported knowing someone who had THA or TKA, and were less likely to report that joint replacement surgery helped someone they knew (135). Overall, African Americans had a lower perception of the efficacy of joint replacement compared with whites (136).

Health disparities exist in the use of THA and TKA. Factors such as geographic location, race, sex, and income may explain the disparities to a certain extent, but not completely. The relationships among these factors are difficult to separate. More research is needed to identify other factors that contribute to these discrepancies, and whether or not the explanatory factors are provider-related or due to a lack of education or misperceptions about the efficacy of joint replacement. There is also a need to develop and evaluate the efficacy of public health initiatives designed to raise awareness about treatment options for individuals with arthritis, as well as to incorporate educational interventions to eliminate health disparities into national health care policies.

Discussion

Total hip and knee arthroplasty have proven to be the most successful surgical interventions aimed at reducing pain and enhancing physical function in people with arthritis. Despite the advances in joint replacement technology, there have been few multicenter, blinded, RCTs evaluating the various hip and knee prostheses. Most of the literature consists of case series, retrospective studies, or prospective studies using consecutive patients, and therefore may not be generalizable to the US population.

More national registries and large, national level research studies are needed to collect population data on the long-term clinical outcomes of joint replacement. The outcome measures utilized in such studies should be consistent with the ICF framework and patient-focused, with an assessment of patient expectations and satisfaction related to surgery. Because of the documented disparities in the utilization of joint replacement, research studies also need to assess factors related to these disparities such as differences in access to health care, patient attitudes and beliefs, and surgeons' recommendations.

The evidence presented on rehabilitation is consistent with the findings of an independent panel of health care professionals and public representatives from a recent consensus development conference on TKA at the National Institutes of Health (137). The use of rehabilitation services is probably the most understudied aspect of joint replacement with little evidence supporting the use of any particular preoperative or postoperative interventions, and a lack of guidelines for the appropriate amount and type of physical activity after surgery (137). To improve consistency in rehabilitation interventions, efforts are underway by researchers in the US and Canada to sponsor an international consensus conference to develop clinical practice guidelines for rehabilitation before and after THA and TKA (138). Determining standardized, cost-effective rehabilitation approaches may be key in maximizing implant longevity, patient quality of life, and overall satisfaction.

This conference included experts in the fields of orthopedics, rheumatology, rehabilitation, and education on the current "best-practice" in hip and knee arthroplasty. More work is needed in these areas, including research to explore the value of preoperative exercise in patients undergoing joint replacement; identifying those at risk for lower levels of functional recovery; determining the most appropriate postoperative exercises, rehabilitation setting, strategies for reducing long-term sequelae, and appropriate activity levels after surgery; and consolidating and standardizing outcome instruments.

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