THA with a Minimally Invasive Technique, Multi-modal Anesthesia, and Home Rehabilitation

Factors Associated with Early Discharge?

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Abstract Multimodal anesthetic and pain regimens with minimally invasive surgical approaches and rapid rehabilitation protocols are thought to decrease length of stay after hip replacement. We asked whether a program including these three elements could achieve 23-hour discharge in a group of 665 patients and whether the length of hospital stay was influenced by patient age, gender, body mass index, change in hemoglobin or estimated blood loss, duration of surgery (≤ 90 or > 90 minutes), or American Society of

Anesthesiologists physical status classification. Of the 665 patients, 259 (38.9%) were discharged home with indwelling peripheral nerve catheters. Hospital discharge in less than 24 hours was achieved in 295 (44.4%) of the 665 patients. After discharge, 73.5% of patients required no home or outpatient nursing care or physical therapy. Eighteen (2.7%) dislocations, eight (1.2%) femoral fractures requiring surgery, and thirteen (2.0%) revision procedures occurred within 90 days. Female gender, increasing age, increasing estimated blood loss, and American Association of Anesthesiologists classification 3 or 4 increased length of stay. Additional study is needed to confirm these factors and develop prospective prediction rules to allow for an outpatient approach to joint arthroplasty.

Level of Evidence: Level II, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research. This work was performed at The University of Pittsburgh Medical Center.

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Introduction

Postoperative care after THA has evolved during the past 40 years. Initially, patients recovered in the hospital, and inpatient stays lasted 2.5 to 3 weeks [7]. Weightbearing was limited and early mobility discouraged. Gradually, postoperative protocols have changed. Weightbearing has been allowed even with uncemented implants, and rehabilitation protocols have allowed for faster mobilization. In the 1990s, this protocol allowed for the early transfer of patients to acute rehabilitation centers [19]. Although this procedure decreased hospital costs, it led to a transfer of costs to the rehabilitation center [12].

During the past 10 years, the number of hip arthroplasties has increased and reimbursement has decreased [11]. To decrease the use of acute rehabilitation centers as

cost transference, the Centers for Medicare and Medicaid Services instituted the 75% rule in 2004, which promoted the restriction of services to patients who are more than 85 years old, who have a body mass index (BMI) of greater than 50, or who are having bilateral procedures [6, 10]. Subsequent efforts to decrease costs have included discharge home after 2 to 3 days with the use of expensive home nursing visits and home or outpatient physical therapy [13, 28]. The minimally invasive surgery (MIS) movement has led to additional decreases in length of hospital stay to variable degrees, including discharge on the same day as surgery [4, 9]. Outpatient arthroplasty has been achieved with the use of more aggressive rehabilitation, improved pain control, and different expectations [1, 2]. Although a 23-hour discharge has been achieved for selected patients, the factors involved in early discharge are relatively unknown. Some investigators have even suggested such an early discharge is dangerous [25].

The goals of this study were (1) to evaluate the efficacy of a specific anesthesia protocol and a multimodal approach to postoperative pain management regimen, an MIS technique, and a rapid rehabilitation protocol in achieving early discharge to home with minimal home or outpatient support services; (2) to evaluate the necessity of home or outpatient support services; (3) to evaluate the early (first 90 days) complications of the approach; and (4) to identify patient factors associated with length of stay.

Materials and Methods

Between June 2002 and December 2005 we retrospectively reviewed prospectively collected data for all 676 patients scheduled to have unilateral THA by the senior author (DCM). For this study we excluded 11 patients for the following reasons: full-exposure hip arthroplasty ($n = 9$) because of Crowe IV developmental dysplasia ($n = 2$), morbid obesity with a BMI of greater than 60 ($n = 3$), fibrous dysplasia ($n = 2$), marked proximal femoral deformity ($n = 1$) and extensive retained hardware ($n = 1$), inability to receive blood transfusion for severe postoperative anemia because of religious affiliation ($n = 1$), and severe coronary artery disease resulting in a coronary artery bypass graft surgery during the same hospitalization ($n = 1$). The final cohort of 665 patients (329 females and 336 males) had an average age of 62 ± 13.05 years and an average BMI of 29.5 ± 6.02 kg/m². The most common diagnosis was osteoarthritis (594 patients), followed by osteonecrosis (37 patients), post-traumatic arthritis (19 patients), dysplasia (13 patients), and inflammatory arthritis (two patients). Eleven patients had an associated hardware removal (two acetabular and nine femoral implants). Our study was approved by the study institution's Institutional Review Board.

Preoperatively, patients were educated with a booklet prepared by the senior author (DCM), the anesthesiology team, and the physical and occupational therapists, which describes expectations and early hospital discharge. Patients also attended a preoperative class that highlighted the discharge goals and illustrated techniques of postoperative mobilization.

During the study period, we used individualized anesthetic protocols [8], a multimodal approach to postoperative pain management [8], an MIS technique, and a rapid rehabilitation protocol. The type of anesthesia used varied: 519 (78.0%) patients had spinal anesthesia, 142 (21.4%) patients had general anesthesia, and four (0.6%) patients had epidural anesthesia. Patients were followed by the Acute Interventional Perioperative Pain Service, a team of anesthesiologists, pain nurses, and fellows who follow the patients for all postoperative pain management issues. The multimodal postoperative pain management regimen consisted of peripheral nerve blocks (629 patients) via a continuous lumbar plexus block (preoperative injection of 7 ml of 0.2% ropivacaine followed by an infusion rate of 7 ml/hr with additional boluses as needed) and a single-dose sciatic nerve block (5 to 8 ml of 0.2% or 0.5% ropivacaine) administered before patient transfer to the operating room, preoperative and postoperative COX-2 inhibitor (rofecoxib from 2002 to April 2004, valdecoxib from April 2004 to November 2004, and celecoxib from November, 2004 to the present), benzodiazepene (midazolam), an N-methyl-D-aspartic acid receptor blocker (ketamine), an intravenous opioid (typically fentanyl), and an oral opioid (typically oxycodone) as necessary. Pregabalin was also added to this multimodal regimen in the fall of 2005. Of the 629 subjects who received a block, 259 (41%) were discharged home with the lumbar plexus block still in place. The Acute Interventional Perioperative Pain Service makes the determination with regard to which patients will go home with a catheter still in place, using a straightforward screening process. Patients were not eligible to be discharged with the block in place if they were more than 70 years old. If the patient and family were agreeable, and showed cognitive adequacy, they were instructed by Acute Interventional Perioperative Pain Service on how to operate an outpatient pump and how to remove the catheters when the pump is empty, and they were given guidelines with a 24-hour contact number for any questions. The rate of infusion was decreased to 5 ml/hr plus the option of an additional bolus of 5 ml once per hour. At this rate, weakness is not typically associated with the block.

To minimize postoperative orthostatic hypotension, we administered a high volume of replacement fluid. Although the fluid volume was based on patient weight and estimated surgical blood loss, a typical intravenous fluid replacement

consisted of 2500 to 3000 mL of crystalloid and 500 to 1000 mL of colloid solutions. An additional source of intravenous fluid replenishment was achieved by the intraoperative use of a cell saver (390 patients), which allowed the return of approximately 40% (range, 50–1000 mL/patient) of the salvaged blood to the systemic circulation. Of those 390 patients, 219 received no other blood products in the postoperative period. The mean estimated blood loss intraoperatively was 482.3 ± 375.1 mL for all patients.

To permit independent hyperextension of the lower extremities during the two-incision approach, we used a Jupiter Operating Table (Trumpf, Inc, Charleston, SC) [17]. Image intensification was used at various stages throughout the procedure. We used the following cementless implants (Zimmer, Inc, Warsaw, IN): 245 (36.8%) Harris-Galante 2[®], 362 (54.5 %) Trilogy[®], and 58 (8.7 %) Trabecular Metal[™] cups, and 385 6-inch FullCoat (57.9%), 140 Fiber Metal Taper (21.1%), and 140 M/L Taper (21.1%) stems. Surgery duration was 95.6 ± 29.30 minutes.

Postoperatively, a patient received a transfusion if the 12-hour hemoglobin/hematocrit was below 10 g/dL and symptoms of anemia were present. During hospitalization, 291 patients (43.8%) received a blood transfusion. The mean change in hemoglobin for all patients was 3.04 ± 1.50 g/dL.

Routine deep vein thrombosis and/or pulmonary embolism prophylaxis consisted of postoperative aspirin (325 mg) twice daily for 2 weeks and then daily for 2 additional weeks after surgery. During hospitalization, patients used pneumatic compression devices and knee-high elastic stockings. After discharge, each patient used the elastic stockings for 1 month. No routine postoperative screening modality was used for deep vein thrombosis.

To facilitate discharge and return to functional activities, a rapid rehabilitation protocol was used for every patient. Shortly after transfer from the recovery area to a hospital ward, each patient was mobilized by physical and occupational therapists with the initial use of a walker and encouragement to transfer to a cane before discharge. Patients older than 75 years were transitioned cautiously from the walker to a cane because of the potential for a fall. While in the hospital, each patient received three or four therapy sessions daily, was permitted weightbearing as tolerated, had unlimited motion of the operative hip, and practiced stair climbing when it was required in the home environment. Each patient also received a brochure outlining a corresponding home exercise program, including various strengthening exercises for the hip and lower extremity. The therapists reviewed the instructions with each patient to ensure the instructions were understood. This postdischarge format was consistent with the hospital

reimbursement policies from the local major third-party payers, who deny full reimbursement to the hospital if a patient is discharged to his or her home with home services or outpatient therapy for the initial postoperative period. Discharge to the home environment required the individual to display independent gait, independent transfers, a capability for activities of daily living, and independent stair climbing (if the home environment had stairs). Satisfactory postoperative pain control was achieved with oral medications and, for the patients who had received nerve blocks, with the continuous infusion of local anesthetic via the lumbar plexus catheter.

We anticipated seven patient characteristics would influence the length of hospital stay: age, gender, weight, duration of surgery in minutes (≤ 90 or > 90), change in hemoglobin, estimated blood loss, and American Society of Anesthesiologists (ASA) physical status classification. We used a multiple regression analysis with ordinary least-square regression with the software R (Free Software Foundation, Inc, Boston, MA) to determine factors associated with the length of hospital stay.

Results

With specialized treatment and rapid rehabilitation protocols, 295 (44.4%) of the 665 patients who had MIS THA procedures were discharged within 24 hours, 297 were discharged between 48 and 72 hours, and 73 were discharged between 4 and 10 days after surgery (Table 1). Reasons for discharge between days 4 to 10 included need for blood transfusion (50 patients), slow progress with physical therapy (39 patients), severe chronic systemic disease (32 patients), psychiatric issues (22 patients),

Table 1. Discharge disposition by length of acute hospital stay

Length of acute hospital stay	Home/self care	Home health agency	Skilled nursing facility	Rehabilitation facility	Other*
Same day	17	1	0	0	0
< 24 hours	247	29	1	0	0
24–48 hours	163	36	5	6	0
49–72 hours	44	18	8	16	1
4 days	12	6	10	18	2
5 days	4	3	5	2	1
6 days	1	2	1	3	0
7 days	1	0	0	0	0
9 days	0	0	1	0	0
10 days	0	0	0	1	0
Total	489	95	31	46	4

* Includes long-term acute care, other facility, or other hospital.

urinary retention (9 patients), cardiac issues (7 patients), revision surgery (5 patients), pulmonary issues (2 patients), and social issues (2 patients). The mean overall length of hospital stay was 1.9 days (range, 0–10 days). Discharge was direct to the home for 584 (87.8%) patients (489 [73.5%] for self care, 95 [14.3%] with home healthcare support as a physical therapist or nurse); the remaining 81 (12.2%) patients were transferred to a rehabilitation center, a skilled nursing center, or a long-term acute care or other facility. Discharge home occurred for 100% of the 18 patients discharged on the day of surgery (17 with self care, one with a home health agency), for 99.6% of the 277 patients discharged on postoperative Day 1 (247 with self care, 29 with home health agency, and one to a skilled nursing facility), and for 94.8% of the 210 patients discharged on postoperative Day 2 (163 with self care, 36 with a home health agency, five to a skilled nursing facility, and six to an inpatient rehabilitation facility).

Early complications (ie, those that occurred up to 90 days after surgery) included femoral fracture, femoral head disarticulation, dislocation, subsidence, and nerve palsy. Eight patients sustained periprosthetic fractures requiring surgery. Four small intraoperative greater trochanteric fractures were treated nonoperatively. Eighteen patients had postoperative dislocations: 14 were treated with closed reduction, two with open reduction, and two with revision. Thirteen patients required revision surgery for loosening. In one patient, the femoral head component became disarticulated from the stem at the Morse taper on postoperative Day 1, requiring revision surgery. Two patients developed deep infection. Two patients developed hematoma requiring surgery. One patient required surgery for a superficial wound breakdown. There were 146 lateral femoral cutaneous nerve palsies that largely or fully resolved, and four partial femoral nerve palsies that fully resolved. There were no sciatic nerve palsies. Two partial brachial plexus palsies in the ipsilateral upper extremity secondary to intraoperative positioning fully resolved spontaneously. Two patients had deep vein thrombosis, but there were no cases of pulmonary embolism. One patient sustained a mild cerebrovascular accident 2 weeks after the surgery, but recovered fully. In four patients, a transient postoperative cardiac arrhythmia developed that required temporary monitoring and resolved uneventfully.

We identified four factors related to a longer hospital stay: (1) female gender ($p < 0.001$); (2) increasing age ($p < 0.001$); (3) higher ASA class (3, $p < 0.01$, or 4, $p < 0.001$); and (4) increasing blood loss ($p < 0.001$). A surgery time of 90 minutes or less was not associated ($p = 0.38$) with an increased length of stay. There was no correlation between length of stay and BMI ($p = 0.94$) or change in hemoglobin ($p = 0.09$).

Discussion

Length of hospital stay after hip replacement surgery has decreased as surgical, anesthetic, and rehabilitation techniques have advanced. Our goals were to determine: (1) the efficacy of a multimodal anesthetic and pain regime with a minimally invasive surgical approach and a rapid rehabilitation protocol for THA in achieving 23-hour discharge; (2) the rates of home and outpatient therapy; (3) the 90 day complications; and (4) if length of hospital stay was influenced by patient age, gender, BMI, change in hemoglobin or estimated blood loss, duration of surgery (≤ 90 or > 90 minutes), or ASA physical status classification.

The limitations of our study were differing anesthetic and/or rehabilitation protocols, the use of the continuous peripheral nerve catheter technique, differing times of surgery, a lack of a comparative group, and possibly an incomplete list of relevant factors. For example, in some cases, patients refused a peripheral nerve block, the attempted nerve block was unsuccessful, or preoperative anticoagulants precluded the use of the nerve block or a spinal anesthetic. Complications have been described with the continuous lumbar nerve block including the possibility of a fall, leakage or failure of the catheter to work [20]. Others have reported the continuous catheter alone to help with mobilization and pain control after surgery [16]. The timing of surgery affected the administration of same-day rehabilitation, especially for a patient who had the procedure in the late afternoon period; surgery early in the day often meant more same-day rehabilitation sessions. In addition, patients who had their surgical procedure on Friday received less therapy during the weekend than did patients who had surgery earlier in the week. We also did not have a comparison group of patients who had a formal home or outpatient therapy program. Finally, it is also possible there are factors that we did not prospectively record that could affect the length of hospital stay. In particular, we think the use of medicinal or recreational opioids and cognitive dysfunction merit additional evaluation.

Our data suggest in an unselected population, including the elderly and obese, it is possible to achieve a 23-hour hospital stay for 44.4% of patients. Previous studies examining rapid rehabilitation protocols after THA have used highly selected groups of patients to achieve short lengths of stay [1, 2]. With respect to support services after the discharge from the hospital, 489 patients (73.5%) were discharged to their homes with no support services, 95 patients (14.3%) were discharged to their homes with home health service, 31 patients (4.7%) were transferred to a skilled nursing facility, and 46 patients (6.9%) were transferred to a rehabilitation facility. These results

Table 2. Lengths of stay and home discharge reported after minimally invasive or mini-total hip arthroplasty

Author(s)	Number of patients	Mean age (years)	Length of stay (days)	Home discharge (%)
Woolson et al. [31]	50	60	4.3	48
Berger et al. [2]	100	—*	< 1	100
Waldman [30]	21	56	2.8	87
Pagnano et al. [24]	36	67	2.6	—
Dorr et al. [9]	30	70	2.6	97
Mears et al. [17]	665	62	1.8	87.7

* Not noted.

compare favorably to other reports of minimally invasive approaches to THA (Table 2) [30, 31].

We experienced complications comparable to those in the literature (Table 3) [3, 14, 31, 32]. Thirteen patients had revision procedures within 90 days, 18 (2.7%) had dislocations despite the fact that hip precautions were not used, and eight had femoral fractures (1.2%) requiring surgery. Although it has been suggested many clinically important medical complications occur after postoperative Day 2, our patients did not seem to experience major complications during the first 90 days after surgery.

The main factors contributing to a longer hospital stay included female gender, an ASA class of 3 or 4, increasing age, and higher estimated blood loss. A patient's BMI, change in hemoglobin, and duration of surgery did not predict longer stays. The factors involved with length of stay after hip arthroplasty with an aggressive approach to surgery have not been previously determined. Others have examined factors involved with need for an acute rehabilitation stay. Our findings agree with those of Bozic et al. [5], who found female gender, ASA Class 3 and 4, and increasing age are associated with an increased need for acute rehabilitation. Other investigators have used a tool termed the Risk Assessment and Predictor Tool to determine the need for acute rehabilitation [22, 23]. This score includes gender, age, and some other factors that we did

not investigate, ie, preoperative walking distance and gait aid, community supports, presence of a caregiver on return home, and patient expectations. Although these studies did not investigate criteria for an early home discharge, the factors seem related, and additional investigation using the Risk Assessment and Predictor Tool may be useful.

Clearly, many factors can affect length of hospital stay, including patient selection, type of anesthesia and pain control, presence of a synchronized therapeutic program, support of the entire team, surgical technique, and reimbursement issues for hospitals. Although there is some evidence that incision length can alter early outcomes [10], the role of the surgical approach is controversial [21, 24]. Rehabilitation protocols, patient motivation, and patient expectations seem to play a large role in early discharge and fast recovery after hip arthroplasty [26].

Currently, in the United States, postdischarge services after joint arthroplasty, including rehabilitation stays and home physical therapy, cost \$3.2 billion annually [13]. Previous studies have questioned the efficacy of physical therapy programs after joint arthroplasty [15, 18, 27] and have shown limiting rehabilitation can decrease costs [28, 29]. Additional work is required to estimate the decrease in cost associated with limiting postdischarge rehabilitation center transfers and physical therapy.

Our data and that of others show multimodal anesthetic and pain regimes with rapid rehabilitation protocols can result in discharge within 24 hours after THA [1, 2], which occurred in 44.4% of our patients. Although other reports have discussed the use of in home or outpatient physical therapy [15, 27, 28], 73.5% of our patients required no home or outpatient nursing care or physical therapy. The main factors that corresponded to a longer length of stay were female gender, increasing age, increasing estimated blood loss, and ASA Class 3 and 4. Additional study is needed to validate these factors with other procedures and at other centers. Such validation would allow for prediction rules for developing an outpatient approach to joint arthroplasty, including discharge home and an informal postdischarge therapy protocol.

Table 3. Intraoperative and 3-month postoperative complications reported for conventional or minimally invasive techniques

Author(s)	Number of patients	Periprosthetic fractures (%)	Dislocation (%)	Deep infection (%)	Revision (%)
Mahomed et al. [14]	61568	—*	3.1	0.2	—
Woolson et al. [31]	50	2	0	1	—
Berry [3] [†]	3121	5.4	—	—	—
Zhan et al. [32]	41744	—	—	—	2.15
Mears et al. [17]	665	1.2 [§]	2.70	0.3	2.0

* Not noted.

[†] Uncemented stems only.

[§] Fractures requiring surgery.

References

- Berger RA. A comprehensive approach to outpatient total hip arthroplasty. *Am J Orthop*. 2007;36:4–5.
- Berger RA, Jacobs JJ, Meneghini RM, Della Valle C, Paprosky W, Rosenberg AG. Rapid rehabilitation and recovery with minimally invasive total hip arthroplasty. *Clin Orthop Relat Res*. 2004;429:239–247.
- Berry DJ. Epidemiology. Hip and knee. *Orthop Clin North Am*. 1999;30:183–190.
- Berry DJ, Berger RA, Callaghan JJ, Dorr LD, Duwelius PJ, Hartzband MA, Lieberman JR, Mears DC. Minimally invasive total hip arthroplasty. Development, early results, and a critical analysis. *J Bone Joint Surg Am*. 2003;85:2235–2246.
- Bozic KJ, Wagie A, Naessens JM, Berry DJ, Rubash HE. Predictors of discharge to an inpatient extended care facility after total hip or knee arthroplasty. *J Arthroplasty*. 2006;21:151–156.
- Centers for Medicare and Medicaid Services. Medicare program; changes to the criteria for being classified as an inpatient rehabilitation facility. Final rule. *Fed Regist*. 2004;69:25752–25776.
- Charnley J. Present status of total hip replacement. *Ann Rheum Dis*. 1971;30:560–564.
- Chelly JE, Ben-David B, Mears D. Anesthesia and acute pain management for minimally invasive hip surgery. *Tech Reg Anesth Pain Manag*. 2004;8:70–75.
- Dorr LD, Maheshwari AV, Long WT, Wan Z, Sirianni LE. 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;89:1153–1160.
- FitzGerald JD, Boscardin WJ, Hahn BH, Ettner SL. Impact of the Medicare Short Stay Transfer Policy on patients undergoing major orthopedic surgery. *Health Serv Res*. 2007;42:25–44.
- Iorio R, Robb WJ, Healy WL, Berry DJ, Hozack WJ, Kyle RF, Lewallen DG, Trousdale RT, Jiranek WA, Stamos VP, Parsley BS. Orthopaedic surgeon workforce and volume assessment for total hip and knee replacement in the United States: preparing for an epidemic. *J Bone Joint Surg Am*. 2008;90:1598–1605.
- Kim S. Changes in surgical loads and economic burden of hip and knee replacements in the US: 1997–2004. *Arthritis Rheum*. 2008;59:481–488.
- Lavernia CJ, D'Apuzzo MR, Hernandez VH, Lee DJ, Rossi MD. Postdischarge costs in arthroplasty surgery. *J Arthroplasty*. 2006;21:144–150.
- Mahomed NN, Barrett JA, Katz JN, Phillips CB, Losina E, Lew RA, Guadagnoli E, Harris WH, Poss R, Baron JA. Rates and outcomes of primary and revision total hip replacement in the United States Medicare population. *J Bone Joint Surg Am*. 2003;85:27–32.
- Mahomed NN, Davis AM, Hawker G, Badley E, Davey JR, Syed KA, Coyte PC, Gandhi R, Wright JG. Inpatient compared with home-based rehabilitation following primary unilateral total hip or knee replacement: a randomized controlled trial. *J Bone Joint Surg Am*. 2008;90:1673–1680.
- Marino J, Russo J, Kenny M, Herenstein R, Livote E, Chelly JE. Continuous lumbar plexus block for postoperative pain control after total hip arthroplasty. A randomized controlled trial. *J Bone Joint Surg Am*. 2009;91:29–37.
- Mears DC, Mears SC, Chelly JE. Two-incision hip replacement in the morbidly obese patient. *Semin Arthroplasty*. 2007;18:272–279.
- Minns Lowe CJ, Barker KL, Dewey M, Sackley CM. Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials. *BMJ*. 2007;Epub (DOI:10.1136/bmj.39311.460093.BE):1–9.
- Munin MC, Rudy TE, Glynn NW, Crossett LS, Rubash HE. Early inpatient rehabilitation after elective hip and knee arthroplasty. *JAMA*. 1998;279:847–852.
- Muraskin SI, Conrad B, Zheng N, Morey TE, Enneking FK. Falls associated with lower-extremity-nerve blocks: a pilot investigation of mechanisms. *Reg Anesth Pain Med*. 2007;32:67–72.
- Ogonda L, Wilson R, Archbold P, Lawlor M, Humphreys P, O'Brien S, Beverland D. 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;87:701–710.
- Oldmeadow LB, McBurney H, Robertson VJ. Predicting risk of extended inpatient rehabilitation after hip or knee arthroplasty. *J Arthroplasty*. 2003;18:775–779.
- Oldmeadow LB, McBurney H, Robertson VJ, Kimmel L, Elliott B. Targeted postoperative care improves discharge outcome after hip or knee arthroplasty. *Arch Phys Med Rehabil*. 2004;85:1424–1427.
- Pagnano MW, Trousdale RT, Meneghini RM, Hanssen AD. Slower recovery after two-incision than mini-posterior-incision total hip arthroplasty. A randomized clinical trial. *J Bone Joint Surg Am*. 2008;90:1000–1006.
- Parvizi J, Mui A, Purtill JJ, Sharkey PF, Hozack WJ, Rothman RH. Total joint arthroplasty: When do fatal or near-fatal complications occur? *J Bone Joint Surg Am*. 2007;89:27–32.
- Pour AE, Parvizi J, Sharkey PF, Hozack WJ, Rothman RH. Minimally invasive hip arthroplasty: what role does patient pre-conditioning play? *J Bone Joint Surg Am*. 2007;89:1920–1927.
- Siggeirsdottir K, Olafsson O, Jonsson H, Jr., Iwarsson S, Gudnason V, Jonsson BY. Short hospital stay augmented with education and home-based rehabilitation improves function and quality of life after hip replacement. Randomized study of 50 patients with 6 months of follow-up. *Acta Orthop*. 2005;76:555–562.
- Sigurdsson E, Siggeirsdottir K, Jonsson H, Jr., Gudnason V, Matthiasson T, Jonsson BY. Early discharge and home intervention reduces unit costs after total hip replacement: results of a cost analysis in a randomized study. *Int J Health Care Finance Econ*. 2008;8:181–192.
- Tribe KL, Lapsley HM, Cross MJ, Courtenay BG, Brooks PM, March LM. Selection of patients for inpatient rehabilitation or direct home discharge following total joint replacement surgery: a comparison of health status and out-of-pocket expenditure of patients undergoing hip and knee arthroplasty for osteoarthritis. *Chronic Illn*. 2005;1:289–302.
- Waldman BJ. Minimally invasive total hip replacement and perioperative management: early experience. *J South Orthop Assoc*. 2002;11:213–217.
- Woolson ST, Mow CS, Syquia JF, Lannin JV, Schurman DJ. Comparison of primary total hip replacements performed with a standard incision or a mini-incision. *J Bone Joint Surg Am*. 2004;86:1353–1358.
- Zhan C, Kaczmarek R, Loyo-Berrios N, Sangl J, Bright RA. Incidence and short-term outcomes of primary and revision hip replacement in the United States. *J Bone Joint Surg Am*. 2007;89:526–533.