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Rapid Recovery Protocols for Primary Total Hip Arthroplasty Can Safely Reduce Length of Stay Without Increasing Readmissions

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Abstract

The purpose of our study is to investigate the impact of incremental perioperative practice changes and the introduction of rapid recovery protocols on hospital LOS and readmission rates associated with primary THAs. 1,751 cases were assigned to one of four protocol cohorts across 13 years: traditional, enhanced pain management, early mobility, and rapid recovery (RR). LOS significantly decreased by 52% between the traditional and RR pathways (IRR=0.48; 95% CI 0.44, 0.53; $p<0.0001$) and differed significantly between all sequential eras ($p<0.001$) without an overall increase in thirty-day readmission rates ($p=0.13$). The odds of readmission for THAs performed under the RR pathway are almost one-third of the traditional era (OR=0.36; 95% CI 0.14, 0.93; $p=0.04$). Accelerated clinical care protocols should be considered for patients undergoing primary THA.

Introduction

As the demand for total hip arthroplasty (THA) continues to escalate, with projections of 570,000 primary THAs by 2030 [12] and already an estimated near 1 million THAs performed annually worldwide [16], there is a push to increase quality, decrease cost and minimize risk. There is incredible global variability in the length of hospital stay after joint arthroplasty, ranging from 1 to 21 days [4, 6, 22, 26]. In the United States (US), healthcare reforms are currently being implemented in an attempt to reduce cost and improve the care of patients. The implementation of Accountable Care Organizations (ACOs) established the

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precedence for reimbursements for total joint arthroplasty to become intimately linked to quality measures, namely patient outcomes [11, 17]. The two primary outcomes at the forefront of policy transformations are hospital length of stay (LOS) and readmissions. Because THAs are costly procedures, totaling over \$9 billion annually in the US alone [1], team-based models of care have been created and commissioned to cut costs and improve patient outcomes [14].

The onus to improve patient outcomes has led to the adoption of clinical pathways, which are specific management plans that utilize the efforts of multiple care providers to impart a cost-efficient and patient friendly experience [29]. Multiple retrospective studies have reported reductions in acute hospital LOS when comparing pre and post-pathway data [8, 10, 19, 27–30]. However, to our knowledge none have followed incremental longitudinal changes to evaluate how stepwise modifications in clinical pathways affect the process and/or outcomes. Moreover, studies commonly rely on large-scale administrative databases, which come from government-sponsored programs, most notably the Center for Medicare & Medicaid Services (CMS) in the US and other country-specific registries internationally [4, 8, 16, 27, 28]. These databases offer timely, low-cost and non-intrusive population information regarding total hip arthroplasty procedures. However, they are limited by coding inaccuracies, lack of information control, population biases not representative of trends towards a younger arthroplasty population and the inherent limitations of administrative, retrospective data [5, 7, 9]. If a paradigm shift is to occur involving surgeon- and patient-reported health information, it will start with vigilant surgeon/institution record keeping and tracking of outcomes for all patients alike.

The purpose of our study is to investigate the impact of incremental perioperative practice changes and the adoption of specific rapid recovery protocols on hospital LOS and readmission rates associated with primary THAs. In addition, we analyzed demographic, comorbidity and surgery-specific factors to determine if hospital LOS and readmission rates were differentially affected across eras depending on these characteristics. We believe our study perspective is unique in that we have tracked the evolution of incremental perioperative protocol changes for primary total hip replacement over time.

Materials & Methods

We retrospectively collected data from 2,142 consecutive primary total hip arthroplasties performed at a single institution by a one surgeon (JCC) between 2000–2012 with IRB permission. Information regarding LOS, discharge disposition and readmission events and diagnosis was collected from the electronic medical record. Additional data, including demographic, perioperative and surgery-specific factors was obtained from our hip and knee replacement registry. Three hundred ninety-one THAs (18%) were excluded on the basis of incomplete records, duplicated records for readmission or irreconcilable conflicting reports between datasets. The remaining 1,751 primary THAs (82%) performed in 1,476 patients from 2000–2012 were divided into four cohorts based on the perioperative clinical pathway protocol in place at the time of index arthroplasty. The four treatment eras for primary THAs at our institution were designated as 1) traditional (281 THAs), 2) enhanced pain

management (660 THAs), 3) early mobility (322 THAs), and 4) rapid recovery (488 THAs) [Figure 1].

The perioperative clinical protocol for THA included four distinct eras for the treating surgeon [Table 1]. During the “traditional” era, total hip arthroplasty care at our institution was reliant on general anesthesia, patient-controlled analgesia (PCA) and delayed postoperative mobilization system in which patients did not get out of bed until POD#2 with activity progression as tolerated. Starting in January 2005, spinal anesthesia and multimodal pain management protocols were introduced in the “enhanced pain management” era. We no longer depended on PCAs and instead instituted scheduled administration of oral narcotics and a cyclooxygenase-2 inhibitor both pre and post-operatively. There was a concurrent shift towards spinal-preferred anesthesia, with exclusions for general anesthesia being for pre-existing valvular stenosis, bleeding diatheses, neurologic disorders, or patient preference.

Beginning in March 2009, a concerted effort was aimed towards optimizing early postoperative physical therapy (PT) and occupational therapy (OT) sessions for THA patients. Changes instituted in this “early mobility” era streamlined these services, such that an inpatient floor supervisor was able to ensure patients received standardized lower extremity range of motion and strengthening exercises, bed mobility and transfers, gait training with appropriate assistive devices, and patient education on hip precautions. With the assurance of early operative times and predictable turnaround, the goal was to have these services initiated by the evening of the day of surgery (POD#0). Additional pathway changes in the early mobility era required patients scheduled for elective THA to meet with the anesthesiologist at a separate pre-operative appointment to assess co-morbidities and discuss anesthetic expectations. Finally, “optional” education classes were introduced during this era, with only 56% of elective THA patients who attended.

Finally in October 2010, a “rapid recovery” (RR) protocol was devised, building on to the previous pathway transformations. This most recent era of THA care sought to further coordinate the efforts between the anesthesia, nursing, therapy and surgical teams, calling for a shortened duration spinal block (goal less than 4 hours) and intra-operative multimodal pain management with a cocktail of injectables and gastrointestinal medications titrated to an individual’s anesthetic needs. The pericapsular injections included a 1:1 mixture of local anesthetic with epinephrine and ketorolac, provided the patient had no contraindications such as poor renal function or allergies. After a short stay in the postoperative care unit where the patients received more aggressive fluid resuscitation and had the head of their bed elevated 30 degrees to combat nausea, patients were transported to the orthopaedic inpatient suite. Within two to three hours of arrival, they were required to stand and ambulate with PT, provided that the patient was awake and alert, had no lingering issues with nausea or vomiting, and had appropriate muscle strength. Concurrently on the morning of surgery, the nurse practitioners for the Adult Reconstructive service would distribute a list at team rounds to inform case management, social work and floor nurses of all RR patients and reiterate a discharge goal of postoperative day one before 12 o’clock noon. Preoperatively, patients were “required” to attend a mandatory educational class and a separate anesthesia assessment appointment. Our records demonstrate a large improvement between the most recent eras, with attendance in the preoperative joint class improving to 99%. In addition, all

patients received a detailed surgical pamphlet to address common questions and reiterate expectations for an expedited recovery and discharge process.

For each surgical cohort, data were retrospectively collected from the hospital and departmental registries. Primary outcome measures included the LOS and thirty-day all cause readmission status. If a subject experienced a readmission, additional data were noted, including admitting diagnosis and if the patient required an unscheduled return to the operative room. Database registries were examined and cross-checked for age at the time of surgery, race, gender, preoperative diagnosis, body mass index (BMI), discharge disposition and medical comorbidities. Surgical variables of interest included anesthesia type, American Society of Anesthesiologists (ASA) physical status category, operative time, and intraoperative blood loss. Patient-reported variables considered were preoperative modified Harris Hip Scores (HHS) and UCLA Activity Scores, which are validated measures to estimate levels of activity and function. There were 275 patients who had staged, bilateral THAs, but they were considered separate as analysis was focused on the era the individual procedure was performed.

Chi-square tests were used to compare categorically measured characteristics across surgical eras. Kruskal-Wallis tests were used to compare ASA category and continuously measured characteristics across surgical eras because the data was not normally distributed. The univariate association between surgical era and the primary outcomes, LOS and readmissions, was assessed with Poisson and logistic regression, respectively. Regardless of the significance of the overall regression model, statistical contrasts with Bonferroni-adjusted p-values were used to determine if the outcome was significantly different between two specific, *a priori* determined surgical eras. Incidence rate ratios (IRRs) are reported for LOS and odds ratios (ORs) are reported for readmission with associated 95% confidence intervals (CIs).

Three categorical demographic variables deemed to be significantly different across surgical eras were being Caucasian when compared to non-Caucasian ethnicities (African-American, Asian and other) ($p=0.01$), having general versus spinal anesthesia ($p<0.0001$), and discharge status ($p=0.004$) [Table 2]. There was a significant trend towards younger patients receiving THA across all eras ($p=0.0002$), but the median BMI of 28 kg/m² did not significantly change across eras (range 13.6–59.3; $p=0.62$) [Table 3]. There was a significant decrease in operative times between eras ($p<0.0001$). Both the UCLA Activity and modified Harris Hip scores differed significantly across groups ($p<0.0001$).

There was no significant difference in the prevalence of the following comorbidities across eras: GI disease ($p=0.18$), smoking ($p=0.15$), cancer ($p=0.86$), thyroid disease ($p=0.48$), diabetes ($p=0.25$), hematologic disease ($p=0.38$), thromboembolic disease ($p=0.75$), rheumatoid arthritis ($p=0.12$), sickle cell disease ($p=0.81$), and autoimmune disease ($p=0.13$) [Supplemental Table 1]. There was a significant decrease in the prevalence of hypertension ($p=0.007$), cardiac ($p=0.006$), and respiratory disease ($p=0.04$) across surgical eras; and a significant increase in the prevalence of mood disorders ($p=0.003$) and hypercholesterolemia ($p<0.0001$).

Multivariate regression analyses were performed to determine if LOS or readmission rate was differentially affected across the four surgical eras depending on *a priori*-determined characteristics of primary interest. For each outcome and characteristic, a multivariable regression model was performed with a focus on the interaction between surgical era and the characteristic of interest; interactions that tested hypotheses regarding the equality of the association between the outcome and the characteristic across surgical eras. The interaction p-value is reported, and when significant, IRRs (for LOS) and ORs (for readmission) with associated p-values are reported from partitioned analysis of the least square means for the interaction.

For all analyses, surgical era group was treated as an unordered variable. Since the unit of analysis was the THA procedure rather than the patient, no adjustment was made for the possible lack of independence between THAs performed for bilateral patients. A p-value of 0.05 or less was considered statistically significant. Analyses were generated using SAS software, version 9.3 of the SAS System for Linux (SAS Institute Inc., Cary, NC, USA).

Results

Across surgical eras, the length of stay significantly decreased over time ($p<0.0001$). The expected number of days in the hospital was reduced by half for the rapid recovery pathway when compared to the traditional pathway (IRR=0.48; 95% CI 0.44, 0.53; $p<0.0001$). Comparisons between each sequential era reveal a significant decrease in length of stay [Table 4]. Protocol changes instituted in the Enhanced Pain Management (IRR=0.74; 95% CI 0.68, 0.80; $p<0.0001$) and Rapid Recovery eras (IRR=0.76; 95% CI 0.68, 0.84; $p<0.0001$) demonstrated the greatest impact on decreasing the expected length of stay between successive eras.

There was no increase in all-cause readmission rates across the different surgical eras ($p=0.13$). Collectively, there were 47 readmissions within thirty days of the index arthroplasty in a total of 46 patients for an overall readmission rate of 2.68%. Across the four pathway eras, 11 (3.9%) readmissions occurred in the traditional group, 22 (3.3%) in the enhanced pain management era, and 7 each under the early mobility (2.1%) and rapid recovery pathways (1.4%) [Table 5]. Twenty readmissions involved females and twenty-seven afflicted males. Seventy percent of those readmitted within 30-days were Caucasian and the other 30% were African-American. Seventy-two percent (34 hips) of all readmits were for issues related with surgery and the other 28% (13 hips) were attributed to other medical problems [Table 6]. Twenty-one THAs (1.2% of all cases) required an unplanned return to the operating room, with the most common surgical indications being draining extra-capsular hematoma (10 cases, 0.57%), deep infection (4 cases, 0.22%), or dislocation (3 cases, 0.17%). The most common procedure performed upon revisiting the OR was an irrigation and debridement with or without polyethylene liner exchange (45%). Multivariable analyses were performed to determine if outcomes were differentially affected across surgical eras depending on the value of certain characteristics. For LOS, there was no statistically significant interaction between surgical era and gender ($p=0.70$), Caucasian race ($p=0.18$), anesthesia type ($p=0.79$), ASA ($p=0.49$), age ($p=0.55$), BMI ($p=0.91$), UCLA Activity ($p=0.07$), and HHS ($p=0.17$). However, discharge status differentially affected LOS

across eras ($p=0.001$). Home discharges significantly reduced LOS as compared to facility discharges in the enhanced pain management ($IRR=0.75$; 95% CI 0.61, 0.93; $p=0.009$), early mobility ($IRR=0.51$; 95% CI 0.41, 0.63; $p<0.0001$), and rapid recovery ($IRR=0.57$; 95% CI 0.46, 0.72; $p<0.0001$) eras, but not in the traditional era ($IRR=0.87$; 95% CI 0.71, 1.06; $p=0.16$). While there was no significant change in overall readmissions across time, there was one significant difference discovered in the pairwise between-era analysis. The odds of readmission for a THA under the rapid recovery protocol was reduced by more than 60% ($OR=0.36$; 95% CI 0.14, 0.93; $p=0.04$) when contrasted against the traditional pathway [Table 5]. This was the only between-era comparison that demonstrated a statistically significant difference. For readmission rates, there was no statistically significant interaction between surgical era and gender ($p=0.75$), race ($p=0.08$), age ($p=0.55$), BMI ($p=0.47$), and HHS ($p=0.54$). Due to sparse data and poor model fit, we could not assess possible interactions between surgical era and anesthesia type, discharge status, or ASA category.

Discussion

Clinical pathways are a useful cost containment strategy in reducing hospital length of stay after THA. However, these protocols require serial evaluation to be most effective. The results presented in this study highlight the major impact of incremental changes made over a thirteen-year period. Our findings suggest that successive changes to systematically manage the perioperative care process have effectively reduced expected hospital LOS without causing an associated rise in readmissions.

One of the primary study limitations is the lack of generalizability given the fact that a single surgeon at a single institution performed all THAs. The patient population under question was treated at a high-volume, tertiary care referral center with the necessary ancillary staff to create an accountable, multidisciplinary care team. It is possible that this population had higher burdens of comorbidity or perceived functional limitations compared to a community arthroplasty practice, which negatively affect both the length of stay and hospital readmissions. Others have suggested that greater hospital and surgeon volume are associated with fewer readmissions, more direct discharges to home and shorter hospital length of stays [3, 25].

Further criticisms include the ethnic homogeneity and the statistical trend towards treating a younger group of patients presented in our cohort compared to averages reported in other national databases. However, we believe capturing a younger population is an added strength of our study since other registries, such as Medicare, focus on a sector of the population greater than 65 years of age. Multiple authors have accurately depicted the changing demographics of arthroplasty recipients, where patients less than 60 years comprise the most significant increase in prevalence and incidence throughout North America [13, 21, 24]. We believe it is in this younger patient cohort that the greatest efficiency is to be gained, and our results demonstrate a stepwise decrease in hospital length of stay by 26%, 14% and 24% with incremental refinements in detailed perioperative protocols. A third limitation of our methods is that our data only captured those readmissions to our hospital system, which could have underrepresented the actual readmission incidence. Parvizi et al. demonstrated that most major and minor complications

related with surgery occur within four to five days of the procedure [18]. While this could potentially be problematic with trends towards accelerating recovery and hospital discharge time, our results do not suggest a shorter LOS increases the risk for readmission. Our data, however, is limited in that we inevitably do not capture those patients who experience a complication and seek treatment elsewhere.

Prior investigations have shown that discharge to a rehabilitation institute or care facility after THA is associated with increased readmission rates [2, 15, 20, 31]. While we found an association between decreased length of stay with discharging patients directly home, we were not able to discover a significant correlation between discharge disposition and readmissions. It should be noted that while there may be an association with readmission and disposition status, our logistic regression provided a poor model fit, showing discrepancies in readmissions when controlling for home versus facilities across surgical era. It is possible that our model failed to detect a difference between discharge disposition and primary outcomes because the majority of our patients were discharged to home (93%). What remains unknown is if facilities have a lower threshold to readmit a patient to the treating hospital if there is concern over a wound or another issue that could be managed without an unplanned inpatient stay. Zmistowski et al. determined that discharge to an inpatient rehabilitation facility, among other risk factors, was an independent predictor of unplanned hospital readmission within ninety days [31]. More recently, Ramos et al. determined that patients discharged to an inpatient facility had a higher comorbidity incidence (12.1 vs. 2.4%, $p < 0.001$) in addition to longer LOS after THA [20]. Robbins et al. have demonstrated that accelerated rehabilitation with day-of-surgery mobilization is associated with a greater than a one-day decrease in LOS and a 96% home discharge rate [23]. It has been suggested that increased complication rates are responsible for longer inpatient stays or readmission after THA [18, 31]. Our results do not confirm this notion, although the number of events detected between all cohorts was low (47/1,751 THAs). We believe that through appropriate education and maintaining an open stream of communication between the patient and the surgeon/support staff, it is possible to achieve greater patient satisfaction while also surveying potential problems [6].

The institution of ACOs for total joint arthroplasty has placed a premium on efficiency and cost containment. Larsen was able to demonstrate a decrease in about \$4000 per case in accelerated rehab protocols after arthroplasty in Denmark [14]. According to our hospital financial records, the cost billed for one inpatient day after arthroplasty is \$3,300 when accounting for direct and indirect variable costs, including housekeeping, medications, nursing support and therapy services and equipment. While we did not perform a formal cost analysis, our data suggest that by decreasing length of stay through clinical pathways by over two days, in-hospital costs can be reduced.

Successive and cumulative changes to systematize the perioperative care process have effectively cut hospital LOS in half across all surgical eras without causing an associated increase in readmissions. Given the imminent reimbursement pressures by the Affordable Care Act and Accountable Care Organizations to reduce cost, optimize quality and minimize risk, we have demonstrated a safe reduction in hospital stay associated with incremental perioperative protocol improvements. These clinical pathways utilize a coordinated, team-

based approach and we will continually look to improve upon practices that optimize patient outcomes, enhance efficiency, and reduce costs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Bhattacharyya T, Mehta P, Freiberg AA. Hospital Characteristics Associated with Success in a Pay-for-Performance Program in Orthopaedic Surgery. *J Bone Jt Surg*. 2008; 90:1240–1243.
2. Bini SA, Fithian DC, Paxton LW, Khatod MX, Inacio MC, Namba RS. Does discharge disposition after primary total joint arthroplasty affect readmission rates? *J Arthroplasty*. 2010; 25:114–117. [PubMed: 19150214]
3. Bozic KJ, Maselli J, Pekow PS, Lindenauer PK, Vail TP, Auerbach AD. The influence of procedure volumes and standardization of care on quality and efficiency in total joint replacement surgery. *J Bone Joint Surg Am*. 2010; 92:2643–2652. [PubMed: 21084575]
4. Crawford LA, Hart W. FACTORS AFFECTING LENGTH OF STAY FOLLOWING TOTAL JOINT REPLACEMENT. *J Bone Joint Surg Br*. 2008; 90-B:546–546.
5. Gandhi, Sanjay; Salmon, J Warren; Kong, Sheldon X.; Zhao, Sean Z. Administrative Databases and Outcomes Assessment: An Overview of Issues and Potential Utility. *J Manag Care Pharm*. 1999; 5:215–222.
6. Husted H, Holm G, Jacobsen S. Predictors of length of stay and patient satisfaction after hip and knee replacement surgery: fast-track experience in 712 patients. *Acta Orthop*. 2008; 79:168–173. [PubMed: 18484241]
7. Iezzoni LI. Assessing Quality Using Administrative Data. *Ann Intern Med*. 1997; 127:666–674. [PubMed: 9382378]
8. Kaboli PJ, Go JT, Hockenberry J, Glasgow JM, Johnson SR, Rosenthal GE, Jones MP, Vaughan-Sarrazin M. Associations between reduced hospital length of stay and 30-day readmission rate and mortality: 14-year experience in 129 Veterans Affairs hospitals. *Ann Intern Med*. 2012; 157:837–845. [PubMed: 23247937]
9. Keeney JA, Adelani MA, Nunley RM, Clohisy JC, Barrack RL. Assessing readmission databases: how reliable is the information? *J Arthroplasty*. 2012; 27:72–76. e1–2. [PubMed: 22579350]
10. Kim S, Losina E, Solomon DH, Wright J, Katz JN. Effectiveness of clinical pathways for total knee and total hip arthroplasty: literature review. *J Arthroplasty*. 2003; 18:69–74. [PubMed: 12555186]
11. Kocher RP, Adashi EY. Hospital readmissions and the affordable care act: Paying for coordinated quality care. *JAMA*. 2011; 306:1794–1795. [PubMed: 22028355]
12. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007; 89:780–785. [PubMed: 17403800]
13. Kurtz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future Young Patient Demand for Primary and Revision Joint Replacement: National Projections from 2010 to 2030. *Clin Orthop*. 2009; 467:2606–2612. [PubMed: 19360453]
14. Larsen K, Hansen TB, Thomsen PB, Christiansen T, Søballe K. Cost-effectiveness of accelerated perioperative care and rehabilitation after total hip and knee arthroplasty. *J Bone Joint Surg Am*. 2009; 91:761–772. [PubMed: 19339559]

15. Mahomed NN, Koo Seen Lin MJ, Levesque J, Lan S, Bogoch ER. Determinants and outcomes of inpatient versus home based rehabilitation following elective hip and knee replacement. *J Rheumatol.* 2000; 27:1753–1758. [PubMed: 10914863]
16. Merx H, Dreinhöfer K, Schröder P, Stürmer T, Puhl W, Günther K-P, Brenner H. International variation in hip replacement rates. *Ann Rheum Dis.* 2003; 62:222–226. [PubMed: 12594106]
17. Miller DC, Ye Z, Gust C, Birkmeyer JD. Anticipating the effects of accountable care organizations for inpatient surgery. *JAMA Surg.* 2013; 148:549–554. [PubMed: 23426556]
18. 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. [PubMed: 17200306]
19. Peters CL, Shirley B, Erickson J. The effect of a new multimodal perioperative anesthetic regimen on postoperative pain, side effects, rehabilitation, and length of hospital stay after total joint arthroplasty. *J Arthroplasty.* 2006; 21:132–138. [PubMed: 16950075]
20. Ramos NL, Karia RJ, Hutzler LH, Brandt AM, Slover JD, Bosco JA. The Effect of Discharge Disposition on 30-Day Readmission Rates After Total Joint Arthroplasty. *J Arthroplasty.* 2014; 29:674–677. [PubMed: 24183369]
21. Ravi B, Croxford R, Reichmann WM, Losina E, Katz JN, Hawker GA. The changing demographics of total joint arthroplasty recipients in the United States and Ontario from 2001 to 2007. *Best Pract Res Clin Rheumatol.* 2012; 26:637–647. [PubMed: 23218428]
22. Rissanen P, Aro S, Paavolainen P. Hospital- and patient-related characteristics determining length of hospital stay for hip and knee replacements. *Int J Technol Assess Health Care.* 1996; 12:325–335. [PubMed: 8707504]
23. Robbins CE, Casey D, Bono JV, Murphy SB, Talmo CT, Ward DM. A multidisciplinary total hip arthroplasty protocol with accelerated postoperative rehabilitation: does the patient benefit? *Am J Orthop Belle Mead NJ.* 2014; 43:178–181. [PubMed: 24730003]
24. Skyttä ET, Jarkko L, Antti E, Huhtala H, Ville R. Increasing incidence of hip arthroplasty for primary osteoarthritis in 30- to 59-year-old patients. *Acta Orthop.* 2011; 82:1–5. [PubMed: 21189098]
25. Styron JF, Koroukian SM, Klika AK, Barsoum WK. Patient vs provider characteristics impacting hospital lengths of stay after total knee or hip arthroplasty. *J Arthroplasty.* 2011; 26:1418–1426. e1–2. [PubMed: 21277159]
26. Vingerhoeds B, Fick D, Middleton R, Olyslaegers C, Wainwright T. A PATIENT-CENTRED PATHWAY DRAMATICALLY REDUCES LENGTH OF STAY AND IMPROVES OUTCOMES IN PRIMARY JOINT REPLACEMENT IN A SAFE WAY. *J Bone Joint Surg Br.* 2010; 92-B:500–500.
27. Vorhies JS, Wang Y, Herndon J, Maloney WJ, Huddleston JI. Readmission and Length of Stay After Total Hip Arthroplasty in a National Medicare Sample. *J Arthroplasty.* 2011; 26:119–123. [PubMed: 21723700]
28. Vorhies JS, Wang Y, Herndon JH, Maloney WJ, Huddleston JI. Decreased length of stay after TKA is not associated with increased readmission rates in a national Medicare sample. *Clin Orthop.* 2012; 470:166–171. [PubMed: 21720934]
29. Walter FL, Bass N, Bock G, Markel DC. Success of clinical pathways for total joint arthroplasty in a community hospital. *Clin Orthop.* 2007; 457:133–137. [PubMed: 17065839]
30. Yoon RS, Nellans KW, Geller JA, Kim AD, Jacobs MR, Macaulay W. Patient education before hip or knee arthroplasty lowers length of stay. *J Arthroplasty.* 2010; 25:547–551. [PubMed: 19427164]
31. Zmistowski B, Restrepo C, Hess J, Adibi D, Cangoz S, Parvizi J. Unplanned Readmission After Total Joint Arthroplasty: Rates, Reasons, and Risk Factors. *J Bone Jt Surg.* 2013; 95:1869–1876.

Figure 1.

Flow diagram of case enrollment and surgical treatment era allocation.

* THA = total hip arthroplasty; PCA = patient-controlled analgesia

Table 1

Description of Four Surgical Groups (“Surgical Eras”).

<u>Variable</u>	<u>Traditional</u>	<u>Enhanced Pain Management</u>	<u>Early Mobility</u>	<u>Rapid Recovery</u>
<i>Era</i>	2000–2004	2005–3/2009	3/2009–10/2010	10/2010–2013
<i>Pre-Op Education</i>	None	Recommended Classes	Recommended Classes + Meeting with Anesthesiologist to set expectations	Mandatory Classes + Meeting with Anesthesiologist & Comprehensive Pamphlet to set expectations
<i>Pain</i>	Patient Controlled Analgesia	Scheduled COX-2 inhibitor, Tramadol & oral narcotics pre-op	Addition of IV Acetaminophen post-op	Intra-op IV Ketorolac + Acetaminophen, Elimination of pre-operative oral narcotics
<i>Mobilization</i>	Delayed	POD#1	Out of bed night of surgery by unit RN or PT	Out of bed + ambulate POD#0 coordinated with PT, OT and RN
<i>Anesthesia</i>	General	Spinal-preferred	Spinal-preferred	Patient-specific spinal dosing & scheduled anti-emetic
<i>Nursing</i>	Not Integrated	Not Integrated	Integrated Pre-op, Recovery and Floor RN duties	Charge RN oversees team and sets expectations for patient care upon arrival to unit

Table 2

Frequency for demographic variables across four surgical eras with p-values determined by Chi-square test, unless otherwise noted.

Eras:	Traditional 2000–2005	Enhanced Pain Management 2005–3/09	Early Mobility 3/09–10/10	Rapid Recovery 10/10–2013	p-value
Time Course					
# of THAs (row %)	281 (16)	660 (38)	322 (18)	488 (28)	
Gender (column %)					0.11
Male	126 (45)	292 (44)	140 (43)	247 (51)	
Female	155 (55)	368 (56)	182 (57)	241 (49)	
Race (column %)					0.01
Caucasian	235 (84)	591 (90)	293 (91)	440 (90)	
Non-Caucasian	46 (16)	69 (10)	29 (9)	48 (10)	
Anesthesia (column %)					<0.0001
General	159 (57)	89 (14)	29 (9)	52 (11)	
Spinal	115 (41)	561 (85)	291 (90)	419 (86)	
Other	5 (2)	9 (1)	2 (1)	17 (3)	
OA Pre-op Dx (column %)					0.24
Present	221 (79)	550 (83)	271 (84)	408 (84)	
Absent	60 (21)	110 (17)	51 (16)	80 (16)	
AVN Pre-op Dx (column %)					0.43
Present	40 (14)	90 (14)	35 (11)	56 (11)	
Absent	241 (86)	570 (86)	287 (89)	432 (89)	
ASA category (column %)					0.44*
1	37 (14)	59 (9)	20 (6)	29 (6)	
2	164 (61)	469 (72)	246 (76)	357 (73)	
3 or 4	68 (25)	121 (19)	56 (17)	101 (21)	
Discharge Status (column %)					0.004
Home	253 (90)	634 (96)	299 (93)	459 (94)	
Facility	28 (10)	26 (4)	23 (7)	29 (6)	

THA = total hip arthroplasty; OA = Osteoarthritis; AVN = Avascular necrosis; ASA = American Society of Anesthesiologists

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P-value by Kruskal-Wallis test, which takes into account the ordered ASA categories.
*

Table 3
Preoperative continuous demographic variables across four surgical eras with p-values by Kruskal-Wallis test.

	<u>Traditional</u>	<u>Enhanced Pain Management</u>	<u>Early Mobility</u>	<u>Rapid Recovery</u>	<u>p-value</u>
<u>Age</u>					0.0002
median	59	56	57	55	
25th Pctl	51	46	47	45	
75th Pctl	67	66	65	64	
<u>BMI</u>					0.62
median	28.06	28.28	28.32	28.29	
25th Pctl	24.68	25.12	24.97	24.76	
75th Pctl	32.49	32.42	32.28	31.74	
<u>Operative Time (minutes)</u>					<0.0001
median	95	80	74	81	
25th Pctl	82	67	60	67	
75th Pctl	115	98	91	97	
<u>UCLA Activity</u>					<0.0001
median	3	4	4	5	
25th Pctl	2	2	4	3	
75th Pctl	4	6	6	8	
<u>mHHS</u>					<0.0001
median	40.7	45.1	48.4	48.4	
25th Pctl	29.7	35.2	35.2	36.3	
75th Pctl	52.8	58.3	58.3	59.4	

BMI = body mass index, mHHS = modified Harris Hip Score, Pctl = Percentile

Table 4

Length of stay (LOS) determinations using Poisson regression. For each contrast performed, data are reported as incidence rate ratios with 95% confidence interval and associated p-value when comparing the specified surgical era to the reference era.

Surgical Era	Length of Stay (LOS)						P-value
	N	Median	25th Pctl	75th Pctl	Minimum	Maximum	
Traditional	281	4	3	4	1	16	< 0.0001
Enhanced Pain Management	660	2	2	3	1	23	
Early Mobility	322	2	2	2	1	26	
Rapid Recovery	488	2	1	2	0	7	
Contrasts							
<i>Variable = surgical era</i>	Traditional (reference) vs. Enhanced Pain Management: 0.74 (0.68, 0.80), p<0.0001 Enhanced Pain Management (reference) vs. Early Mobility: 0.86 (0.79, 0.94), p=0.0005 Early Mobility (reference) vs. Rapid Recovery: 0.76 (0.68, 0.84), p<0.0001 Traditional (reference) vs. Rapid Recovery: 0.48 (0.44, 0.55), p<0.0001						

N = sample size; Pctl = percentile.

Readmissions by surgical era determined by logistic regression modeling. For each contrast performed, data are reported as the odds ratio (95% confidence interval) modeling the probability of readmission when comparing the specified surgical era group to the reference surgical era group, with associated p-value.

Table 5

Readmissions	Surgical Era					
Frequency (<i>column</i> %)	Traditional	Enhanced Pain Management	Early Mobility	Rapid Recovery	Total	P-value
No	270 (96)	638 (97)	315 (98)	481 (99)	1704	
Yes	11 (4)	22 (3)	7 (2)	7 (1)	47	
Total	281	660	322	488	1751	0.13
Contrasts						
Traditional (reference) vs. Enhanced Pain Management: 0.85 (0.40, 1.77), p=0.66						
Enhanced Pain Management (reference) vs. Early Mobility: 0.64 (0.27, 1.52), p=0.32						
Early Mobility (reference) vs. Rapid Recovery: 0.65 (0.23, 1.89), p=0.43						
Traditional (reference) vs. Rapid Recovery: 0.36 (0.14, 0.93), p=0.04						

Table 6

Thirty-day all cause readmissions broken down as a surgical or medically related reason.

All Readmissions	N= 47	
<u>Surgical</u>		<u>Return to OR</u>
Extra-capsular Hematoma	14	10
Dislocation	5	3
Stitch Abscess	1	1
Deep Infection	4	4
Wound Dehiscence	3	3
Pulmonary Embolus	1	-
Hip pain or weakness	3	-
Cellulitis	3	-
Total (% of all readmissions)	34 (72%)	21 (45%)
<u>Medical</u>		
<i>C. diff</i> colitis	3	-
Acute Renal Failure	1	-
Anemia	1	-
Chest pain/ACS	2	-
Dyspnea	1	-
Sickle Cell Crisis	2	-
GI (non-infectious)	2	-
Hematologic	1	-
Total (% of all readmissions)	13 (28%)	-