Journal of Anesthesia & Clinical Research - Open Access

Research Article
OPEN ACCESS Freely available online
doi:10.4172/2155-6148.1000101

The Economic Implications of a Multimodal Analgesic Regimen Combined with Minimally Invasive Orthopedic Surgery: A Comparative Cost Study

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Abstract

Objectives: To evaluate the economic impact of the combined effect of minimally invasive surgery (MIS) and a multimodal analgesia regimen (Total Joint Regional Anesthesia [TJRA] Clinical Pathway) on the estimated direct medical costs of patients undergoing total knee arthorplasty (TKA) or total hip arthroplasty (THA).

Patients and Methods: A retrospective cohort, cost comparison study from the hospital prospective was performed on Mayo Clinic patients (n=37) undergoing MIS TKA or THA using the TJRA Clinical Pathway. Study patients were matched 1:1 with historical controls undergoing similar procedures using traditional surgical and anesthetic (non-TJRA) techniques. Hospital-based direct costs were collected for each patient and analyzed in standardized inflation-adjusted constant dollars using cost-to-charge ratios, wage indexes, and physician services valued using Medicare reimbursement rates. The estimated mean direct hospital costs were compared between groups and a subgroup analysis was performed based upon ASA physical status classification.

Results: The estimated mean direct medical costs were significantly reduced among MIS with TJRA patients compared to controls (cost difference: $4582; 95% CI $3299-$5864; P < .001). A significant reduction was found in both the hospital-based (Medicare Part A) costs and the physician-based (Medicare Part B) costs.

Conclusions: The combined use of minimally invasive surgical (MIS) approaches and a multimodal analgesic regimen (TJRA Clinical Pathway) in patients undergoing lower extremity joint replacement provides a significant reduction in the estimated mean medical costs. A significant reduction occurs in both the hospital based (Medicare Part A) and the physician based (Medicare Part B) costs. In subgroup analysis, the greatest difference was found among the patients with significant comorbidities (ASA III-IV patients).

Introduction

Total knee and total hip arthroplasty are two of the most common surgical procedures performed in the United States. In 2005, the number of lower extremity joint replacement procedures exceeded 900,000 with a U.S. national healthcare cost of greater than 34 billion dollars [1] These numbers represent a 300% increase in the number of procedures performed and more than a 200% increase in the national healthcare cost since 2000. Currently, total knee and total hip arthroplasty represent the greatest single Medicare procedural expenditure, with continued growth expected through 2030 secondary to an ageing “baby-boomer” population, an increased number of indications for joint replacement surgery, and a growing need for revision surgeries.[2-4] Therefore, changes in surgical or anesthetic practice that are capable of decreasing or containing joint replacement costs could have a significant impact on national healthcare expenditures.

The use of minimally-invasive (MIS) surgical techniques for total joint arthroplasty has been reported to reduce pain, decrease hospital length-of-stay, and reduce episode of care costs [5-9] Similarly, the use of a comprehensive, preemptive multimodal analgesic regimen has been shown to reduce pain and opioid requirements, minimize opioid-related side effects, decrease hospital length-of-stay, and reduce inpatient costs associated with non-minimally invasive total knee and total hip replacement surgery.[10-14] However, there is currently a lack of data evaluating the combined effect of minimally-invasive surgical techniques and a multimodal analgesic regimen on inpatient costs for patients undergoing lower extremity total joint arthroplasty. Therefore, the goal of this investigation was to assess the economic impact of using a comprehensive, preemptive multimodal analgesic regimen in patients undergoing minimally-invasive total knee or total hip arthroplasty. Direct medical inpatient costs—including hospital and physician time costs—were evaluated to determine if the increased cost of implementing a multimodal regional anesthesia clinical pathway for MIS surgery was off-set by the potential cost savings from a reduction in the number of hospital services required and decreased hospital length-of-stay.

Materials and Methods

Approval for the study was granted by the Mayo Foundation Institutional Review Board. Patients who did not grant access to their medical or administrative records for research purposes were excluded as per Minnesota statute. This was an observational, retrospective cohort study using a convenience sample of patients from a previous outcome study performed within the institution [11].

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Received July 23, 2010; **Accepted** September 06, 2010; **Published** September 06, 2010

Citation: Duncan CM, Long KH, Warner DO, Pagnano MW, Hebl JR (2010) The Economic Implications of a Multimodal Analgesic Regimen Combined with Minimally Invasive Orthopedic Surgery: A Comparative Cost Study. J Anesthe Clinic Res 1:101 doi:10.4172/2155-6148.1000101

MAYO CLINIC College of Medicine	Mayo Clinic Total Joint Regional Anesthesia Clinical Pathway
Preoperative Holding Area	1. Oxycodone (Extended Release) 20 mg PO upon arrival to patient waiting area 2. Rofecoxib 50 mg PO upon arrival to patient waiting area
Anesthesia Procedure Room	1. Lumbar plexus continuous peripheral nerve catheter a. Total knee arthroplasty: posterior lumbar plexus (psoas) or femoral continuous nerve catheter b. Total hip arthroplasty: posterior lumbar plexus (psoas) continuous nerve catheter 2. Sciatic nerve blockade (total hip and total knee arthroplasty patients)
Post-Anesthesia Care Unit (PACU)	1. Acetaminophen 1000 mg + oxycodone 10 mg PO in PACU PRN VAS pain score ≥4 2. Lumbar plexus continuous peripheral nerve catheter a. Bolus 10 mL 0.2% bupivacaine upon arrival in PACU b. Begin continuous infusion bupivacaine 0.2% at 10 mL/hr
Patient Care Unit	1. Ketorolac 15 mg IV every 6 hrs x 4 doses 2. Acetaminophen 1000 mg PO TID (08:00, 12:00, 16:00 hrs) 3. Oxycodone (Extended Release) 20 mg PO BID if <70 years old (10 mg PO BID if >70 years old) 4. Oxycodone 5 mg PO every 4 hrs PRN VAS pain score ≤4 (10 mg PO every 4 hrs PRN VAS pain score >4) 5. Lumbar plexus continuous peripheral nerve catheter: Change infusion on POD #1 (6:00 a.m.) to bupivacaine 0.1% at 12 mL/hr for 24 hours 6. Heplock IV PRN 7. Do not discontinue Heplock until peripheral nerve catheter removed

The clinical pathway described above was used for the current investigation. However, subsequent modifications have been made and incorporated into our current practice. These include (1) Celecoxib 400 mg PO upon arrival to patient waiting area as a replacement for rofecoxib, (2) the addition of gabapentin 600 mg PO upon arrival to the patient waiting area, (3) sciatic nerve blockade for total knee arthroplasty patients only, and (4) the discontinuation of Oxycodone (Extended Release) after 4 doses. PO = per os; VAS = verbal analog pain score; POD = postoperative day; IV = intravenous; mL = milliliters; hr(s) = hour(s); BID = twice a day; TID = three times a day; PRN = pro re nata (as necessary)

Table 1: Mayo Clinic Total Joint Regional Anesthesia Clinical Pathway.

Study population

An economic analysis was performed on Mayo Clinic patients (n=40) undergoing minimally-invasive total knee (n=20) or total hip (n=20) arthroplasty using the Mayo Clinic Total Joint Regional Anesthesia (TJRA) Clinical Pathway (MIS + TJRA cohort) who were retrospectively reviewed for a previous clinical investigation [11]. The Mayo Clinic TJRA Clinical Pathway is a comprehensive perioperative analgesic regimen designed for patients undergoing major joint replacement surgery (Table 1). Peripheral nerve blockade and the use of perineural catheters are a major component of the clinical pathway. The TJRA protocol was developed from the collective experience of Mayo Clinic anesthesiologists and orthopedic surgeons based upon previous experience and exposure to physicians and practice models outside the institution. Participant eligibility for the current study was restricted to those patients receiving MIS from a single surgeon utilizing the TJRA Clinical Pathway. Study patients were then matched 1:1 with historical controls (Control cohort) undergoing total knee or total hip arthroplasty within 5 years of the matched MIS + TJRA patient using traditional (non-minimally invasive) surgical and anesthetic (non-TJRA) techniques. Traditional (non-TJRA) anesthetic techniques were defined as no preoperative administration of analgesic adjuvants (opioids, nonsteroidal anti-inflammatory agents, COX-II inhibitors), intraoperative general or neuraxial anesthesia without peripheral nerve blockade, and intravenous opioids during the intraoperative and postoperative (patient-controlled analgesia) periods with conversion to oral opioid analgesics after 48 hours. Patients were matched on: 1) type of procedure; 2) age; 3) gender; 4) surgeon and 5) American Society of Anesthesiologists (ASA) physical status classification. We selected this convenience sample of patients for economic evaluation since our previous investigation demonstrated a benefit in clinical outcomes. Clinical outcomes are important considerations when evaluating the economic impact of health care alternatives. Proposed changes in clinical practice should meet—or exceed—the documented clinical benefit of traditional practice models [15].

Economic data collection and outcomes

The economic analysis was performed from the perspective of the cost to the hospital. Health care utilization and associated billed charges were collected from the Olmsted County Healthcare Expenditure and Utilization Database (OCHEUD). The OCHEUD provides a standardized inflation-adjusted estimate of the costs of each service or procedure provided since 1987 at Mayo Clinic and affiliated hospitals in constant dollars. Data from administrative sources was used to evaluate and compare the direct medical costs between the MIS + TJRA and Control cohorts for the surgical episodes of interest. Billed charges were grouped into the Medicare Part A and Part B classification system (Figure 1) [16]. However, this methodology was used for classification purposes only, and does not imply that only Medicare patients were evaluated. Patients from several payer types were used within the study. Costs associated with Medicare Part A hospital services were estimated by adjusting billed charges using cost-to-charge ratios at the department level and wage indexes. Costs associated with Medicare Part B physician services were acquired using Medicare reimbursement rates. All costs were adjusted to reflect 2004 constant dollars.

The primary study outcome was the estimated mean difference in direct medical cost for each surgical episode of interest. The economic analysis takes into account differences in the variable equipment and

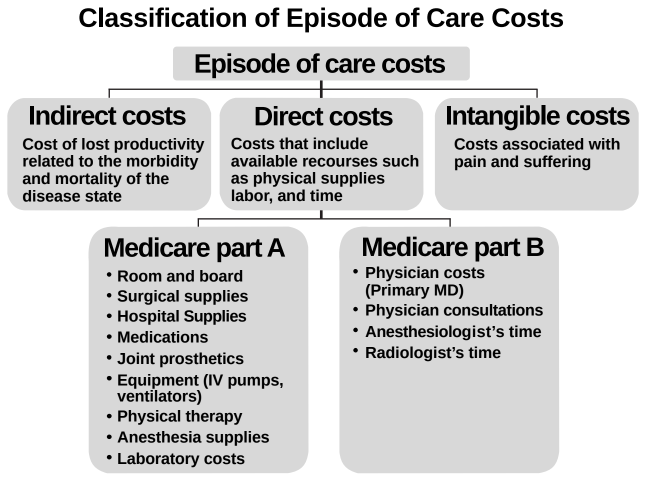

Figure 1: Classification of Episode of Care Costs [16].

medication costs (Medicare Part A) as well as estimated physician costs (Medicare Part B) [15,17-19]. Medicare Part A data was further sub-grouped by revenue codes for detailed hospital cost analyses. Medicare Part A subgroups included hospital room and board costs, operating room costs, medical and surgical supply costs, pharmacy costs, and anesthesia supply costs. Operating room cost is reflective of operating room time. It is calculated from patient entry and exit times from the operating room, and includes the time to perform the regional anesthetic technique (single-injection and continuous peripheral nerve blockade), to induce anesthesia for the procedure, and for patient emergence and immediate anesthesia recovery. Operating room time is also used to calculate direct anesthesia physician costs in a unit per time basis.

Data validation

Data validation is often recommended when using administrative data sources that are not intended for research purposes [20,21]. Therefore, we performed extensive data validation at the line-item level by evaluating outliers and reviewing expected utilization and associated billed costs to ensure that each surgical episode of interest was correctly billed and appropriately identified within administrative data sources.

Statistical analysis

The most appropriate statistical analysis from an economic and budgetary perspective is to derive the mean costs per patient [14,22,23]. Although median values may provide important descriptive information, all unadjusted costs are reported as means to account for patient outliers that represent actual costs to the institution. This methodology provides insight into the overall provider based cost for an institution. However, both mean and median values have been reported for comparison purposes (Tables 2 and 3). Paired t-tests were used to compare intra-pair mean differences in total direct costs, hospital costs, and physician costs. Further data analysis was performed using non-parametric bootstrap methods to compare the mean costs between groups and to derive the 95% confidence intervals [24,25].

One factor that may influence the intensity of services, and thus costs, is patient comorbidity. Therefore, ancillary subgroup analyses were performed of costs by treatment group (MIS + TJRA vs. Control cohort) within ASA physical status (PS) classification. ASA PS I and II patients were collectively analyzed as Group ASA PS I-II, while ASA PS III and IV patients were collectively analyzed as Group ASA PS III-IV patients—the latter group indicating patients with more severe systemic comorbidity.

Results

Of the 40 patients who underwent minimally-invasive total hip or total knee arthroplasty using the TJRA Clinical Pathway (MIS + TJRA cohort), consent for research review of the medical record was withdrawn by two subjects [11]. In addition, one subject was found to have an incorrect medical record number—making linkage to the correct administrative data episode of care difficult. Therefore, a final convenience sample of 37 matched case-control pairs was available for economic analyses.

Economic outcomes

The estimated hospital (Medicare Part A), physician (Medicare Part B), and total costs for each cohort are listed in (Table 2). Overall, total direct medical costs of hospitalization were $4,582 lower for MIS + TJRA patients when compared to controls ($11,816 vs. $16,398; 95% C.I. $3,299-$5,864). Component analysis of hospital (Medicare Part A) and physician (Medicare Part B) costs found that both cost categories were significantly reduced within the MIS + TJRA cohort, with hospital-based costs accounting for the majority of the total cost savings (Table 2). The observed difference in hospital-

	MIS + TJRA Cohort† (n=37)	Control Cohort† (n=37)	Cost Difference§ (95% CI)	P-value
Hospital Costs (Medicare Part A)	$9,763 (9,696) ±1,165	$13,895 (12,493) ±3,617	$4,132 (2,939; 5,289)	<0.001
Room and Board	$2,679 (2,717) ±750	$4,317 (4,146) ±1,299	$1,638 (1,178; 2,095)	<0.001
Medical/Surgical Supply	$2,329 (2,752) ±709	$3,449 (2,980) ±1,701	$1,120 (600; 1,706)	<0.001
Operating Room	$2,524 (2,539) ±181	$3,050 (3,061) ±398	$526 (399; 667)	<.001
Pharmacy	$716 (667) ±194	$906 (814) ±372	$190 (52; 332)	0.01
Anesthesia Supply	$106 (148) ±60	$199 (231) ±75	$93 (64; 122)	<0.001
Physician Costs (Medicare Part B)	$2,053 (2,082) ±113	$2,502 (2,378) ±571	$449 (274; 650)	<0.001
Anesthesia	$336 (340) ±38	$442 (428) ±94	$106 (77; 138)	<0.001
Total Costs	$11,816 (11,822) ±1,195	$16,398 (15,010) ±3,996	$4,582 (3,299; 5,864)	<0.001

*Estimated costs per patient are reported in 2004 constant dollars.
†Values are presented as mean (median) ± standard deviation
§ Intra-pair differences are calculated as Control minus (MIS + TJRA). Bootstrap 95% C.I. using the percentile method.
MIS=minimally-invasive surgery; TJRA=Total Joint Regional Anesthesia Clinical Pathway; C.I=Confidence interval

Table 2: Hospital and Physician Costs of Total Joint Replacement Surgery.

ASA I-II Patients	**MIS +TJRA Cohort† (n=25)**	**Control Cohort † (n=25)**	**Cost Difference§ (95% CI)**	**P-value**
Hospital Costs (Medicare Part A)	$9,727 (9,687) ±1,126	$13,365 (12,412) ±2,847	$3,638 (2,512; 4,982)	<0.001
Physician Costs (Medicare Part B)	$2,036 (2,062) ±110	$2,432 (2,366) ±594	$396 (197; 693)	0.003
Anesthesia	$335 (340) ±39	$431(428) ±73	$96 (65; 130)	<0.001
Total Costs	$11,763 (11,774) ±1,165	$15,796 (15,010) ±3,179	$4,034 (2,758; 5,514)	<0.001
ASA III-IV Patients	**MIS + TJRA Cohort† (n=9)**	**Control Cohort† (n=9)**	**Cost Difference§ (95%CI)**	**P-value**
Hospital Costs (Medicare Part A)	$9,364 (9,440) ±1,111	$15,013 (12,493) ±5,210	$5,649 (2,679; 9,334)	0.006
Physician Costs (Medicare Part B)	$2,078 (2,082) ±129	$2,570 (2,486) ±466	$492 (176; 819)	0.008
Anesthesia	$336 (345) ±42	$481 (454) ±144	$144 (58; 242)	0.01
Total Costs	$11,443 (11,416) ±1,100	$17,583 (14,979) ±5,643	$6,140 (2,937; 10,145)	0.006

*Estimated costs per patient are reported in 2004 constant dollars.
†Values are presented as mean (median) ± standard deviation.
§Intra-pair differences are calculated as Control minus (MIS + TJRA). Bootstrap 95% C.I. using the percentile method.
MIS=minimally-invasive surgery; TJRA=Total Joint Regional Anesthesia; C.I=Confidence interval

Table 3: Hospital and Physician Costs of Total Joint Replacement Surgery and ASA Physical Status.

based costs was attributed primarily to significant reductions in room and board costs, medical and surgical supply costs, and operating room costs. Anesthesia supply costs and inpatient pharmacy costs were also significantly lower within the MIS + TJRA cohort. However, these two cost categories accounted for only a small proportion of the overall cost savings. Finally, physician costs (Medicare Part B) were also significantly lower among MIS + TJRA patients (mean cost difference $449; P<0.001), with a significant proportion (24%) of the overall cost savings coming from a reduction in physician anesthesia costs.

ASA Physical status subgroup analyses

The estimated hospital (Medicare Part A), physician (Medicare Part B), and total costs for ASA PS I-II and ASA PS III-IV patients are listed in Table 3. Three patients could not be matched on ASA physical status. Therefore, ASA subgroup analyses were limited to 34 matched pairs. Among ASA PS I-II patients, the MIS + TJRA cohort had significantly lower hospital (Medicare Part A), physician (Medicare Part B), and overall total costs when compared to ASA PS I-II controls (Table 3). Anesthesia physician costs were also significantly lower within the MIS + TJRA cohort. Among ASA PS III-IV patients, the MIS + TJRA cohort had significantly lower hospital (Medicare Part A), physician (Medicare Part B), and overall total costs when compared to ASA PS III-IV controls (Table 3). The observed cost savings within the MIS + TJRA cohort was greatest among patients with more severe systemic comorbidity (ASA PS III-IV patients; $6,140).

Discussion

The primary objective of the current investigation was to evaluate the economic impact of implementing a multimodal analgesic regimen (TJRA Clinical Pathway) on estimated mean inpatient costs in patients undergoing minimally-invasive total knee or total hip arthroplasty. The findings suggest that changes in surgical (MIS surgery) and anesthetic (TJRA Clinical Pathway) practice results in an estimated total direct medical cost reduction of $4,500 per surgical episode when compared to traditional surgical (non-minimally invasive) techniques and postoperative intravenous opioids. The majority of the cost savings were hospital-based (Medicare Part A) costs, including significant reductions in hospital room and board and medical and surgical supply costs. Patients with greater disease burden (ASA PS III-IV) appeared to economically benefit the most from the combined MIS + TJRA approach. However, significant cost savings were observed for both ASA PS I-II and ASA PS III-IV patients. We postulate that a synergistic effect on clinical outcomes—and secondarily on direct medical costs—is possible when minimally invasive surgical techniques are combined with a comprehensive, preemptive multimodal analgesic pathway that emphasizes peripheral nerve blockade.

Currently, there is limited data available on the economic impact of either multimodal analgesia [10,13,14] or minimally-invasive surgery[31] on hospital costs. Many of the studies evaluating minimally-invasive total knee or total hip arthroplasty are limited to clinical outcomes—including postoperative analgesia and hospital length-of-stay [6,9,26-30]. Although a cost savings *may* occur based upon a reduction in hospital length-of-stay, this economic benefit is highly dependent on the total length-of-stay. For example, patients with a length-of-stay reduction from 3 to 2 days may have a significantly greater economic impact than a length-of-stay reduction from 5 to 4 days [17]. In one of the few economic comparisons, Bertin and colleagues evaluated the cost of performing MIS surgery in outpatients undergoing total hip arthroplasty[31]. In this very select study population, hospital charges for MIS outpatients were compared to patients undergoing traditional surgical techniques and inpatient care. MIS outpatients had a significant reduction ($4000) in hospital costs when compared to surgical inpatients. The authors also reported a reduction in hospital reimbursement of $1,155 for the MIS group. Unfortunately, the ability to perform outpatient total hip arthroplasty is limited to an extremely select group of patients. Therefore, any potential reduction in costs from using an MIS approach cannot be extrapolated to the general *inpatient* population given these results.

Prior clinical studies of the patient cohort used in this investigation have demonstrated a significant reduction in hospital length-of-stay (2.2 days), postoperative cognitive dysfunction, opioid requirements, opioid-related side effects, and time to ambulation [11]. The reduction of each of these factors likely contributed to the overall reduction in hospital-related direct medical costs. For example, the reduction in hospital length-of-stay resulted in a significant reduction in the associated room and board costs and indirectly reduced medical supply costs by limiting the amount of time in the hospital. In general, patients spending less time in the hospital will naturally accrue fewer hospital supply costs. Although speculative, lower opioid requirements and fewer opioid-related side effects may have also resulted in fewer interventions (venous blood draws, laboratory analysis, medication administration, intravenous fluids, nasogastric tube or urinary catheter placement, ambulation assistance)—lowering the overall medical supply costs during the patient's hospital stay.

In the current study, the placement of the continuous peripheral nerve blocks was performed in the operating room. The average time to perform lumbar plexus blockade and sciatic nerve block was 14 minutes [11]. The cost of this increased procedure time would be reflected in the operating room cost. Operating room costs directly reflect operating room time. The results of our study demonstrate that even with the increased time for regional anesthesia, there remains a statistically significant reduction in operating room cost. We speculate that a reduction in opioid administration, deep sedation, or general anesthesia may decrease operating room time secondary to abbreviated emergence intervals and the time required to exit the surgical suite.

The combined MIS with TJRA techniques demonstrated a significant reduction in direct medical costs in both healthy patients (ASA I-II) and in those with more significant comorbidities (ASA III-IV). The cost reduction was far greater in the ASA III-IV patients. Prior studies have demonstrated improved analgesia with reduced opioid use, a reduction in opioid related side-effects and complications, and earlier ambulation in both MIS patients and patients receiving multimodal analgesia [9,11,32,33]. The improvement in pain control and postoperative functional status may minimize exacerbations of preexisting comorbidities within ASA III and IV patients—resulting in a significantly greater reduction in direct medical costs when compared to ASA I and II patients. However, additional data is needed to determine if MIS surgery and the TJRA protocol preferentially benefits patients with more severe comorbidities.

It is important to note that the estimated mean direct medical cost reduction found in patients undergoing MIS with the TJRA Clinical Pathway may not reliably translate into an overall net savings for the institution. For example, many of the costs associated with maintaining a surgical practice within a hospital setting are fixed

[34-38]. Nursing, physical therapy, housekeeping, food service, and maintenance staff are salaried employees in most major institutions. Therefore, a reduction in hospital length-of-stay for any given patient does not directly reduce the personnel costs of the institution [17]. Furthermore, the reduction in per patient mean direct medical cost does not take into consideration the opportunity costs associated with vacant operating rooms or hospital beds. However, if the associated reduction in hospital length-of-stay allows an increase in surgical volume for elective joint replacement surgery, the institution may benefit from an increased revenue stream. United States healthcare financing is further complicated by providers and healthcare institutions having a variety of contracts with third party payers for procedural payment [7]. In cases of fixed payments—regardless of the patient's postoperative hospital course—the institutional cost savings realized from a reduced length-of-stay may have an even greater impact on the profit margin for an institution. Conversely, some payer compensation programs increase hospital payments based on duration of hospitalization, and could therefore provide an economic *disincentive* for accelerated hospital discharge times [2]. Finally, long-term outcomes for minimally invasive surgical procedures are unknown. Some authors suggest that patients undergoing minimally-invasive techniques may be at higher risk of joint failure or a decreased lifespan of the replaced joint [6,9,30,39,40]. Subsequent costs for revision surgery would potentially negate any cost savings—and actually increase the overall cost per patient.

An important strength of the current investigation was the ability to use the Olmsted County Healthcare Expenditure and Utilization Database (OCHEUD). This unique administrative database provides a standardized inflation-adjusted estimate of the costs of each service or procedure provided since 1987 at Mayo Clinic and affiliated hospitals in constant dollars. The value of each unit of service is adjusted to national cost norms by the use of widely accepted valuation techniques. This process minimizes discrepancies between billed charges and true resource use. The database is also able to provide an estimated economic cost for each line item in the billing record and is able to aggregate these costs into categories. Use of the database allowed us to describe and compare the estimated mean costs between study subjects and their matched controls with a degree of economic resolution that would have otherwise been very difficult or impossible. In addition, the database provides standardized dollar values for surgical procedures that may have occurred during different time periods.

The study has several important limitations. First, the current investigation compared the economic impact of two simultaneous interventions: minimally-invasive surgery and the implementation of a multimodal analgesic regimen. Therefore, it is difficult to identify precisely which change in clinical practice contributed to the significant cost savings. However, it is likely that both interventions played a role in the overall economic outcome. Prior investigations have demonstrated that use of the TJRA Clinical Pathway may result in a cost savings of $1,999 in patients undergoing traditional (non-minimally invasive) joint replacement surgery [10]. Although this finding is significant, it does not approach the $4,500 cost savings identified in the current investigation—suggesting that minimally-invasive surgical techniques may have also played a role in cost reduction. Second, the study design used a retrospective convenience sample from a prior clinical investigation, resulting in a non-randomized assignment of patients to either the MIS + TJRA or Control cohort. Sample size determinations were based upon the assessment of clinical—not financial—outcomes. Third, data acquisition occurred at a single, high-volume referral medical center. Patients and results may differ at other institutions or within alternative practice settings. Finally, the current investigation was limited to the evaluation of direct medical costs during a single episode of care. It did not take into consideration the extended (3-6 month) economic impact of minimally-invasive surgery or the TJRA Clinical Pathway; nor did it evaluate indirect costs such the patient's time away from work, the potential cost to family members caring for the patient (loss time and wages), or indirect costs associated with perioperative morbidity. The evaluation of indirect costs such as these would be essential to determine the overall economic impact of changes in clinical practice.

In summary, the TJRA Clinical Pathway used in conjunction with minimally-invasive surgical techniques provides a significant reduction in the estimated total direct medical costs associated with total knee and total hip arthroplasty. The reduction in mean cost is primarily associated with lower hospital-based (Medicare Part A) costs—with the greatest overall cost difference appearing among patients with significant comorbidities (ASA III-IV patients). These results suggest that changes in both surgical and anesthetic practice can have a significant economic impact on inpatient costs within a single institution. However, additional prospective clinical and economic studies are needed to evaluate the cost effectiveness and economic impact of these and other changes in clinical practice on local, regional, and overall national healthcare expenditures.

Financial support

Mayo Clinic Department of Anesthesiology and Mayo Foundation for Medical Education and Research.

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