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Economics of Nerve Block Pain Management after Anterior Cruciate Ligament Reconstruction

Potential Hospital Cost Savings via *Associated Postanesthesia Care Unit Bypass and Same-day Discharge*

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Background: **Anterior cruciate ligament reconstruction is a complex outpatient surgical procedure often associated with pain. Traditionally, the procedure is performed under general anesthesia and often requires the use of the PACU. Refractory pain and/or nausea/vomiting occasionally leads to an unplanned hospital admission. In this study, the authors examine the associations of nerve block analgesia for these patients and its associated reductions in PACU use, hospital admission, and hospital costs.**

Methods: **This was an observational, nonrandomized study in which existing data regarding patients' day-of-surgery outcomes were merged with hospital cost data. We reviewed a consecutive sample of 948 men and women who were in good health and underwent anterior cruciate ligament reconstruction in an outpatient surgery unit between July 1995 and June 1999.**

Results: **The use of nerve block analgesia was associated with reduced PACU admissions to 18% and decreased unplanned hospital admission rates from 17% to 4%. Multivariate linear regression analysis showed that patients bypassing the PACU had an associated hospital cost reduction of 12% ($P = 0.0001$), whereas patients who needed hospital admission had an associated hospital cost increase of 11% ($P = 0.0003$).**

Conclusions: **The use of nerve blocks for acute pain management in patients undergoing anterior cruciate ligament reconstruction is associated with PACU bypass and reliable same-day discharge. Although the cost savings for this one procedure are unlikely to generate sufficient cost savings *via* staffing reductions, extrapolating these results to a large volume of all types of invasive outpatient orthopedic procedures may have the potential to create significant hospital cost savings.**

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THE constant search for increased healthcare efficiency has led to the performance of a greater number of procedures on an outpatient basis. These procedures now include anterior cruciate ligament (ACL) reconstruction, a complex operation that has traditionally been followed by acute pain as well as postoperative nausea and/or vomiting (PONV). Although moderate-to-severe postoperative pain has generally been treated with opioids, these agents are known to create or exacerbate significant adverse effects and complications, including PONV, hypoxia, and urinary retention. In contrast, when pain is controlled with a nerve block given before the patient emerges from anesthesia, these adverse effects are less likely to occur.[1–5] Recent research indicates that effective pain relief, avoidance of PONV, and rapid emergence from anesthesia all decrease the need for intensive postoperative care in the PACU[6] and that bypassing the PACU accelerates the discharge of patients.[4]

It is difficult to determine the costs of resources used to avoid pain and PONV. Activity-based hospital cost accounting systems tabulate the use of personnel (time) and material resources (*e.g.*, supplies and equipment) for the performance of activities. In healthcare organizations, as in all service organizations, the majority of costs are attributable to the salaries of personnel needed to administer routine or advanced technology services.[7,8] Therefore, actual cost savings cannot usually be achieved without making reductions in personnel or reassigning personnel to perform other value-adding healthcare activities when they are not performing their usual activities.[9,10]

In the case of ACL reconstruction, we believed that pain management with peripheral nerve blocks would allow patients to bypass the PACU, would facilitate their same-day discharge, would bring about a workload reduction for postoperative nurses, and would reduce hospital costs significantly. To determine the cost savings, we examined the anesthesia techniques, resource utilization, and costs associated with the care of 948 consecutive outpatients who underwent ACL reconstruction in a surgical unit in our teaching hospital during a 4-yr period.

Materials and Methods

Study Subjects and Setting

We received approval from the Institutional Review Board at the University of Pittsburgh (Pittsburgh, Pennsylvania) to examine the database containing day-of-surgery processes and outcomes for all patients who underwent ACL reconstruction between July 1995 and June 1999 in an outpatient surgery unit of the University of Pittsburgh Medical Center. This unit performs an average of 3,000 invasive outpatient orthopedic procedures each year, including ACL reconstruction. We defined *ACL reconstruction* as a procedure classified as *International Classification of Diseases, 9th Revision–Clinical Modification* code 81.43. We excluded patients if, during ACL reconstruction, they underwent reconstruction of another knee ligament (posterior cruciate, medial collateral, or lateral collateral ligament) or underwent another procedure that produces significant periosteal trespass on the sciatic nerve distribution (*e.g.*, tibial osteotomy or meniscal reconstruction). The final study sample consisted of 948 men and women who underwent ACL reconstruction.

Clinical Care Objectives: Standard Safety and PACU Bypass

The clinical objective for our patients, aside from achieving standard perioperative safety parameters, was to render patients awake and pain-free, with otherwise minimal symptoms, immediately before exit from the operating room. PACU bypass was initiated to simultaneously meet the needs of these awake and comfortable patients while offsetting PACU workload increases created by forced downsizing of clinical nursing staff during the mid-1990s.

Demographic and Treatment Data

For each patient, we gathered data regarding the following: age; sex; preoperative physical status; type of ACL reconstruction performed (autograft or allograft); types of perioperative care received, including anesthetic, analgesic, and antiemetic agents; and patient disposition after surgery, including information about PACU use and hospital admission.

Use of Anesthetic, Analgesic, and Antiemetic Agents

Patients were categorized as having received general anesthesia (GA) if the airway was secured with an endotracheal tube or a laryngeal mask, and then a volatile agent (*e.g.*, isoflurane, sevoflurane, or desflurane) was administered by inhalation. Total intravenous GA techniques (*e.g.*, with propofol) were not used during the period of our study. Many patients received spinal anesthesia or epidural anesthesia instead of GA, but neither of these types of anesthesia provides prolonged analgesia. Some patients received long-acting analgesia with a femoral nerve block, using a local anesthetic agent (*e.g.*, ropivacaine or bupivacaine).

For each patient, we classified the anesthesia and analgesia technique as one of the following: (1) general anesthesia with a volatile agent (GAVA) and no nerve block for pain relief; (2) GAVA with nerve block for pain relief; (3) neuraxial anesthesia (spinal or epidural anesthesia) without nerve block; (4) neuraxial anesthesia with nerve block; or (5) complete lower extremity nerve block, which provides both anesthesia during surgery and pain relief after surgery.

We recorded whether the patient received antiemetics during surgery to help to prevent PONV, and we also recorded whether the patient received parenteral interventions by a nurse after surgery for the management of pain or PONV. If a patient received at least one parenteral dose of an analgesic (opioid or ketorolac) or an antiemetic (dexamethasone, ondansetron, perphenazine, or droperidol), the patient was deemed to have had postoperative pain or PONV necessitating a parenteral intervention.

Patient Disposition after Surgery

Until July 1996, the policy at our institution was to send all patients to the PACU after surgery. Beginning in July 1996, patients who experienced a rapid emergence from anesthesia; showed hemodynamic and respiratory stability; and were free from pain, PONV, and other symptoms were transferred to a step-down recovery unit, rather than being sent to the PACU. For purposes of our study, instead of using traditional criteria to determine recovery room bypass eligibility (*i.e.*, the score described by Aldrete[11]), we used a modified set of criteria (table 1), the details of which we reported elsewhere.[3,4] In addition to recording whether the patient bypassed the PACU, we recorded whether the patient was admitted to the hospital. For purposes of our study, a *hospital admission* was defined as an admission that occurred on the same day as surgery. A *readmission* was defined as an admission that occurred after same-day discharge or occurred after same-day admission and subsequent discharge.

It should be noted that PACU bypass was available to all patients at our institution, not just those undergoing ACL reconstruction. This factor is important when making cost extrapolations for our institutional population of invasive outpatient orthopedics and is detailed further in the Discussion.

Hospital Cost Data

The clinical database described above was linked, *post hoc*, to the hospital cost database. The hospital cost database used was the same as that used in an earlier study determining cost differences associated with accelerated rehabilitation programs after total joint re-

Table 1. Regional Anesthesia PACU Bypass Criteria and Scoring System

Parameters	Scores
Movement	
Purposeful movement of (at least) one lower and one upper extremity	2
Purposeful movement of at least one upper extremity (but neither lower extremity)	1
No purposeful movement	0
	Movement score:
Blood pressure	
Within 20% of baseline, without orthostatic changes	2
Between 20 and 40% of baseline, without orthostatic changes	1
Less than 40% of baseline, and/or orthostatic changes	0
	BP score:
Level of consciousness	
Awake, follows commands	2
Arousable, follows commands	1
Obtunded or persistently somnolent	0
	LOC score:
Respiratory effort	
Able to cough involuntarily or on command	2
Only able to cough involuntarily, not on command	1
Dyspnea or apnea	0
	Respiratory score:
Pulse oximetry	
$Spo_2 \geq 95\%$ on room air	2
$Spo_2 \geq 95\%$ with facemask or nasal cannula	1
$Spo_2 < 95\%$	0
	Pulse oximetry score:
	Total score:

The minimum score to qualify for PACU bypass is 8. Patients considered for PACU bypass should not need interventions for pain, nausea, vomiting, pruritis, or shivering.

BP = blood pressure; LOC = level of consciousness; Spo_2 = oxygen saturation measured by pulse oximetry.

placement surgery.[12] The total costs of same-day surgery and hospital admission (if applicable) were identified using the hospital's cost accounting database. Costs for preapproved hospital admissions were the same as costs for unplanned hospital admissions, according to our institution's cost accounting system. Costs included both *direct* and *indirect costs* and were defined as the dollar amount of resources utilized to provide all aspects of patient care. Costs were calculated using the ratio of cost to charge to the patients' charges in a given department. In our institution, ratios of cost to charge are updated each fiscal year. The annual ratio of cost to charge adjustments were independent of anesthesia processes before and during surgery. To apportion indirect costs to direct cost centers, a step-down method was used where the indirect department that receives the least amount of services from other indirect departments and provides the most service to other departments allocates its costs first.[13] This process is repeated to determine the order of cost allocation for each remaining indirect department. Overhead costs were distributed based on specific hospital statistics. For example, housekeeping costs were allocated to other cost centers based on square footage, whereas billing department costs were allocated based on gross charges. Visits to the outpatient clinic, return visits to the hospital, and professional fees were not included in the cost analysis.

Statistical Analysis

Because PACU bypass was the variable with the greatest impact on costs, we tabulated demographic and treatment data on the basis of this variable and categorized patients into two groups: those who stayed in the PACU and those who bypassed the PACU (table 2). We also cross-tabulated the following categories of variables: patient-specific variables (age, sex, and American Society of Anesthesiologists physical status classification); surgery-specific variables (ACL autograft *vs.* allograft); anesthesia-related variables (anesthetic, analgesic, and antiemetic agents used); and disposition variables (nursing interventions, PACU use *vs.* PACU bypass, and hospital admission).

The association between PACU use (no/yes) and other variables was examined using bivariate analyses. For continuous variables, means and SEMs were calculated, and the unpaired *t* test was used to test the significance of the differences between the means in the two groups. For categorical variables, statistical significance was assessed using the chi-square test. Similar bivariate analyses were used to assess the association between anesthesia techniques and same-day surgery outcomes after ACL reconstruction.

Because hospital costs were not normally distributed, costs were transformed for regression analysis. Predictedvalues for log costs were retransformed into predicted costs using a standard method that corrected for asymptotic bias, which arises from the simple exponentiation

Table 2. Demographic and Treatment Variables in a Sample of 948 Patients Who Underwent ACL Reconstruction

Variable	All Patients (n = 948)	Patients Who Stayed in PACU (n = 394)	Patients Who Bypassed PACU (n = 554)	*P* Value
Age, mean ± 2 SEM, y	26.6 ± 0.7	27.2 ± 1.1	26.2 ± 0.9	—
Sex				—
Male	589 (62)	250 (63)	339 (61)	
Female	359 (38)	144 (37)	215 (39)	
Preoperative PS				—
ASA PS I	759 (80)	310 (79)	449 (81)	
ASA PS II	174 (18)	79 (20)	95 (17)	
ASA PS > II	9 (1)	4 (1)	5 (1)	
Unknown ASA PS	6 (1)	1 (<1)	5 (1)	
Type of ACL reconstruction				—
ACL autograft	733 (77)	295 (75)	438 (79)	
ACL allograft	215 (23)	99 (25)	116 (21)	
Perioperative care				
Received GAVA	288 (30)	235 (60)	53 (9)	< 0.001
Received neuraxial anesthesia without prolonged analgesia	142 (15)	64 (16)	78 (14)	—
Received prolonged nerve block analgesia	608 (64)	135 (22)	473 (88)	< 0.001
Received intraoperative antiemetics	484 (51)	124 (31)	360 (65)	< 0.001
Received PPNI for pain	267 (28)	189 (48)	78 (14)	< 0.001
Received PPNI for PONV	249 (26)	125 (32)	124 (22)	0.001
Received specific PPNI for nausea	212 (22)	111 (28)	101 (18)	< 0.001
Received specific PPNI for emesis	115 (12)	48 (12)	67 (12)	—
Was admitted to hospital, preapproved or unplanned	151 (16)	128 (32)	23 (4)	< 0.001
Hospital cost, mean ± 2 SEM (median), US $	3,660 ± 61 (3,507)	3,761 ± 99 (3,613)	3,588 ± 78 (3,447)	0.005

Values are number (percentage of column totals) unless otherwise indicated.

ACL = anterior cruciate ligament; ASA = American Society of Anesthesiologists; GAVA = general anesthesia with a volatile agent; PPNI = postoperative parenteral nursing interventions; PONV = postoperative nausea and/or vomiting; PS = physical status.

of predicted log costs. This methodology permits the regression analysis to be run in logs and predictions to be made in levels without the introduction of bias.[14–18]

For linear regression modeling of the transformed cost variable, indicated variables were constructed for the following categories: quarter (*i.e.*, 3-month period of the study); ACL allograft (no/yes); PACU bypass (no/yes); postoperative pain or PONV necessitating a nursing intervention (no/yes); and hospital admission (no/yes). Regression models were run using hospital costs as the dependent variable. Univariate regressions were run first, and covariates found to be predictors at $P < 0.15$ were entered into a multivariate regression model.

Demographic and the cost analysis data were tabulated using SPSS for Windows version 11 (SPSS, Inc., Chicago, IL). Nonparametric transformations and linear regression techniques were performed using SAS version 6.12 (SAS Institute, Cary, NC). *P* values less than 0.05 were considered significant.

Results

PACU Bypass

In our study, 713 of the 948 patients were seen after July 1996, the date when our institution initiated PACU bypass. Of these 713 patients, 554 (78%) bypassed the PACU, 473 (88%) of which received long-acting nerve block analgesia. The patients who received only regional anesthetics were more likely to bypass the PACU than were the patients who received GAVA (86% [402 of 466] *vs.* 62% [152 of 247]; odds ratio, 3.85; 95% confidence interval, 2.70–5.56; $P < 0.001$).

In the total sample of 948 patients, PACU bypass was significantly associated with receipt of prolonged nerve block analgesia and receipt of intraoperative antiemetics (table 2). Patients who stayed in the PACU were more likely to have pain (necessitating at least one parenteral nursing intervention) than were patients who bypassed the PACU (48% [189 of 394] *vs.* 14% [78 of 554]; $P < 0.001$). Moreover, patients who stayed in the PACU (*vs.* PACU bypass patients) needed significantly more nursing interventions to alleviate pain (2.7 interventions [95% confidence interval, 2.3–3.0] *vs.* 1.4 interventions [95% confidence interval, 1.2–1.6]; $P < 0.001$). Although patients who stayed in PACU were more likely to have nursing interventions for PONV than were patients who bypassed the PACU (32% [125 of 394] *vs.* 22% [124 of 554], respectively; $P = 0.001$), there were no significant differences between groups in the number of nursing interventions needed to alleviate PONV (overall mean, 2.0 interventions [95% confidence interval, 1.8–2.1]).

Hospital Admission and Readmission

During the study period, 151 patients were admitted to the hospital. Eighty-eight patients were admitted on a

Table 3. Associations between Anesthesia and Analgesia Technique and Same-day Surgery Outcomes after ACL Reconstruction

Variable	All Patients (n = 948)	Anesthesia and Analgesia Technique Used during Surgery: GAVA without NB (n = 198)	GAVA with NB (n = 90)	Neuraxial Anesthesia without NB (n = 142)	Neuraxial Anesthesia with NB (n = 365)	Lower Extremity NB (n = 153)	*P* Value
Postoperative pain requiring at least one PPNI	267 (28)	121 (61)	30 (33)	35 (25)	74 (20)	7 (5)	< 0.001
PONV requiring at least one PPNI	249 (26)	75 (38)	25 (28)	22 (15)	90 (25)	37 (24)	< 0.001
No intraoperative antiemetics used*	128 (14)	65 (33)	5 (6)	18 (13)	29 (8)	11 (7)	0.001
One or more intraoperative antiemetics used*	104 (11)	9 (5)	18 (20)	3 (2)	50 (14)	24 (16)	0.412
Intraoperative antiemetics not legibly documented in the anesthesia record	17 (2)	1 (1)	2 (2)	1 (1)	11 (3)	2 (1)	NA†
PACU bypassed	554 (58)	3 (2)	50 (56)	78 (55)	279 (76)	144 (94)	< 0.001
Hospital admissions‡	151 (16)	64 (32)	12 (13)	28 (20)	42 (12)	5 (3)	NA
Admission preapproved	88 (9)	37 (19)	6 (7)	16 (11)	29 (8)	0 (0)	NA
Admission unplanned	63 (7)	27 (17)	6 (7)	12 (10)	13 (4)	5 (3)	< 0.001
Unplanned admission for both pain and PONV	19/63 (30)	11/27 (41)	0/6 (0)	3/12 (25)	5/13 (35)	0/5 (0)	
Unplanned admission for either pain or PONV	32/63 (51)	14/27 (52)	5/6 (83)	6/12 (50)	4/13 (31)	3/5 (60)	

Values are number (percentage) unless otherwise indicated.

ACL = anterior cruciate ligament; GAVA = general anesthesia with a volatile agent; NA = not applicable; NB = nerve block; PPNI = postoperative parenteral nursing intervention.

* These counts are referent to patients who had postoperative nausea and/or vomiting (PONV) requiring at least one postoperative parenteral nursing intervention (n = 249), not all patients. † Because of missing data, statistical analyses were not performed. ‡ Because preapproved hospital admissions were independent of the anesthesia technique used, statistical analyses were not performed for preapproved admissions or total admissions. Preapproved admissions were subtracted from the column totals when calculating the percent of unplanned patient hospital admissions.

preapproved basis after an otherwise uncomplicated surgery and anesthesia (table 3). The remaining patients (n = 63) were admitted for pain, PONV, somnolence, or urinary retention. Eighty-one percent (51 of 63) of the patients with an unplanned hospital admission (table 3) needed it for refractory pain, PONV, or both or symptoms associated with the medications used to treat PONV and/or pain (*e.g.*, somnolence). Only 4% (24 of 608) of the patients with long-acting nerve block analgesia had an unplanned hospital admission. Of the 88 admissions that were preapproved, 46 occurred before July 1996, whereas only 42 occurred during or after July 1996.

Twenty patients were readmitted to the hospital after same-day discharge, and three were readmitted after their initial unplanned admission and subsequent discharge. All 23 patients who were readmitted returned to the hospital during the last 3 yr of the observational period (September 1996–May 1999). Most were readmitted for infection (10 of 23 [43%]) or swelling of the surgically treated extremity (5 of 23 [22%]). Only one patient (4%) was readmitted for PONV, and only three (13%) were readmitted for pain. All three patients who were readmitted for pain had received nerve blocks for postoperative analgesia and were returning because the nerve blocks had dissipated and the perceived pain was uncontrollable. Because the incidence of readmissions for pain and PONV (4 of 948 [0.4%]) was low and because no readmissions were attributable to bypassing the PACU *per se*, the costs of readmission were not considered in our cost analysis.

Hospital Costs

The mean and median hospital costs for patients who bypassed the PACU were $173 lower and $166 lower, respectively, than the mean and median costs for patients who stayed in the PACU ($P = 0.005$; table 2).

The univariate linear regression model (table 4) indicated that each quarter (*i.e.*, 3-month period) was associated with a 1.2% incremental increase in hospital costs ($P = 0.0001$). ACL allograft (*vs.* ACL autograft) was associated with an 8.9% increase in costs ($P = 0.0001$), and hospital admission (*vs.* same-day discharge) was also associated with an 8.9% increase in costs ($P = 0.0056$). In contrast, PACU bypass (*vs.* PACU stay) was associated with a 4.8% reduction in hospital costs ($P = 0.0048$).

The multivariate linear regression model (table 4) indicated that quarter, ACL allograft, PACU bypass, and successful same-day discharge were independent predictors of hospital costs ($P \leq 0.0003$ for each) and that these four variables accounted for 17% of the variance of total hospital costs. After quarterly adjustments, PACU bypass was associated with a 12% hospital cost reduction (amounting to $420/patient), whereas hospital ad-

Table 4. Results of Linear Regression Testing for Predictors of Hospital Costs*

Model and Predictor	Hospital Costs		
	Point Estimate %	95% CI	*P* Value
Univariate linear regression			
Quarter (1–16)	1.21	0.87, 1.55	0.0001
ACL allograft (no/yes)	8.87	5.01, 12.73	0.0001
PACU bypass (no/yes)	−4.77	−1.46, −8.07	0.0048
Postoperative pain or PONV requiring a PPNI (no/yes)	−2.36	−0.16, −4.56	0.1582
Hospital admission (no/yes)	8.90	2.62, 15.18	0.0056
Multivariate linear regression			
Quarter (1–16)	2.10	1.74, 2.46	0.0001
ACL allograft (no/yes)	7.51	3.78, 11.25	0.0001
PACU bypass (no/yes)	−12.13	−8.61, −15.64	0.0001
Hospital admission (no/yes)	10.93	4.90, 16.96	0.0003

* $R^2 = 0.1766$. Adjusted $R^2 = 0.1725$.

ACL = anterior cruciate ligament; PONV = postoperative nausea and/or vomiting; PPNI = postoperative parenteral nursing intervention.

mission was associated with an 11% hospital cost increase (amounting to $385/patient). Including demographics (age, sex, and American Society of Anesthesiologists physical status classification), nursing interventions, and anesthesia techniques as covariates in the multivariate model did not change the estimated cost savings associated with bypassing the PACU and avoiding hospital admission. For the sake of simplicity, the results of including these variables in the univariate models are not reported.

Discussion

Our study was designed to examine the anesthesia techniques, resource utilization, and costs associated with the care of 948 consecutive outpatients who underwent ACL reconstruction in the outpatient surgical unit of our teaching hospital during a 4-yr period. We found that pain management with peripheral nerve blocks was associated with 82% of the patients bypassing the PACU and with 96% avoiding hospital admission. Using the median cost of $3,500 as an index, we found that PACU bypass was associated with a 12% hospital cost reduction ($420/patient) and that avoidance of hospital admission was associated with an 11% hospital cost reduction ($385/patient). We believe that the associated cost reductions per patient were attributable to the routine use of peripheral nerve block anesthesia/analgesia for this invasive outpatient orthopedic procedure, facilitating faster emergence, PACU bypass, and fewer postoperative symptoms (especially pain, PONV, and somnolence). Our view on the association between the use of peripheral nerve blocks in invasive outpatient orthopedic surgery and the favorable outcomes described must be confirmed *via* a randomized clinical trial. However, hospital costs associated with the implementation of randomized trials may cloud the results of hospital costs noted for patients undergoing routine clinical care. Therefore, the presented hospital cost data in this observational study may or may not be reproducible *via* randomized trials. Further study is needed to distinguish hospital cost differences in research settings *versus* routine clinical settings.

Estimates of Hospital Cost Savings

Institutional cost savings for the annual population of ACL reconstruction patients were estimated. Assuming the group practice through June 1996 was maintained (consisting effectively of 100% GAVA with no PACU bypass, and 17% unplanned hospital admissions), cost values were determined for a rounded annual count of 250 patients undergoing outpatient ACL reconstruction. With transformation of the group practice to a theoretical 100% use of nerve block anesthesia/analgesia, with 82% PACU bypass (table 2) and 4% unplanned hospital admission, cost values were similarly calculated for the same 250 patients, and cost differences were calculated between the traditional care and nerve block scenarios.

For the rounded value of 250 patients/yr undergoing ACL reconstruction in our institution, assuming a GAVA-dominated practice with no PACU bypass, the hospital cost was just over $996,000. The costs associated with a practice transformed into the exclusive use of nerve blocks, with implemented PACU bypass, these costs were just under $898,000. Therefore, the potential cost savings achieved was just over $98,600 for the one surgical procedure (table 5).

Based on these cost savings estimates for ACL reconstruction only, we then determined cost savings estimates for our institution's 3,000 annual invasive outpatient orthopedic procedures. During the time period studied, our institution annually performed 800 invasive outpatient procedures on the knee (including ACL reconstruction, excluding routine diagnostic arthroscopy), 1,200 on the foot and ankle, and 1,000 on the shoulder and upper extremity. Based on these case volumes and the cost savings estimates shown in table 5, we calculated the potential cost savings assuming the perfor-

Table 5. Hospital Cost Savings Estimates for 250 ACL Reconstruction Procedures per Year*

Scenario	Base Cost, $	PACU Cost, $	Hospital Admission Cost, $	Total Cost, $
Traditional care scenario (100% general anesthesia, 0% nerve blocks, 0% PACU bypass, and 17% unplanned hospital admission)	875,000	105,000	16,363	996,363
Nerve block scenario (0% general anesthesia, 100% nerve blocks, 82% PACU bypass, and 4% unplanned hospital admission)	875,000	18,900	3,850	897,750
Savings with nerve block scenario	0	86,100†	12,513‡	98,613

* The hospital base cost for each procedure is $3,500. † Based on the multivariate regression analysis data in table 4, each PACU bypass is associated with a 12% cost savings. For the traditional care scenario, $875,000 × 0.12 = $105,000 PACU admission costs. For the nerve block scenario, $10,500,000 × 0.12 × (1 − 0.82 PACU bypass rate) = a savings of $86,100. ‡ Based on the multivariate regression analysis data in table 3, each unplanned hospital admission is associated with an 11% cost increase. For the traditional care scenario, $875,000 × 0.11 × 0.17 = $16,363. For the nerve block scenario, $10,500,000 × 0.11 × 0.04 = $3,850 = a savings of $12,513.

ACL = anterior cruciate ligament.

mance of this number of procedures per year and assuming a hospital base cost of $3,500/procedure (table 6).

Traditional care and nerve block scenarios were again created to estimate costs for the treatment of 3,000 patients undergoing invasive outpatient orthopedic procedures. In the traditional care scenario, we assumed that GAVA without nerve block analgesia was used 100% of the time and that a stay in the PACU was mandatory (*i.e.*, that the PACU bypass rate was 0%). We considered these assumptions to be reasonable because PACU bypass after invasive orthopedic surgery is not practiced on a routine basis throughout North America. That is, this cost analysis scenario is provided for centers that do not currently use PACU bypass (and mandate a PACU stay for all patients) and exclusively uses GAVA without nerve blocks for invasive outpatient orthopedic surgery. Based on our previous research[3] and on the data presented in table 3, we assumed an unplanned hospital admission rate of 17% in the traditional care scenario. Although a 17% unplanned admission rate is considered exceedingly high, this represents our institution's unplanned admission rate after GAVA was used for ACL reconstruction; we attribute the high unplanned admission rate to the high incidence of somnolence and PONV associated with the use of GAVA and opioid analgesia and the incomplete analgesia provided by opioids after invasive outpatient orthopedic surgery in the absence of nerve block analgesia. Although a 17% unplanned admission rate may seem excessive in the traditional care scenario, we were not able to review the medical records of 3,000 patients/yr undergoing all categories of invasive outpatient orthopedic surgery to accurately determine preapproved *versus* unplanned admissions. In either case, PACU bypass after nerve block anesthesia/analgesia seems to be a higher-probability event (exceeding 80% in our institution), and logically, the greatest overall cost savings when comparing the two scenarios would be related to PACU bypass, more so than by avoiding unplanned hospital admissions.

In the traditional care scenario (100% GAVA, 0% nerve blocks, 0% PACU bypass, and 17% unplanned hospital admission), we found that the annual hospital costs approached $12 million. In the nerve block scenario, we assumed that nerve blocks were used for pain relief and that GAVA was not used. In addition, based on the data presented in tables 2 and 3, we assumed a recovery room bypass rate of 82% and an unplanned admission rate of 4% in this scenario. In the nerve block scenario, we found that the annual hospital costs approached $10.8 million. In our institution, the nerve block scenario, with

Table 6. Cost Estimates for 3,000 Invasive Outpatient Orthopedic Procedures per Year*

Scenario	Base Cost, $	PACU Cost, $	Hospital Admission Cost, $	Total Cost, $
Traditional care scenario (100% general anesthesia, 0% nerve blocks, 0% PACU bypass, and 17% unplanned hospital admission)	10,500,000	1,260,000	196,350	11,956,350
Nerve block scenario (0% general anesthesia, 100% nerve blocks, 82% PACU bypass, and 4% unplanned hospital admission)	10,500,000	226,800	46,200	10,773,000
Savings with nerve block scenario	0	1,033,200†	150,150‡	1,183,350

* The hospital base cost for each procedure is $3,500. † Based on the multivariate regression analysis data in table 3, each PACU bypass is associated with a 12% cost savings. For the traditional care scenario, $10,500,000 × 0.12 = $1,260,000. For the nerve block scenario, $10,500,000 × 0.12 × (1 − 0.82 PACU bypass rate) = a savings of $1,033,200. ‡ Based on the multivariate regression analysis data in table 3, each unplanned hospital admission is associated with an 11% cost increase. For the traditional care scenario, $10,500,000 × 0.11 × 0.17 = $196,350. For the nerve block scenario, $10,500,000 × 0.11 × 0.04 = $46,200 = a savings of $150,150.

PACU bypass implemented as part of the care program, was associated with an estimated savings of about $1.2 million in hospital costs each year. Even if unplanned admissions were equal in the traditional care scenario *versus* the nerve block with PACU bypass scenario, the hospital cost savings associated with PACU bypass alone for 3,000 patients/yr exceed $1 million (table 6). This amount (regardless of unplanned admission rate) seems to be sufficient to provide the personnel and incentives needed to routinely administer peripheral nerve blocks and meet these patient care objectives.

How Much of the Cost Savings Was Attributable to PACU Staffing Reductions?

We have previously shown that PACU bypass can be achieved in nearly 90% of patients receiving exclusively regional anesthesia techniques (including neuraxial techniques if hemodynamic criteria are met).[4] Dexter *et al.*[10] (1999) have shown that in surgical pavilions with large caseloads (*e.g.*, 50 cases/day), an 80% PACU bypass rate (when compared with no PACU bypass) can lead to a PACU nurse full-time equivalent (FTE) staffing reduction of up to 4 FTEs (if the PACU nurses are full-time employees), or by 20 nursing hours (if the PACU nurses are part-time employees). We cannot determine retrospectively whether further PACU nurse staff downsizing occurred during the 1996–1999 period, but it is known within our institution that most of the downsizing was said to have occurred before January 1995. However, we believe that the outpatient pavilion case volume and the PACU bypass rate of our institution match the projections made by the work of Dexter *et al.*[10] with respect to FTE reduction.

Our institution's PACU manager informed us that the PACU nurses initially available for duty at the outpatient pavilion were reassigned to the PACU of the university critical care surgical hospital immediately across the street from the outpatient pavilion. In December 2000 (the oldest-available archive of PACU staffing logs), at the peak of PACU bypass in our ambulatory surgery unit, the PACU nurse staffing count for our entire institution (*i.e.*, both inpatient and outpatient surgical suites) was 28.3 FTEs, consisting of 24 full-time, 8 part-time (0.5 FTE each), and 3 casual (0.1 FTE each). This number of FTEs was responsible for the clinical care of 24,969 annual surgical patients (from January through December 2000). This equals 1 PACU FTE/882 patients during our institution's peak use of PACU bypass. During the period of April 2001 through December 2002, 2,500 annual outpatient cases were transferred in phases to a community hospital recently acquired by the university hospital. By June 2003, PACU bypass at the university hospital campus had returned to approximately baseline (*i.e.*, only for monitored anesthesia care cases). In June 2003, 33.1 PACU FTEs (26 full-time, 13 part-time, and 6 casual) were needed to provide care for 22,560 annual surgical patients (from July 2002 through June 2003), translating to 1 PACU FTE/682 patients (a difference of 200 patients/FTE after *vs.* during PACU bypass). Therefore, 4.8 additional PACU FTEs were needed to manage 2,400 fewer annual surgical patients. With standardizing to a total of 25,000 cases/yr, the relative staff reduction with PACU bypass was 8.4 FTEs. The actual PACU staff reduction of 4.8 FTEs (and relative staff reduction of 8.4 FTEs/25,000 cases) is consistent with the simulated projections of Dexter *et al.*[10] (1999). This staff reduction may indeed have been a significant contributor to the hospital cost reductions that we extrapolated earlier in the Discussion, associated with 80% PACU bypass for a large surgical population.

Study Limitations

Our study has several limitations. First, this was an observational study, and patients were commonly recommended to receive nerve block techniques by members of our institution's outpatient regional anesthesia service. Nerve blocks were recommended by our anesthesiologists largely because of the poor same-day outcomes in our institution's historic controls from the 1995–1996 period. We cannot rule out that PACU bypass was influenced by nerve block use. However, our criteria designed to qualify patients for PACU bypass were based on the modified Aldrete score,[11] which was originally designed to assess patient recovery profiles primarily after GAVA. Regardless of the patient's selection of a given anesthetic technique (with or without GAVA), staff anesthesiologists who were part of the outpatient regional anesthesia service of our institution from July 1996 forward were instructed by the medical director of same-day services to provide patients with the best possible chance of bypassing the PACU safely while still achieving standard safety objectives and symptom-free outcomes.

To illustrate this point, any one of 25 anesthesiologists provided clinical care to the historic control patients in the 1995–1996 period; the five anesthesiologists responsible for 57% (135 of 235) of the clinical care of these patients in 1995–1996 did not use (or offer) peripheral nerve block analgesia as part of their clinical practice for knee surgery. The annual counts of staff anesthesiologists providing care for these patients in subsequent years were 12 (1996–1997), 14 (1997–1998), and 18 (1998–1999). Of note, during the 3-yr period of 1996–1999, investigators B. A. W. and M. L. K. provided the care for approximately 66% (468 of 713) of the patients, whereas a core of six other members of the outpatient regional anesthesia service provided the care for an additional 21% (147 of 713). To summarize, we acknowledge that bias may have been introduced into the outcomes of patients cared for by routine GAVA practitioners (*e.g.*, in 1995–1996) *versus* subsequent years (with care provided predominantly by specialists in out-

patient regional anesthesia). This introduction of scientific bias is offset by the common sense notion that subspecialists with dedication to and experience in accomplishing the clinical objectives for a given subspecialty may be in a prime position to translate these subspecialty skills to significant hospital cost savings.

The second study limitation is that it does not present detailed costs for drugs, supplies, and equipment used with different types of anesthesia. However, costs for anesthesia care make up only approximately 6% of total hospital costs,[19] and differences in anesthesia techniques are not expected to account for large changes in this percentage. Using the same data set as we used for the current study, we previously reported the costs of drugs, supplies, and equipment used to provide anesthesia to patients during the first 2 yr of the study period and found no significant differences in costs associated with the various anesthesia techniques.[2]

The third limitation is that our study does not report differences in professional fees for anesthesia services. Because reimbursements for nerve block techniques at our institution were commonly withheld by third-party payers or were nominal at best, reporting the differences may have been misleading.

Finally, we did not address hospital collections or profits. However, during the time period studied, reimbursements evolved from a fee-for-service to a flat fee or capitation, and this rendered the collections data irrelevant in the current reimbursement environment.

Applicability of Cost Savings Extrapolations

Several studies have estimated costs of various processes in outpatient anesthesia. Hill *et al.*,[20] for example, estimated the cost of 1 h of a registered nurse's services to be $21 and the cost of a 1-h delay in discharge from the PACU to be $35. If these values were used to compare preemptive antiemetic strategies, the estimated mean costs would be $82 to manage an episode of nausea and $305 to manage an episode of emesis. It seems logical that the treatment of an episode of pain would require labor and resources similar to the treatment of an episode of nausea. In our data, 28% of recovery room patients had at least one episode of nausea (mean, 1.5 episodes), 12% had at least one episode of emesis (mean, 1.5 episodes), and 48% had at least one episode of pain (mean, 2.7 episodes). If weighted averages of the costs reported by Hill *et al.* are used, these symptoms translate to per-patient costs of $35 for nausea, $56 for emesis, and $105 for pain. When combined with the reported cost of $35 for a 1-h delay in recovery room discharge, the sum of weighted averages for symptom management ($231) accounts for more than half of the $420 costs associated with a PACU admission in our database review, lending credibility to our calculations of the costs savings associated with PACU bypass.

Gebhard *et al.*[21] reported that patients receiving nerve blocks for peripheral orthopedic surgery (specifically, carpal tunnel release) were discharged home 68 min sooner than patients receiving GA. In addition, we previously reported that patients who bypassed the PACU were discharged 34 min sooner than patients who did not.[4] Although difficult to quantify, it is probable that a faster time to discharge contributes to the cost reductions associated with PACU bypass shown in our current study.

Woolhandler and Himmelstein[22] estimated the cost of hospital admission for all case mixes and patient locations to be $1,050. This number included $260 in fixed costs for administration. Our cost associated with hospital admission was $385, including fixed costs. We presume that our cost per admission was lower because it is based on providing only one peripheral procedure to healthy outpatients at one institution (ACL reconstruction with same-day discharge *vs.* admission to a surgical ward), whereas Woolhandler and Himmelstein addressed all medical and surgical procedures for patients with varying health status. The hospital cost increase associated with admission after ACL reconstruction in our institution seems reasonable in the context of reported national findings.

In our multivariate hospital cost model, the inclusion of demographic variables, nursing interventions, or anesthesia techniques as covariates did not change the estimated cost savings associated with bypassing the recovery room and avoiding hospital admission. This is probably because PACU use and hospital admissions represent such costly components of ambulatory surgery. Therefore, if surgical facility administrators are interested in containing costs, we recommend that they actively involve anesthesiologists in redesigning their anesthesia care to cut down on use of these costly components. In redesigning our anesthesia care, we deemphasized the use of GAVA and focused on administering nerve blocks appropriate to the level of surgical invasiveness and the level of anticipated surgical pain. As a result, more than 85% of patients who underwent knee surgery in our facility were able to bypass the PACU.[4] The use of nerve blocks as the anesthesia or postoperative analgesia technique of choice has been reported in detail elsewhere[3,4] and has been associated with meeting the two objectives of bypassing the PACU and avoiding hospital admissions. Further research is necessary regarding other reliable anesthesia techniques that can achieve both of these objectives.

Market forces will likely maintain pressures to reduce healthcare costs. With respect to anesthesia and acute pain management, these forces have reduced the reimbursements per billable unit of anesthesia care and have led to changes in the proportion of physician to nonphysician anesthesia providers or to other strategies that provide disincentives to improving the quality of care.[23] Traditionally, many policy makers, including hospital

administrators, third-party payers, and federal regulators, have assumed that "one anesthetic fits all,"[24] and that this one anesthetic is GA. The results of the current study indicate the potential for reducing costs as well as enhancing quality of care by de-emphasizing the use of GAVA and focusing instead on the use of peripheral nerve blocks for anesthesia and postoperative analgesia. In our patients, the use of nerve blocks was associated with PACU bypass and avoided hospital admission, and it seems that these factors applied together *via* transforming group practice and updating hospital policies are associated with a significant potential savings in hospital costs when applied to a large surgical population of invasive outpatient orthopedics. However, only anesthesiologists can perform peripheral nerve blocks. Therefore, our data reinforce the need for policy makers to recognize the predominant role played by the physician in the containment (and not the inflation) of healthcare expenses and to provide the necessary support. Hospital administrators should provide anesthesiologists with appropriate resources to develop effective and safe clinical pathways to bypass the PACU and avoid unplanned hospital admissions. Third-party payers should separate the payments for nerve blocks used to manage acute pain from the payments for the usual anesthesia global fee. Finally, legislators should reinforce proper third-party reimbursements and should promote logistical necessities such as allowing anesthesiologists to perform nerve block pain management techniques in direct proximity to the operating room (as is done when anesthesiologists place catheters to administer epidural anesthesia to women in labor). With the cooperation of policy makers at these various levels, anesthesiologists will be able to provide pain management that is both economical and effective.

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