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ORIGINAL RESEARCH

Cost of opioid intravenous patient-controlled analgesia: results from a hospital database analysis and literature assessment

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Background: Intravenous patient-controlled analgesia (PCA) equipment and opioid cost analyses on specific procedures are lacking. This study estimates the intravenous PCA hospital cost for the first 48 postoperative hours for three inpatient surgeries.

Methods: Descriptive analyses using the Premier database (2010–2012) of more than 500 US hospitals were conducted on cost (direct acquisition and indirect cost for the hospital, such as overhead, labor, pharmacy services) of intravenous PCA after total knee/hip arthroplasty (TKA/THA) or open abdominal surgery. Weighted average cost of equipment and opioid drug and the literature-based cost of adverse events and complications were aggregated for total costs.

Results: Of 11,805,513 patients, 272,443 (2.3%), 139,275 (1.2%), and 195,062 (1.7%) had TKA, THA, and abdominal surgery, respectively, with approximately 20% of orthopedic and 29% of abdominal patients having specific intravenous PCA database cost entries. Morphine (57%) and hydromorphone (44%) were the most frequently used PCA drugs, with a mean cost per 30 cc syringe of $16 (30 mg) and $21 (6 mg), respectively. The mean number of syringes used for morphine and hydromorphone in the first 48 hours were 1.9 and 3.2 (TKA), 2.0 and 4.2 (THA), and 2.5 and 3.9 (abdominal surgery), respectively. Average costs of PCA pump, intravenous tubing set, and drug ranged from $46 to $48, from $20 to $22, and from $33 to $46, respectively. Pump, tubing, and saline required to maintain patency of the intravenous PCA catheter over 48 hours ranged from $9 to $13, from $8 to $9, and from $20 to $22, respectively. Supplemental non-PCA opioid use ranged from $56 for THA to $87 for abdominal surgery. Aggregated mean intravenous PCA equipment and opioid cost per patient were $196 (THA), $204 (TKA), and $243 (abdominal surgery). Total costs, including for adverse events, complications, and intravenous PCA errors, ranged from $647 to $694.

Conclusion: Although there is variation between different types of surgery, the hospital cost of intravenous PCA after major surgery is substantial. Novel technology should demonstrate cost-effectiveness in addition to clinical superiority.

Keywords: patient-controlled analgesia, intravenous, total knee arthroplasty, total hip arthroplasty, abdominal surgery, cost

Introduction

Although intravenous patient-controlled analgesia (PCA) with opioids has been utilized for over 40 years to manage postoperative pain, the cost of providing this method of pain control for patients is not insignificant. This treatment modality continues to be used because there is little debate in the literature that patients having control over their pain medication have lower pain scores and higher patient satisfaction compared with nurse-administered modalities.[1,2] The rationale for PCA is that better pain control is achieved by use of small, frequent doses of opioids, while avoiding the risks of

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overdosing and analgesic gaps that can occur with large, infrequent bolus administration of opioids by health care providers.

While the patient-controlled aspect of intravenous PCA is a clear advantage, the invasive nature of the delivery system and the programming required to match the selected drug and dosing parameters with the delivery device (intravenous PCA pump) are obvious disadvantages. The requirement of a patent intravenous line, necessitating an indwelling intravenous catheter and intravenous tubing that tethers the patient to a computerized pump attached to an intravenous pole, results in a risk of infection, reduced mobility, and analgesic gaps due to infiltration of the intravenous catheter or obstruction of the tubing. Programming of the pump, which is performed by the nurse setting up the device, can result in dosing errors.[3–6] Furthermore, the frequency of patient dosing with intravenous PCA is usually 1–3 times per hour, which is not frequent enough to maintain patency of the intravenous catheter. This necessitates additional set-up of an intravenous infusion pump, tubing set, and saline bag to run the intravenous fluid at a "to keep open" rate throughout use of intravenous PCA therapy. Lastly, following major surgeries that result in moderate-to-severe postoperative pain, such as joint replacement or open abdominal surgery, patients utilizing intravenous PCA opioids often have inadequate analgesia and attempt to redose during lockout, which would then require additional nurse-administered opioid treatment as rescue analgesia.[7]

The purpose of this study was to analyze the equipment and drug costs for US hospitals providing intravenous PCA opioid treatment for patients following major surgery using the Premier hospital database, which is the largest inpatient resource and drug utilization database and contains complete billing and coding history on more than 45 million hospital discharges for acute care, ambulatory, surgery center and clinic visits.[8] In addition, a literature analysis of the additional costs due to adverse events occurring in patients using intravenous PCA opioids was included to estimate a complete total cost from the hospital payer perspective.

Materials and methods

Descriptive analyses using the Premier database (2010–2012) for more than 500 US hospitals were conducted to determine the hospital cost of intravenous PCA after total knee arthroplasty (TKA), total hip arthroplasty (THA), and open abdominal surgery. The International Classification of Diseases-9 (ICD-9) codes[9] used to identify surgeries were: 81.54 and v43.65 for TKA; 81.51 and v43.64 for THA; 54.11, 51.21, 51.22, 68.49, 45.73, 45.75, 17.33, 17.35, 55.5x, 45.76, 45.74, 45.8x, and 41.5 for abdominal surgery. Current Procedural Terminology codes[10] applied were 27130 for TKA, 27447 for THA, and 49000, 47600, 47605, 47610, 58150, 44140, 44204, 50220, and 38100 for abdominal surgery. Direct acquisition and indirect costs (eg, labor and pharmacy) were included in all costs. The study estimated the cost of the first 48 hours of postoperative management by cost of day 0 to day 2 from the surgery. The key search term "PCA" in Premier standard charge codes was conducted to identify PCA-related charges. The four most commonly used intravenous PCA opioid drugs (morphine, hydromorphone, fentanyl, and meperidine) were used to search for PCA drug cost entries. The term "intravenous" was explicitly specified only in bills of extension set and PCA opioid drugs but not in pump-related entries. In order to focus on intravenous PCA patients, a patient was categorized as an epidural-only patient if he or she had only an epidural PCA pump but no intravenous extension or intravenous opioid drugs recorded, so was excluded from the analysis population. Not all patients have complete entries for each component in the database, so each component (pump, set, and drug) was analyzed separately, and the weighted average for total PCA-related costs was analyzed.

The cost of supplemental non-PCA opioid drugs as well as non-PCA intravenous infusion pumps, intravenous tubing, and saline bags (to maintain the patency of the PCA catheter) during the first 48 hours postoperatively were also analyzed separately as part of the total cost. The cost of supplemental opioid drugs on day 1 after surgery was multiplied by two to approximate the cost of the first 48 hours given that the cost incurred on day 0 might include intraoperative opioid use and the cost on day 2 might include use beyond 48 hours. It was further assumed that for non-PCA carrier supplies, one infusion pump, one intravenous tubing set, and two 1,000 mL saline bags (50 mL/hour) were used over 48 hours.

In order to calculate the total cost of intravenous PCA, the medical literature was used to obtain the frequency and costs of specific adverse events and complications associated with intravenous PCA. The average per patient cost of intravenous PCA complications was calculated using a bottom-up microcosting approach, with the frequency of specific events multiplied by a literature-based cost. The costs of the specific complications from the literature were then added to the drug and equipment costs derived from the Premier database. Costs from the literature were inflated to a common year of 2012 (the end year of the Premier database) for consistency using the medical component of the Consumer Price Index.[11]

Results

Premier database analysis

Of 11,805,513 patients with at least one inpatient stay, 272,443 (2.3%), 139,275 (1.2%), and 195,062 (1.7%) had TKA, THA, and abdominal surgery, respectively. Patient attrition counts by surgical procedure are shown in Figure 1. Approximately 20% of orthopedic patients and 29% of abdominal surgery patients had specific intravenous PCA database cost entries.

Of the patients in the three separate surgical groups, morphine (56%–57%) and hydromorphone (42%–44%) were the most frequently used PCA drugs. The cost per syringe (30 cc) of drug was consistent across the three types of surgery, with mean values at approximately $16 (30 mg) and $21 (6 mg) for morphine and hydromorphone, respectively. The respective numbers of syringes used for morphine and hydromorphone were 1.9 and 3.2 for TKA, 2.0 and 4.2 for THA, and 2.5 and 4.0 for abdominal surgery (Table 1).

In Table 2, the cost of each individual resource item is listed and weighted to obtain the average cost for the PCA pump, intravenous extension set, and intravenous PCA opioid drugs. "Pump PCA per day" (77%–83%) and "set intravenous extension PCA" (42%–47%) were the most frequently billed terms for the PCA pump and extension set, respectively. It was assumed that a typical intravenous PCA patient would incur the average cost of each component mentioned above plus the cost of non-PCA intravenous fluid carrier supplies (ie, intravenous infusion pump, tubing, and saline bags) to maintain patency of the intravenous PCA catheter. Average costs for the PCA pump, intravenous tubing set, and opioid drugs ranged from $46 to $48, from $20 to $22, and from $33 to $46, respectively. Use of supplemental non-PCA opioids during intravenous PCA ranged from a low of $56 for THA to $86 for abdominal surgery. The additional cost of the non-PCA pump, tubing, and saline over 48 hours ranged from $9 to $13, from $8 to $9, and from $20 to $22, respectively.

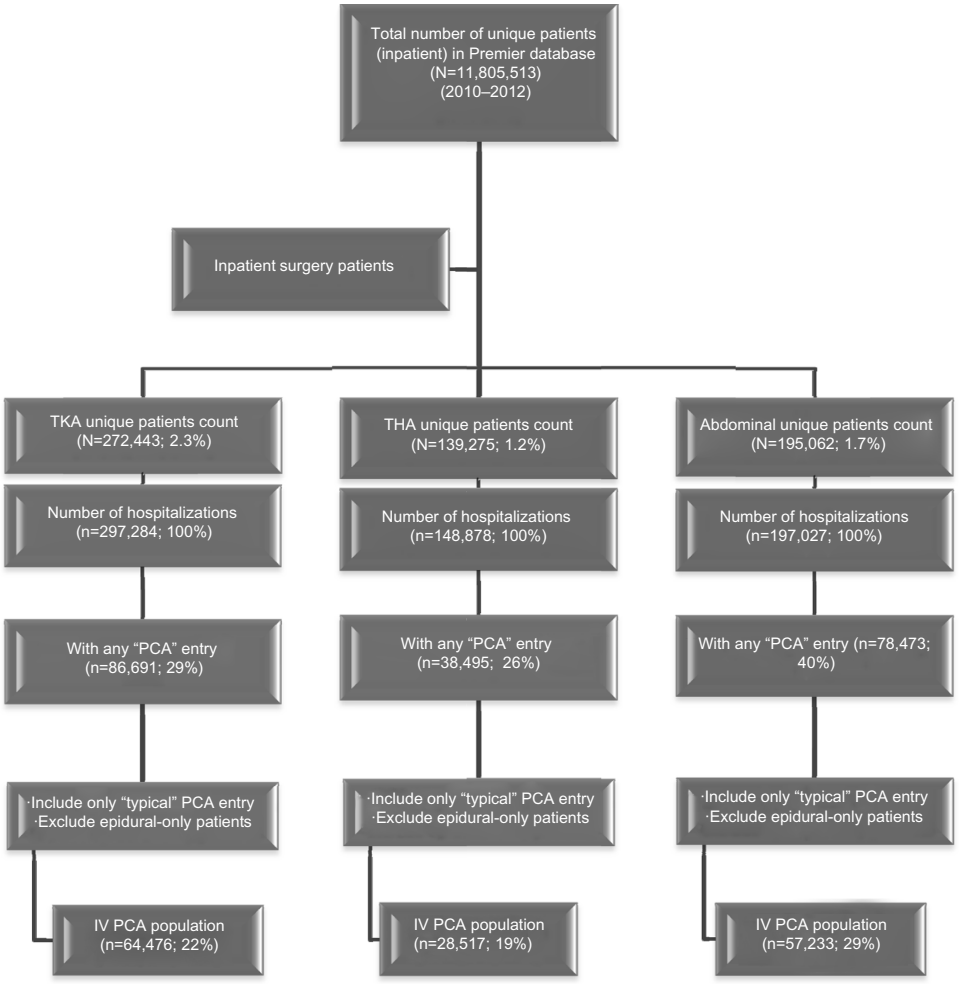

Figure 1 Patient attrition flow chart.
Abbreviations: IV, intravenous; THA, total hip arthroplasty; TKA, total knee arthroplasty; PCA, patient-controlled analgesia.

Table 1 Cost per syringe of intravenous PCA opioid drugs (day 0 to 2 from surgery)

Surgery	Morphine, mean ± SD (10th–90th percentile)		Hydromorphone, mean ± SD (10th–90th percentile)	
	Cost per syringe, US$	Number of syringes	Cost per syringe, US$	Number of syringes
TKA	$16±12 (6–29)	1.9±1.6 (1–3)	$21±23 (4–38)	3.2±4.2 (1–5)
THA	$15±12 (7–26)	2.0±3.9 (1–3)	$21±23 (3–38)	4.2±9.6 (1–6)
Abdominal surgery	$16±15 (6–28)	2.5±2.1 (1–5)	$20±20 (3–37)	4.0±5.6 (1–8)

Abbreviations: THA, total hip arthroplasty; TKA, total knee arthroplasty; PCA, patient-controlled analgesia; SD, standard deviation.

The aggregated mean total intravenous PCA/opioid costs per patient were $196 for THA, $204 for TKA, and $243 for abdominal surgery.

Published literature on costs of complications of intravenous PCA

Peripheral line infection and needle-stick injury

Assessment of the risk of infection due to peripheral venous lines has been performed using the Cochrane database.[12] The risk of phlebitis ranged from 7% to 9% depending on routine replacement versus replacement for clinical indication, while the risk of bacteremia ranged from 0.2% to 0.4%. Treatment for catheter-related peripheral venous phlebitis requires replacement of the intravenous catheter and tubing to a new site, and this cost has been estimated at $24.50 (2008 US dollars), including cost of equipment and nursing time.[13] Published costs of treatment for bacteremia due to an indwelling vascular catheter range from $24,034 to $36,441 per episode.[14,15] While the addition to average overall hospitalization costs of intravenous PCA patients due to development of phlebitis is low ($2.18), the incremental cost due to bacteremia is higher ($106.76).

Table 2 Per patient total cost of equipment and opioid drugs (day 0 to 2 from surgery)

Cost component	Bill standard entry	TKA			THA			Abdominal surgery		
		Total cost, US$ (mean)	SD	% (weight)	Total cost, US$ (mean)	SD	% (weight)	Total cost, US$ (mean)	SD	% (weight)
PCA pump	Pump PCA ancillary	$12	2	6.45%	$12	2	6.48%	$21	26	2.79%
	Pump PCA per day	$50	79	81.16%	$49	74	83.09%	$50	86	77.34%
	Pump PCA setup	$50	79	12.38%	$49	76	10.43%	$36	77	19.87%
	Weighted subtotal	$48	–	100%	$47	–	100%	$46	–	100%
PCA IV extension set	Set IV extension PCA	$20	39	42.24%	$24	46	46.57%	$21	50	42.49%
	Set IV PCA anti-siphon	$35	48	7.64%	$21	23	8.74%	$20	37	10.01%
	Set IV PCA anti-siphon extension	$27	9	0.40%	$29	8	0.92%	$17	10	0.17%
	SET IV PCA anti-siphon primary	$36	43	4.95%	$34	41	6.00%	$29	35	9.56%
	Set IV PCA microbore	$15	14	8.21%	$14	13	7.01%	$21	18	3.84%
	Set IV PCA Pump Y	$15	13	36.37%	$17	14	30.59%	$18	24	34.92%
	Set IV Stratofuse PCA	$22	9	1.88%	$19	8	1.53%	$28	10	0.59%
	Weighted subtotal	$20	–	100%	$22	–	100%	$21	–	100%
IV PCA opioid drugs	Morphine	$27	27	57.45%	$25	23	57.51%	$36	41	55.96%
	Hydromorphone	$44	48	42.55%	$44	45	42.49%	$58	67	44.04%
	Weighted subtotal	$35	–	100%	$33	–	100%	$46	–	100%
Non-PCA*	Supplemental opioids	$62	104	2†	$56	100	2†	$86	318	2†
	IV infusion pump	$9	22	1	$9	23	1	$13	28	1
	IV tubing	$8	7	1	$9	8	1	$9	7	1
	Saline (0.9% NaCl 1,000 mL)	$22	26	2	$20	24	2	$22	34	2
Total hospital cost of equipment and opioid drugs‡		$204	–	–	$196	–	–	$243	–	–

Notes: *Mean total cost values in non-PCA cost items reflect the cost based on assumed number of units (in column "% [weight]"); †cost reflects the first 48-hour cost of supplemental opioids by doubling the day 1 cost; ‡total equipment and opioid cost = weighted subtotal (PCA pump) + weighted subtotal (PCA IV extension set) + weighted subtotal (IV PCA opioid drugs) + non-PCA (opioids + pump + tubing + saline).

Abbreviations: IV, intravenous; THA, total hip arthroplasty; TKA, total knee arthroplasty; PCA, patient-controlled analgesia; SD, standard deviation.

The cost of needle-stick injury in health care workers is also a concern when utilizing intravenous PCA over noninvasive analgesic modalities. The rate of hollow-bore intravenous tubing needle-stick injuries is reported at 36.7 per 100,000 devices purchased.[16] The direct medical costs associated with initial and follow-up treatment of exposed health care workers has been documented to be $3,437 based on the treatment provided,[17] which results in a relatively small incremental cost of $1.26 compared with the average overall hospitalization costs for intravenous PCA patients.

Intravenous PCA errors

The morbidity and mortality due to intravenous PCA errors, mainly due to human factors such as misprogramming, has been well documented over the years.[3–6] Meissner et al[5] have performed the most extensive analysis to date regarding the cost of such intravenous PCA errors as incorrect flow rates, missing decimal places, dosage strength errors (μg versus mg), and malfunctions of the intravenous PCA device itself. We evaluated both the MEDMARX and Manufacturer and User Facility Device Experience (MAUDE) datasets for errors related to intravenous PCA. The average cost per error event was $733 (MEDMARX) and $552 (MAUDE) which, annualized in 2006 dollars, resulted in an additional $388 million for medication-related errors (MEDMARX data) and $12 million for device-related errors (MAUDE data) for the cost of health care in the USA. Based on the reported rate of 407 intravenous PCA medication errors and 17 device-related errors per 10,000 intravenous PCA patients annually, the addition to the average overall hospitalization costs for intravenous PCA patients due to these errors is $35.52.

Summary of total costs of intravenous PCA

Based on the data available from the Premier database and the complications directly attributable to the invasive and programmable nature of intravenous PCA reported in the literature, the total cost of postoperative delivery of opioids in the first 48 hours after surgery via a regimen involving intravenous PCA is tabulated in Table 3. The average cost of each component of total hospital cost is also shown in Figure 2.

Adverse events due to decreased mobility

Although not directly attributable to intravenous PCA per se, the cost of certain adverse events related to decreased ambulation after surgery should not be ignored. Common adverse events are deep venous thrombosis, pulmonary embolism, and postoperative pneumonia. A recent assessment of the relative cost of these events in patients utilizing intravenous PCA opioids for postoperative pain control found that 2.1% of intravenous PCA patients, compared with 1.6% of patients using nonintravenous PCA opioids, reported these complications over the first 2 days postoperatively. The addition to the average overall hospitalization costs of intravenous PCA patients due to development of deep venous thrombosis was $18.17, for pulmonary embolism was $43.19, and for postoperative pneumonia was $265.02.[18]

Discussion

Analysis of the Premier database demonstrates that the cost of intravenous PCA equipment and opioid drugs in the first 48 hours following major surgery ranges from $196 to $243. Hospitals have been willing to cover these costs, as studies have shown the advantages of providing a patient-controlled option for patients suffering from acute pain in the hospital setting. As hospitals look to decrease costs and as governmental agencies increase their awareness of the morbidity and mortality of infusion pump errors,[19] the additional costs due to intravenous PCA complications, both economically

Table 3 Total average per patient cost of postoperative pain management via intravenous PCA

Drugs, equipment, and adverse events	Estimated cost per patient in US dollars (2012)	Assumption (total cost × incidence or frequency)	Source
Equipment and opioid drug costs	$196–$243	Premier database analysis	Premier
Phlebitis	$2.18	US$24.50 (AUD$28.84*) × 8% = US$1.96 (2008**)	12, 13
Bacteremia	$106.76	(US$36,441 + US$24,034)/2 × (0.2% + 0.4%)/2 = 90.71 (2005**)	12, 14, 15
Health care worker needle-stick injury	$1.67	US$3,437 × 36.7/100,000 = 1.26 (2000**)	16, 17
IV PCA errors	$35.52	(US$733 × 407 + US$552 × 17.22)/10,000 = US$30.78 (2006**)	5
Total	$342–$389	–	–

Notes: *Australian dollars. **Assumptions for cost show the original base year of cost data reported prior to inflation to 2012 US dollars. Some equations show the weighted average of two prices; others calculate price based on incidence.
Abbreviations: IV, intravenous; PCA, patient-controlled analgesia.

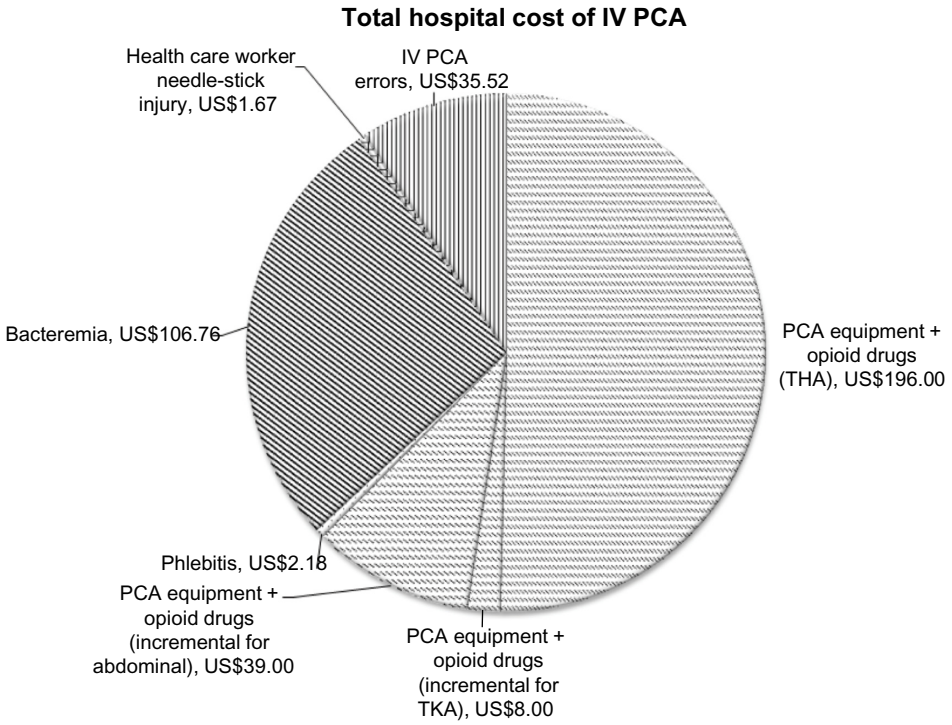

Figure 2 Average hospital cost component of IV PCA.
Abbreviations: IV, intravenous; THA, total hip arthroplasty; TKA, total knee arthroplasty; PCA, patient-controlled analgesia.

and in terms of patient lives, cannot be ignored. While this paper has highlighted recent published analyses of the costs of such adverse events, quantifying these costs is difficult, and our estimates are rough at best. Costs associated with troubleshooting of intravenous PCA equipment by health care professionals or the effect of reduced mobility on physical therapy and time to discharge were not assessed in this study.

The finding that patients undergoing abdominal surgery have overall higher postoperative opioid costs in the first 48 hours than patients undergoing TKA is somewhat surprising, given the higher levels of pain usually experienced following knee replacement. It is likely that use of femoral and/or sciatic nerve blocks may decrease opioid consumption in TKA patients to some degree. In fact, the use of nonopioid analgesics (local anesthetic blocks, anti-inflammatory agents, gabapentanoids) to supplement opioids in a multimodal analgesia approach has increased over the years. Blinded, placebo-controlled studies of nonopioid adjuvants show either no effect on opioid consumption in the postoperative period or various levels of opioid-sparing effects ranging from 20% to 50%,[20–23] with combinations of adjuvants producing slightly higher opioid-sparing effects.[24,25] While these nonopioid analgesics can reduce opioid requirements, patients still use a significant amount of opioid analgesics in the first 48 hours after major surgery.

Therefore, in patients suffering from moderate-to-severe pain in the hospital setting, providing the flexibility of patient control over opioid dosing should remain a goal of postoperative analgesia for both increased patient satisfaction and better analgesic efficacy.[1,2] Novel opioid delivery systems that contain a patient-activated dosing feature while avoiding invasive, cumbersome delivery routes and the risk of dosing errors should be a focus of future hospital-based analgesia regimens. Given the scheduled nature of these drugs (ie, Schedule II Controlled Substances[26]), it is important that these bedside opioid systems have security features, such as locked drug access and/or single-user identification. It will also be important for these newer systems to be cost-neutral compared with the current standard of care for hospitals, since postoperative analgesia is included in third-party payments to hospitals for overall surgical care of the patient. A sublingual microtablet system for sufentanil is one such system currently under review by the US Food and Drug Administration. The delivery of a fixed dose of sufentanil (15 μg) and a preset lockout time of 20 minutes avoids prescribing and programming errors, while the sublingual route avoids mobility and intravenous catheter-related issues. A locked security tether,

a locked drug cartridge, and a radiofrequency identification patient thumb tag provide secure access. In an open-label, active-comparator study, postoperative patients randomized to the sufentanil system had superior patient satisfaction, higher ease-of-care scores for both patients and health care providers, and fewer patients with oxygen desaturation events compared with intravenous PCA morphine.[27]

Conclusion

In summary, patient requirements for opioids are significant after major surgery, and the costs of opioid drugs and intravenous PCA equipment, while varying slightly between the different types of surgery, are just above $100 per day. The added costs of intravenous PCA-related adverse events are difficult to quantify but may significantly increase this cost to over $300 per day. These adverse events are possibly avoidable with the advent of the newer noninvasive patient-activated analgesia systems. In the current health care reimbursement environment, it is optimal when novel hospital-based drug and device technology can demonstrate cost-effectiveness in addition to clinical superiority to the current standard of care.

Disclosure

This research was sponsored by AcelRx Pharmaceuticals, Inc. Pharmerit International received research fees to conduct the database analysis. PP is an employee of AcelRx, the developers of novel pain therapies. XJ and JS are employees of Pharmerit International, a health economics consulting firm. This research was presented in part as a poster at the International Society for Pharmacoeconomics and Outcomes Research 19th Annual International Meeting, May 31 to June 2, 2014, Montreal, Canada. The authors report no other conflicts of interest in this work.

References

1. Ballantyne JC, Carr DB, Chalmers TC, Dear KB, Angelillo IF, Mosteller F. Postoperative patient-controlled analgesia: meta-analyses of initial randomized control trials. *J Clin Anesth*. 1993;5(3):182–193.
2. Hudcova J, McNicol E, Quah C, Lau J, Carr DB. Patient-controlled opioid analgesia versus conventional opioid analgesia for postoperative pain. *Cochrane Database Syst Rev*. 2006;4:CD003348.
3. Hankin C, Schein J, Clark J, Panchal S. Adverse events involving intravenous patient-controlled analgesia. *Am J Health Syst Pharm*. 2007;64(14):1492–1499.
4. Hicks RW, Sikirica V, Nelson W, Schein JR, Cousins DD. Medication errors involving patient-controlled analgesia. *Am J Health Syst Pharm*. 2008;65(5):429–440.
5. Meissner B, Nelson W, Hicks R, Sikirica V, Gagne J, Schein J. The rate and costs attributable to intravenous patient-controlled analgesia errors. *Hosp Pharm*. 2009;44(4):312–324.
6. Institute for Safe Medication Practices. High alert medication feature: reducing patient harm from opiates. ISMP Medication Safety Alert, February 22, 2007. Available from: http://www.ismp.org/Newsletters/acutecare/articles/20070222.asp. Accessed January 27, 2014.
7. Badner NH, Doyle JA, Smith MH, Herrick IA. Effect of varying intravenous patient-controlled analgesia dose and lockout interval while maintaining a constant hourly maximum dose. *J Clin Anesth*. 1996;8(5):382–385.
8. Finn T. Premier perspectives database: comparative effectiveness research. Available from: http://hcmatters.com/2012/04/premier-perspectives-database-comparative-effectiveness-research-cer-validated/#sthash.WPix7UW0.dpuf. Accessed May 1, 2014.
9. ICD-9 Code Lookup [webpage on the Internet]. Baltimore: Centers for Medicare & Medicaid Services; 2014. Available from: http://www.cms.gov/medicare-coverage-database/staticpages/icd-9-code-lookup.aspx. Accessed May 31, 2014.
10. CPT – Current Procedural Terminology [webpage on the Internet]. Chicago: American Medical Association; 2014. Available from: http://www.ama-assn.org/ama/pub/physician-resources/solutions-managing-your-practice/coding-billing-insurance/cpt.page. Accessed May 31, 2014.
11. Consumer Price Index [webpage on Internet]. Washington: United States Department of Labor; 2014. Available from: http://www.bls.gov/cpi/. Accessed May 31, 2014.
12. Webster J, Osborne S, Rickard C, Hall J. Clinically indicated replacement versus routine replacement of peripheral venous catheters. *Cochrane Database Syst Rev*. 2010;3:CD007798.
13. Webster J, Clarke S, Paterson D, et al. Routine care of peripheral intravenous catheters versus clinically indicated replacement: randomized controlled trial. *BMJ*. 2008;337:157–160.
14. Engemann JJ, Friedman JY, Reed SD, et al. Clinical outcomes and costs due to Staphylococcus aureus bacteremia among patients receiving long-term hemodialysis. *Infect Control Hosp Epidemiol*. 2005;26(6):534–539.
15. Reed D, Kemmerly SA. Infection control and prevention: a review of hospital-acquired infections and the economic implications. *Ochsner J*. 2009;9(1):27–31.
16. Jagger J, Hunt EH, Brand-Elnaggar J, Pearson RD. Rates of needle-stick injury caused by various devices in a university hospital. *N Engl J Med*. 1988;319(5):284–288.
17. Hatcher IB. Reducing sharps injuries among health care workers: a sharps container quality improvement project. *Jt Comm J Qual Improv*. 2002;28(7):410–414.
18. Schechter LN, Harshaw Q, Frye CB, Ernst FR, Krukas MR, Shillington AC. Costs associated with intravenous patient-controlled analgesia (IV PCA) in US hospitals. *Value Health*. 2013;16:A117.
19. Association for the Advancement of Medical Instrumentation. Infusing patients safely: priority issues from the AAMI/FDA Infusion Device Summit, 2010. Available from: http://www.aami.org/infusionsummit/AAMI_FDA_Summit_Report.pdf. Accessed January 27, 2014.
20. Klein JR, Heaton JP, Thompson JP, Cotton BR, Davidson AC, Smith G. Infiltration of the abdominal wall with local anaesthetic after total abdominal hysterectomy has no opioid-sparing effect. *Br J Anaesth*. 2000;84(2):248–249.
21. Ng A, Parker J, Toogood L, Cotton BR, Smith G. Does the opioid-sparing effect of rectal diclofenac following total abdominal hysterectomy benefit the patient? *Br J Anaesth*. 2002;88(5):714–716.
22. Reynolds LW, Hoo RK, Brill RJ, North J, Recker DP, Verburg KM. The COX-2 specific inhibitor, valdecoxib, is an effective, opioid-sparing analgesic in patients undergoing total knee arthroplasty. *J Pain Symptom Manage*. 2003;25(2):133–141.
23. Kehlet H. Postoperative opioid sparing to hasten recovery: what are the issues? *Anesthesiology*. 2005;102(6):1083–1085.
24. Fayaz MK, Abel RJ, Pugh SC, Hall JE, Djaiani G, Mecklenburgh JS. Opioid-sparing effects of diclofenac and paracetamol lead to improved outcomes after cardiac surgery. *J Cardiothorac Vasc Anesth*. 2004;18(6):742–747.

25. Gilron I, Orr E, Dongsheng T, O'Neill JP, Zamora JE, Bell AC. A placebo-controlled randomized clinical trial of perioperative administration of gabapentin, rofecoxib and their combination for spontaneous and movement-evoked pain after abdominal hysterectomy. *Pain*. 2005;113(1–2):191–200.
26. Electronic Code of Federal Regulations [webpage on the Internet]. Washington: U.S. Government Printing Office; 2014 [updated May 19, 2014]. Available from: http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=21:9.0.1.1.9. Accessed May 31, 2014.
27. Melson T, Boyer DL, Minkowitz H, Palmer PP, Royal M. Sufentanil NanoTab® PCA system versus IV PCA morphine for postoperative pain: a randomized, open-label, active-comparator trial (A3087). Available from: http://www.asaabstracts.com/strands/asaabstracts/abstract.htm;jsessionid=36082DD5A67E4B69D165AC547A95748C?year=2013&index=17&absnum=5065. Accessed January 27, 2014.