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Original contribution

Cost impact of unexpected disposition after orthopedic ambulatory surgery associated with category of anesthesia provider☆

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Abstract
Study Objective: To provide estimates of the costs and health outcomes implications of the excess risk of unexpected disposition for nurse anesthetist (NA) procedures.
Design: A projection model was used to apply estimates of costs and health outcomes associated with the excess risk of unexpected disposition for NAs reported in a recent study.
Setting: Ambulatory and inpatient surgery.
Patients: Base-case model parameters were based on estimates taken from peer-reviewed publications when available, or from other sources including data for all hospital stays in the United States in 2013 from the Healthcare Cost and Utilization Project Web site. The impact of parameter uncertainty was assessed using 1-way and 2-way sensitivity analyses.
Interventions: Not applicable.
Measurements: Major complication rates, relative risks of complications, anesthesia costs, costs of complications, and cost-effectiveness ratios.
Main Results: In the base-case model, there were on average 2.3 fewer unexpected dispositions for physician anesthesiologists compared with NAs. Overall, anesthesia-related costs (including the cost of managing unexpected dispositions) were estimated to be about $31 higher per procedure for physician anesthesiologists compared with NAs. Alternative model scenarios in the sensitivity analysis produced estimates of smaller additional costs associated with physician anesthesia administration, to the point of cost savings in some scenarios.
Conclusions: Provision of anesthesia for ambulatory knee and shoulder procedures by physician anesthesiologists results in better health outcomes, at a reasonable additional cost, compared with procedures with NA-administered anesthesia, at least when using updated cost-effectiveness willingness-to-pay benchmarks.

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1. Introduction

The role of certified registered nurse anesthetists (NAs) in the provision of anesthesia services for surgery in the United States has grown over the last few decades, with NAs augmenting or substituting for anesthesiology services provided by physician anesthesiologists [1]. Based on calculations using the National Plan and Provider Enumeration System database containing all National Provider Identifier (NPI) numbers, as of December 2016, there were 48,647 unique NPIs for active NAs and 46851 NPIs for active physicians listing anesthesiology as a primary specialty, with an additional 3117 listing anesthesiology-pain medicine as a primary specialty [2].

Although NAs generally have been shown to safely and effectively provide a range of anesthesiology services under the supervision of physician anesthesiologists [3-8], the rising role of NAs in the provision of anesthesia care has sparked some concern about the potential impact of the quality of anesthesia services [4,9,10]. For example, in a study examining performance managing a set of simulated intraoperative emergencies, Henrichs et al. [4] found that board-certified physician anesthesiologists achieved a modestly higher mean overall performance score than NAs (66.6% ± 11.7% vs 59.9% ± 10.2%; $P < .01$). Similarly, Silber et al. [9] found higher rates of death and failure-to-rescue when anesthesia care was not directed by physician anesthesiologists (odds ratio for death, 1.08; $P < .04$; odds ratio for failure-to-rescue, 1.10; $P < .01$), but no statistically significant difference in complication rates (odds ratio for complication, 1.00; $P < .79$). This corresponds to 2.5 excess deaths/1000 patients and 6.9 excess failures-to-rescue (deaths) per 1000 patients with complications.

In a recent study focused on outcomes for ambulatory surgical procedures, Memtsoudis et al. [11] examined whether patient characteristics, ambulatory facility type, anesthesia provider and technique, procedure type, and temporal factors impact the outcome of unexpected disposition after ambulatory knee and shoulder surgery. Unexpected disposition was defined as either an admission to a hospital or death following ambulatory surgery, but death as an outcome was too rare to be analyzed as a separate end point. Their results indicated that a factor independently increasing the risk for unexpected disposition was the type of anesthesia provider. Specifically, the reported relative risk for unexpected disposition for anesthesia provided by NAs vs physician anesthesiologists was 1.38 ($P < .01$) for knee procedures and 1.79 ($P < .01$) for shoulder procedures.

Although the literature indicates a lower risk of unexpected disposition after ambulatory knee and shoulder surgery when anesthesia is provided by physician anesthesiologists compared with NAs, the cost impact or cost-effectiveness of this reduction is largely absent from the literature. The objective of present study is to fill this gap by using estimates of the excess risk of unexpected disposition after ambulatory knee and shoulder surgery associated with anesthesia administered by NAs compared with physician anesthesiologists (reported by Memtsoudis et al.) to generate estimates of the cost and effectiveness implications of unexpected dispositions. Estimates of resource costs and health-related quality of life obtained from the literature are used to project the differences in overall costs for anesthesia administered by NAs compared with physician anesthesiologists in relation to differences in treatment effectiveness (ie, outcomes). Outcomes are estimated alternatively as "hospitalizations avoided" or "quality-adjusted life-years (QALYs) gained" from fewer unexpected dispositions with physician administered anesthesia.

2. Materials and methods

Base-case model parameters are derived from estimates in published peer-reviewed studies when available, but in some instances when no specific data from the literature are available, reasonable assumptions are used for base-case parameters. The impact of parameter uncertainty is assessed using both 1-way and 2-way discrete sensitivity analyses for key model parameters.

The base-case model parameters relating to rates of serious complications for ambulatory knee and shoulder surgery are reported in Table 1, along with their sources. The base-case parameter estimates relating to the relative risk of unexpected disposition are taken from the study by Memtsoudis et al. To facilitate subsequent cost analysis, we specify a ratio of 1 physician anesthesiologist for 4 NAs (1:4 ratio) to represent the mix for the nonspecific physician/NA team category in the study by Memtsoudis et al. Studies by Lovald et al. [12], Gill et al. [13], and Martin et al. [14] provide additional detail about the likelihood of serious complications, including death. However, the base-case model assumes no differences in rates for "other" serious complications associated with type of anesthesia provider.

Similarly, base-case cost parameters and their sources are reported in Table 2. Estimates of professional service costs by type of anesthesia provider are taken from Hogan et al. [15], inflated to 2014 dollars using the Consumer Price Index—all items [16]. Gonano et al. [17] provide base-case parameter estimates for anesthesia supply costs, which are assumed to be the same for all types of anesthesia providers.

The base-case value of the cost of an unexpected admission is derived from data for all hospital stays in the United States in 2013 from the Healthcare Cost and Utilization Project (HCUP) Web site [18]. After excluding all neonatal and maternal hospital stays, HCUP's online database query tool, H·CUPNet (http://hcupnet.ahrq.gov/), generated an estimated mean length of stay (LOS) of 4.9 days for 2013, with a mean cost per stay of $12,539 in 2013 dollars ($12,742 after inflated to 2014 dollars). Simply dividing the mean total cost per stay by the mean LOS yields an estimate of $2600 per inpatient day. To be conservative, for our base-case cost estimate, we assume that the mean LOS for unexpected hospitalizations

Table 1 Base-case parameter assumptions, complication rates.

	Base	Sources
Major complication rates		
Knee		
Any	5.8%	
Unexpected admission	3.8%	[11]
Other major	1.7%	[12]
Death	0.28%	[11,13]
Shoulder		
Any	9.9%	
Unexpected admission	7.9%	[11]
Other major	1.7%	A
Death	0.25%	[13,14]
Relative risks of complication, knee		
Unexpected admission		
Physician anesthesiologist–alone	1	[11]
Physician-directed NA—1:4	0.931	[11]
NA-alone	1.379	[11]
Death		
Physician anesthesiologist–alone	1	A
Physician-directed NA—1:4	1	A
NA-alone	1	A
Relative risks of complication, shoulder		
Unexpected admission		
Physician anesthesiologist–alone	1	[11]
Physician-directed NA—1:4	1.339	[11]
NA-alone	1.786	[11]
Death		
Physician anesthesiologist–alone	1	A
Physician-directed NA—1:4	1	A
NA-alone	1	A

A = authors' assumption; NA = nurse anesthetist.

Table 2 Base-case parameter assumptions, costs.

	Base	Sources
Anesthesia costs (2014$)		
Professional services		
Physician anesthesiologist–alone	$369	[16,17]
Physician-directed NA—1:4	$294	[16,17]
NA-alone	$187	[16,17]
Drugs, supplies		
Physician anesthesiologist–alone	$95	[17,18]
Physician-directed NA—1:4	$95	[17,18]
NA-alone	$95	[17,18]
Costs of complications (2014$)		
Major complication, knee		
Unexpected admission		
Cost per inpatient day	$2600	[17,19]
No. of days	2.5	[19]
Postdischarge recovery ($/d)	$20	A
Postdischarge recovery days	0.0	A
Other major	$1000	A
Death	$2000	A
Major complication, shoulder		
Unexpected admission		
Cost per inpatient day	$2600	[17,19]
No. of days	2.5	[19]
Postdischarge recovery ($/d)	$20	A
Postdischarge recovery days	0.0	A
Other major	$1250	A
Death	$2000	A

A = authors' assumption; NA = nurse anesthetist.

was 2.5 days (about half the national average for all inpatient stays excluding neonatal and maternal stays). It is likely that the average costs per day for a stay of 2.5 days would exceed the average cost per day for a stay of 4.9 days. Indeed, Taheri et al. [19] report that among patients with a LOS greater than 4 days, additional days account for a relatively small share of the total cost for the entire stay. However, for simplicity, in the base-case scenario, we assume constant costs per inpatient day regardless of LOS. Thus, the estimated inpatient cost of an unexpected hospitalization is $6500 ($2600/d times 2.5 days).

Finally, as shown in Table 3, assumptions about the characteristics of the treatment population are taken from the study by Memtsoudis et al. and estimates of life expectancy at various ages by gender are taken from the Social Security Administration actuarial tables [20]. In the base-case model, the impact of unexpected hospitalization on health-related quality of life is assumed to operate via the temporary disability associated with hospitalization. In an alternative scenario, the potential impact of partial disability during a postdischarge recovery period is examined. The potential for any long-term or permanent disability or other significant and persistent adverse health effects associated with an unexpected disposition is not accounted for in the model.

3. Results

For the base-case model, as shown in Table 4, average estimated anesthesia-related treatment costs (including costs of unexpected dispositions) over a 1-year period were $807 per ambulatory procedure for anesthesia administered by physician anesthesiologists, compared with $776 for NAs and $750 for a physician anesthesiologist/NA team (1:4 ratio). In terms of effectiveness, there were an estimated 6.9% unexpected dispositions for NAs, compared with 4.6% for physician anesthesiologists and 4.8% for teams. Focusing on QALYs, the expected value of QALYs in the base-case model is 0.0004 lower for NA treatment compared with physician anesthesiologist treatment (or about 0.15 quality-adjusted days, or about 3.5 quality-adjusted hours). Turning to cost-effectiveness ratios, the estimated cost per unexpected hospitalization avoided is $1325 for physician anesthesiologist treatment vs NA treatment, and the estimated incremental cost per QALY gained is about $77,400 in the base-case scenario.

Table 3 Parameter assumptions, effectiveness (life-years, QALYs)

	Base	Sources
Treatment cohort		
Age (%)		
20-44	45.6%	[12]
45-64	43.3%	[12]
65+	11.1%	[12]
Sex (male, %)	54.9%	[12]
Knee (%)	81.3%	[12]
Shoulder (%)	18.7%	[12]
QALYs		
Life expectancy at age 32 y (2011)		
Male	45.9	[21]
Female	50.0	[21]
Life expectancy at age 55 y (2011)		
Male	25.4	[21]
Female	28.7	[21]
Life expectancy at age 70 y (2011)		
Male	14.1	[21]
Female	16.3	[21]
HR-QoL (utility) decrement (year 1)		
Unexpected admission		
Decrement	0.0139	A
Decrement/inpatient day (%)	100%	A
Decrement/postdischarge day (%)	25%	A
Death	1	A

QALYs = quality-adjusted life-years; HR-QoL = health-related quality of life; A = authors' assumption.

The base-case model scenario uses a number of conservative parameter assumptions where guidance from the literature is lacking. One-way sensitivity analyses, reported in Table 5, are used to assess the impact of a change in an assumed parameter value on estimated cost effectiveness. For example, as noted in the study by Memtsoudis et al. death was too rare of an outcome of ambulatory surgery to analyze, given the study sample size. However, Silber et al. [9] found higher rates of death when anesthesia care was not directed by physician anesthesiologists. If the same relative risk ratio used for unexpected disposition is also applied to the risk for death, the estimated incremental cost per QALY gained falls to about $17,400.

For those patients experiencing an unexpected hospitalization, it may be plausible to assume that they would not have completely recovered from the cause for their hospitalization at the date of their discharge. Accounting for the potential for modest follow-up treatment costs and for the disutility of post-discharge health effects lowers the estimated cost per QALY gained to about $15,900 (for 5-day postdischarge recovery time) or about $6600 (for 10-day recovery time).

The estimated differential between professional service costs for NAs vs physician anesthesiologists is an influential parameter in the cost analysis. Abouleish et al. [21] report that NAs billed the Texas Medicaid program for more units of anesthesia time compared with physician anesthesiologists. Thus, our base-case assumption regarding relative professional service costs may be excessively favorable for NAs. If NA professional services costs are assumed to be 5% higher than in the base case, the incremental cost per QALY falls to $54000, and if NA professional services costs are assumed to be 15% higher than in the base case, the incremental cost per QALY falls to $7200. Indeed, if the cost of NA professional services is at least 17% higher than in the base case, provision of outpatient anesthesia by physician anesthesiologists is cost saving compared with NA administration.

A key element affecting both costs and outcomes in the model is the likelihood of an occurrence of an unexpected disposition and the magnitude of the cost and health impact of an unexpected disposition event. Fig. 1 provides a 2-way sensitivity graph for 2 parameters: (1) the first parameter affects the likelihood of an unexpected disposition associated with type of anesthesia provider (ie, the assumed excess risk for NA), and (2) the second parameter affects the conditional magnitude of the event (mean inpatient costs for unexpected hospitalization). The orange-dashed lines represent the base-case parameter values of 100% and $6500/hospitalization. If the assumed cost per hospitalization is $6000, and the assumed excess risk

Table 4 Cost-effectiveness summary

		Effectiveness	
		Year 1	
Cost and effectiveness	*Expected costs*	*UnexpAdm*	*QALYs*
Physician anesthesiologist–alone	$807	4.57%	0.9965
Physician-directed NA—1:4	$750	4.85%	0.9964
NA-alone	$776	6.90%	0.9961
Cost-effectiveness ratios (vs NA-alone)		*Δ$/UnexpAdm*	*Δ$/QALY*
NA-alone		–	–
Physician-directed NA—1:4		Cost saving	Cost saving
Physician anesthesiologist–alone		$1325	$77,400

QALYs = quality-adjusted life-years; NA = nurse anesthetist; UnexpAdm = unexpected admission.

Table 5 Summary of 1-way sensitivity analyses

Cost-effectiveness ratios (physician vs NA)	Δ$/UnexpAdm	Δ$/QALY
Base case	$1325	$77,400
Same RRs for death, NA vs physician	1220	17,400
Postdischarge costs and disutility (5 d)	1225	15,900
Postdischarge costs and disutility (10 d)	1125	6600
Base-case NA professional service cost +5%	924	54,000
Base-case NA professional service cost +10%	524	30,600
Base-case NA professional service cost +15%	123	7200
Base-case NA professional service cost +20%	Cost saving	Cost saving

NA = nurse anesthetist; UnexpAdm = unexpected admission; RR = relative risk.

is 100% of the value reported in the study by Memtsoudis et al. then the estimated incremental cost per QALY gained for physician vs NA anesthesia administration is about $100,000. Similarly, if the assumed excess risk is 95% of the base-case value and the cost per hospital stay is $7000, then the estimated incremental cost per QALY gained is about $75,000. In general, lower assumed excess risk associated with NA-only administration and lower assumed costs per hospitalization yield higher incremental cost/QALY estimates.

4. Discussion

The base-case model results suggest that compared with ambulatory shoulder and knee procedures with physician-administered anesthesia, procedures with NA-administered anesthesia would result in an additional 2.3 unexpected dispositions per 100 procedures. Total anesthesia-related costs (including the costs of managing unexpected dispositions) for physician-administered anesthesia is estimated to be about $31 higher per procedure than NA-administered anesthesia. Thus, the estimated incremental cost per unexpected disposition avoided using physician anesthesiologist vs NA-administered anesthesia is $1375 in the base-case model.

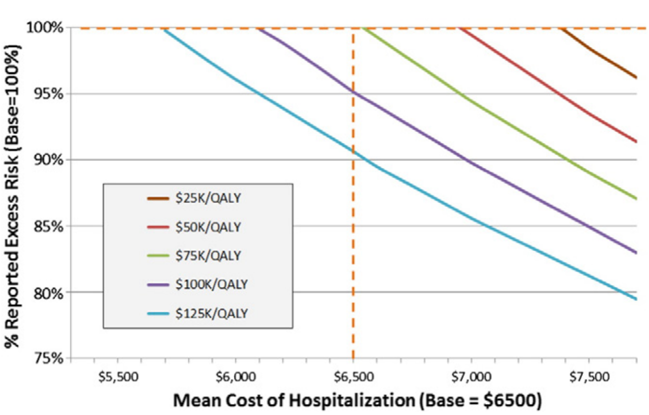

Fig. 1 Two-way sensitivity analysis: % of base-case NA excess risk for unexpected disposition and mean hospital cost per unexpected hospitalization. NA = nurse anesthetist.

The estimated cost per QALY gained is about $77,400 in the base-case model. This result is mainly attributable to the small estimated impact of unexpected dispositions on QALYs in the base-case model, which in turn is attributable to the infrequency of unexpected disposition coupled with the assumption that all disutility effects are transitory and resolve within 1 year. However, it is possible that some complications resulting in unexpected disposition (and not resulting in death) have treatment costs and health effects that persist for more than 1 year. This possibility was not assessed in any of our sensitivity analyses, but accounting for potential long-term or permanent effects on health-related quality of life would reduce the estimated cost per QALY gained over a time horizon exceeding 1 year.

The base-case model is likely to overestimate the cost per unexpected disposition avoided and cost per QALY gained, using physician vs NA-administered anesthesia. There are a number of elements of the consequences of unexpected dispositions (such as temporary partial disability immediately after hospital discharge) with plausible cost or health-related quality of life implications, but none of these are accounted for in the base-case model due to a lack of evidence relating to the magnitude of the effects. In sensitivity analyses, when conservative assumptions about the magnitude of such effects are incorporated into the model, the estimated incremental cost per QALY gained falls well below $50,000 per QALY gained.

Although "$50,000/QALY" often is cited as a threshold for acceptable cost-effectiveness, as Neumann et al. [22] note, no one really knows the original source of the $50,000 benchmark, or why the figure has been used unchanged for decades, without even an adjustment for inflation. Simply adjusting for inflation from 1980 to 2014 would make the oft-cited standard $144,000/QALY. Hirth et al. [23] use estimates from the literature examining the value of a "statistical" life in an attempt to produce an evidence-based threshold value. When focusing on safety-related revealed preference studies, they conclude that the median value of a QALY implied by estimates of the willingness to pay for a statistical life was $265,000 in 1997 dollars ($391,000 in 2014 dollars). Similarly, Braithwaite et al. [24] report an estimated willingness to pay threshold of $183,000 to $264,000 per QALY in 2003 dollars ($235,000–$340,000 in 2014 dollars).

Even our base-case estimate of cost per QALY gained falls well below these revised benchmarks. However, although Neumann et al. conclude that the traditional benchmark is almost certainly too low, they caution that any single benchmark value is unlikely to be appropriate across different settings for value assessments.

Prior studies have shown that ambulatory knee and shoulder procedures are less likely to result in an unexpected disposition if anesthesia is administered by physician anesthesiologists compared with NAs. Although professional service costs are higher for physician anesthesiologists compared with NAs, these higher costs are partially offset by costs of managing additional unexpected dispositions with NAs. Overall, the improvement in outcomes associated with anesthesia administered by physician anesthesiologists is attained at a reasonable additional cost, based on updated cost-effectiveness benchmark thresholds, and may be cost saving under some model scenarios. If future studies replicate this finding in other surgical settings, current policies promoting greater reliance on NAs operating independently (without physician anesthesiologist supervision) may need to be reevaluated.

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