Cost Effectiveness Analysis of Anesthesia Providers

Paul F. Hogan, MS, Rita Furst Seifert, PhD, Carol S. Moore, PhD, Brian E. Simonson, MS

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Abstract and Introduction

Introduction

In the United States, anesthesia services are administered predominately by two types of providers. Anesthesiologists are physicians who have completed medical school, a clinical base year residency, and 3 years as a resident in an anesthesia program. Certified registered nurse anesthetists (CRNAs) are advanced practice nurses who have earned a baccalaureate degree, practiced at least 1 year as an acute care nurse, and have successfully completed a graduate-level nurse anesthetist program. These graduate programs have an average duration of 28 months and may be as long as 36 months. Cur rently, there are approximately 40,000 practicing anesthesiologists in the United States (Health Resources and Services Administration, 2007) and over 36,000 CRNAs (American Association of Nurse Anesthetists [AANA], 2009). Both types of providers are critical to the safe, efficient provision of anesthesia services.

Anesthesia services are provided by CRNAs and by anesthesiologists in a variety of different delivery models. The delivery models vary by the degree of autonomy in which CRNAs may deliver anesthesia, as well as economic considerations. At one end of the spectrum, the CRNA may provide and bill for anesthesia services. At the other end, anesthesiologists may be the only providers administering and billing for anesthesia services in a particular practice setting. Between the two end points, CRNAs may work under varying degrees of supervision or medical direction. Delivery models may vary by practice setting based on the preferences and beliefs of the particular hospital or other setting, and because of state-specific and federal laws and regulations regarding the delivery and billing for services.

In this article, CRNAs who provide anesthesia for a patient under the care of an operating practitioner, but are not supervised nor medically directed, are referred to as "independent." CRNAs who provide anesthesia under anesthesiologist oversight are either "medically directed" or "supervised." These terms are used in the context of anesthesia staffing models and costs, not in terms of clinical decisions.

Analysis of the data examined the cost effectiveness of the alternative delivery models, and the implications of this for providing quality, cost-effective anesthesia services. Anesthesia is a component of surgical, medical, and diagnostic procedures as well as in pain management. The cost, access, and quality of health care services in general will be affected in no small measure by the availability of cost-effective anesthesia services.

In cost-effectiveness analysis, one compares the cost of alternative ways of achieving a given outcome. The issue of whether the quality of anesthesia services or outcomes is likely to vary across delivery models and providers was considered first. A reliance on literature review and a claims analysis to establish that there is no evidence to suggest that the quality of services or the outcomes will vary across the delivery models was considered. Next, a cost effectiveness of the alternative delivery models was examined. A stochastic simulation model was developed and applied, which simulates likely costs and revenues associated with each delivery model, holding constant other conditions likely to affect costs and revenues in the comparisons. Claims data for private payers were examined to determine how the costs to payers vary by delivery model. (Note that payments of the largest public payer, Medicare, are made according to a formula.) Finally, the costs to society of educating nurse anesthetists and anesthesiologists were examined and compared.

The information presented can help inform payers and employers (e.g., hospitals, anesthesia provider groups, public and private insurers) regarding the cost, quality, and access implications of alternate delivery models. The findings provide an evidence base to inform federal and state regulators and legislators who are formulating rules and regulations regarding the delivery of anesthesia. Further, information from this study can help federal and state legislators, education program directors, and other stakeholders regarding the potential return on investment from investing in anesthesia education and improving access to quality, cost-effective anesthesia care.

Quality of Care

Quality of care, usually measured in terms of patient outcomes, is an important component in understanding the potential advantages and disadvantages of using alternate anesthesia provider types or delivery models to provide required services. Cost-effectiveness analysis, which focuses on the most efficient way to achieve a given outcome, is conditioned on the premise that the quality of care does not change across alternatives. Cost or price of services is a secondary concern if quality of care varies significantly across provider types or delivery models. Therefore, first there was an examination of the evidence to determine if the quality of care differs by provider or delivery model.

Although some adverse cases are highly publicized, anesthesia-related mortality rates have declined substantially during the past 2 decades to about 1 death for every 240,000 anesthetics (AANA, 2008b). National estimates of anesthesia-related mortality in the United States for years 1999–2005 are 1.1 per million population per year and 8.2 per million hospital surgical discharges (Li, Warner, Lang, Huang, & Sun, 2009). National estimates of anesthesia complications for inpatients in 2005 found an incidence rate of 1.0 case per 1,000 admissions; of patients who developed complications, 0.9% died by discharge (Kuo, Lang, & Li, 2008). New anesthetic agents and improved patient monitoring have contributed to these improved outcomes (Martin-Sheridan & Wing, 1996).

The Centers for Disease Control (CDC) conducted a pilot study in 1980 and found the rate of adverse outcomes with anesthesia as a contributing factor was 6.25/10,000 procedures. The rate for adverse outcomes totally attributed to anesthesia was 1.25/10,000 procedures (Klaucke, Revicki, & Brown, 1988). The CDC concluded the low frequency of anesthesia-related adverse outcomes made the cost of a full-scale study prohibitive.

Research studies have found no significant differences in rates of anesthesia complications or mortality between CRNAs and anesthesiologists or among delivery models for anesthesia that involve CRNAs, anesthesiologists, or both after controlling for other pertinent factors (Hoffman, Thompson, Burke, & Derkay, 2002; Needleman & Minnick, 2008; Pine, Holt, & Lou, 2003; Simonson, Ahern, & Hendryx, 2007). There are limitations to the literature. Some researchers were not able to identify, precisely, the anesthesia delivery model. They might use the typical practice at a hospital rather than the anesthesia provider(s) for a specific procedure to identify delivery model (Forrest, 1980; Needleman & Minnick, 2008; Simonson et al., 2007). Sometimes the study identified those procedures which an anesthesiologist personally performed or directed, but may not distinguish whether medical direction was of CRNAs or anesthesiology residents (Silber et al., 2000). Given the low incidence of adverse anesthesia-related complications and anesthesia-related mortality rates in general, it is not surprising there are no studies that show a significant difference between CRNAs and anesthesiologists in patient outcomes.

Claims Analysis for Quality of Care

In addition to reviewing the evidence from the literature, health care claims and discharge data were used to assess adverse anesthesia outcomes including death and anesthesia complications. Anesthesia complications were identified using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis codes (Donnelly & Buechner, 2001).

The Ingenix national database contains integrated medical and financial claims data from commercial payers in 2008. A total of 52,636 claims that included anesthesia were reviewed. There were no complications arising from anesthesia in these claims. The National Survey of Ambulatory Surgery (2006) contains information about surgical and nonsurgical procedures performed on an ambulatory (outpatient) basis in hospitals or freestanding ambulatory surgery centers for 2006. There are 52,233 sampled visits, representing almost 35 million total visits in the United States. Only one visit resulted in a complication from anesthesia. For that visit, anesthesia was provided by an anesthesiologist and a CRNA. The Healthcare Cost and Utilization Project Nationwide Inpatient Sample (2007) contains information for approximately 8 million hospital stays from about 1,000 hospitals sampled to represent a 20% stratified sample of U.S. community hospitals. The unit of observation is an inpatient stay record rather than one specific procedure. It does not include anesthesia provider information. The percentage of complications is very low at 0.12% for the sample and 0.11% for the national estimate.

Quality of care by anesthesia providers is excellent. The incidence of adverse anesthesia-related complications and anesthesiarelated mortality rates is very low. Our review of the literature revealed no studies that demonstrated a significant difference between CRNAs and anesthesiologists or differences between anesthesia delivery models in rates of anesthesia complications or mortality after controlling for hospital and patient factors.

Cost Effectiveness of Anesthesia Providers and Anesthesia Delivery Models

The total cost to provide required anesthesia services is compared across anesthesia delivery models. The most cost-effective approach is the one which produces the output or service at the lowest cost, while maintaining quality. An economically viable model is one where the revenues generated exceed the costs.

A review of the literature found that previous studies were largely based on simulation analyses. Abenstein, Long, McGlinch, and Dietz (2004), using outcome data from Silber et al. (2000), found that a medical direction model is more cost effective with respect to years of life saved than a model in which CRNAs act independently. The data were not based on mortality due to anesthesia complications, but mortality in general. Moreover, variation in delivery models may be correlated with variation in other factors affecting quality of care or patient risk.

Glance (2000) finds that an anesthesiologist alone is not a cost-effective delivery model. Medical direction models are cost effective, with ratios varying optimally based on risk class of case. The Glance (2000) study used subjective estimates of patient risk in the analysis. Quintana, Jones, and Baker (2009) estimated the costs associated with a number of different delivery models, under the assumption outcomes are held constant. They found that anesthesiologist intensive forms of delivery are less efficient, and more likely to require subsidization by the hospital.

Using claims and national databases to determine what model is being used to provide anesthesia care is problematic. Hospital discharge data do not include the delivery model. There are difficulties in classifying types of supervision or medical direction by anesthesiologists in facilities that employ both CRNAs and anesthesiologists (Smith, Kane, & Milne, 2004). Recent studies have used surveys of hospital staffing patterns to determine provider type for obstetrical patients (Needleman & Minnick, 2008; Simonson et al., 2007). Even so, there are limitations on distinguishing models in facilities where CRNAs and anesthesiologists both practice. Needleman and Minnick (2008) differentiated hospitals where CRNAs and anesthesiologists both practiced based on the requirement that an anesthesiologist be present at the initiation of all planned cesarean sections. Simonson et al. (2007) resolved this dilemma by comparing hospitals with CRNA-only staffing to hospitals with only anesthesiologists.

Two complementary approaches to the analysis of the cost effectiveness of anesthesia delivery models were implemented. In the first, a stochastic simulation model that permits us to compare the cost effectiveness of the most prominent anesthesia delivery models while explicitly controlling for the factors that may influence the cost effectiveness was developed. In the second, an analysis of the actual claims data in which the anesthesia delivery model is identified to compare the actual costs of anesthesia services to the payer was conducted.

Simulation Model

A model to simulate the costs associated with delivery of anesthesia under a variety of delivery models and settings was developed. The purpose of the model is to estimate the costs and revenues that would likely occur under each delivery model, under a given scenario of patient demand. A total of seven different delivery models were considered:

1. CRNA practicing without an anesthesiologist involved in anesthesia delivery.
2. An anesthesiologist practicing alone.
3. Four medical direction model variants consisting of one anesthesiologist directing one to four CRNAs.
4. A supervisory model where one anesthesiologist supervises more than four CRNAs.

An important distinction between a medical direction model and a supervisory model is there are more prescriptive requirements for the anesthesiologist to actually be present during critical parts of the procedure in the medical direction model, compared to the supervisory model. These differences are captured in the model along with their effect on efficiency.

The set-up for a simulation requires the user of the model to specify a number of key factors. Key variables include:

- *Demand*. This is the number of patients seeking an operation in a given day. Because the model is stochastic, a probability distribution is specified.
- *Characteristics of the anesthesia procedure*. There are two dimensions to the procedure. The first is the number of base units represented by the procedure (a measure of complexity). The second is the number of time units required to complete the procedure. Base units and time units, which describe the anesthesia procedure, are also the key factors which determine the reimbursement for the procedure. These are also specified as probability distributions.
- *Payer distribution*. The user also specifies the proportion of patients by payer type. These include Medicare, Medicaid, private payer, and self-pay. The latter is unreimbursed.

The model is stochastic, that is, one specifies a distribution for patient demand, base units, time units and so forth, rather than a single number for each. However, by putting 100% of the probability weight on a single value, the model will become non-stochastic. One can simulate different settings, such as inpatient, ambulatory surgery, etc., by specifying the distribution of demand, base units, and time units associated with that setting. Empirically observed mean values to distinguish among the different settings were used. A typical inpatient surgery center, for example, will have a greater mean number of base units and time units per procedure than will an ambulatory surgery center. For a given simulation, each delivery model considered faces the same set of realized values of patient demand, base units, and time units. These parameters are held constant in the comparisons of cost and revenue.

The simulation model estimates the cost of providing the anesthesia service. The cost estimate is based on the salary or annual earnings of CRNAs and anesthesiologists and the delivery model used to administer the service. Intuitively, in an anesthesiologist-only model, the cost of providing a given anesthesia procedure is the implied cost of the anesthesiologist's time. However, if demand in a given day is unexpectedly low so that the anesthesiologist has idle time and completes fewer procedures, the implied cost per procedure will be greater.

In addition to estimating the cost of providing the anesthesia procedures, the model also estimates the reimbursement or revenue for the procedure. The reimbursement for the procedure will depend on the type of delivery model and the type of payer. The user may change the reimbursement rules and estimate the effects on revenues, but in our analyses we used the billing rules in effect for each payer. In particular, the billing rules for Medicare Part B used in our simulations are displayed in .

Table 1. Medicare Billing Rules

Delivery Model	CRNA	Anesthesiology
Anesthesiologist	▫	

alone		(Base units + Time units) * Conversion factor
CRNA alone	(Base units + Time units) * Conversion factor	▫
Medical direction	(Base units + Time units) * Conversion factor * 0.5	(Base units + Time units) * Conversion Factor * 0.5
Supervisory	(Base units + Time units) * Conversion factor * 0.5	Four units

A number of simulations across practice settings were conducted. The set-up for these simulations was the same (see).

Table 2. Key Parameters Held Constant in Simulations

▫	Medicare	Medicaid	Private	Self-pay
Payer proportions	0.45	0.1	0.4	0.05
Conversion factors	$21.00	$15.00	$50.50	0
Costs				
Anesthesiologist	$336,000/year	Nurse anesthetist	$170,000/year	▫

The practice settings were defined by the characteristics of the procedures. shows the mean values for the number of base units per procedure and the number of time units per procedure typically found in each setting.

Table 3. Mean Values for Procedures by Setting

Setting	Base Units	Time Units
Inpatient	6.2	7.1
Outpatient surgery	4.0	4.0
Ambulatory surgery center	5.0	2.1

For each scenario, first facility-level data to define the types and volume of anesthesia services provided at a typical facility over the course of 1 year was used. Then, the total cost to provide anesthesia services was modeled under each of the delivery models. Efficiencies, under some delivery models, will vary depending on how many patients simultaneously receive anesthesia as well as how many patients receive anesthesia in a setting in a year. The simulation model will analyze the effect of different patient workload demands on the costs associated with the model. This is potentially important because the cost associated with a delivery model must be analyzed in the context of a patient workload, and the distribution of this patient workload. For example, if the delivery model consists of an anesthesiologist in a medical direction role for up to four nurse anesthetists, the average cost of providing anesthesia will vary depending upon whether there is actual patient workload demand to support the model. If patient demand is such that the anesthesiologist is actually supervising the administration of anesthesia by four CRNAs simultaneously only 30% of the time, the costs will be higher than if there were patients to support full utilization.

The first scenario compares the results of the seven delivery models in an inpatient setting. For comparison purposes, we assume each delivery model operates at a facility with 12 distinct locations (stations or operating rooms). Hence, in a medical direction 1:4 model, three anesthesiologists would be directing a total of 12 CRNAs. The results are put on an annual basis assuming typical hours and days of operation.

shows the results from simulating the delivery models in an inpatient setting operating for a year under ideal conditions. The flow of patients is sufficient to conduct four procedures per day, on average, at each station. The same flow of patients is present for each delivery model. However, the actual number of procedures conducted will vary slightly across the delivery models, because of differences in the efficiency with which the models are capable of meeting demand. The results indicate the CRNA acting independently model is the least costly and produces the greatest net revenue. The supervisory model is the second lowest cost but reimbursement policies limit its profitability. Revenues for all models exceed costs except for the medical direction 1:1 model. The medical direction models, operating when demand is sufficient to insure full utilization, is economically viable except for the 1:1 variant. Among the medical direction models, the 1:4 model does the best in terms of net revenue. (Among the medical direction models, gross revenue declines slightly as we go from the 1:1 to 1:4 model. The medical direction model requires the anesthesiologists to be present at certain times during a procedure. This creates some delays in start times for procedures, as one station must wait while the anesthesiologist is attending another station. The delays are greater in 1:3 and 1:4 models. The qualitative implications do not change, however, when these delays are assumed to be zero.)

Table 4. Inpatient Simulation with Average Demand (Results in Dollars)

Model Four per Station per Day	Yearly Total Revenue (12 stations)*	Yearly Total Costs (12 stations)*	Yearly Total Revenue Minus Total Cost (12 stations)*
Medical direction 1:4	$5,401,171	$3,048,000	$2,353,171
Medical direction 1:3	$5,593,158	$3,384,000	$2,209,158
Medical direction 1:2	$5,673,606	$4,056,000	$1,617,606
Medical direction 1:1	$5,697,316	$6,072,000	−$374,684
Anesthesiologist only	$5,317,945	$4,032,000	$1,285,945
CRNA only	$5,317,945	$2,040,000	$3,277,945
Supervisory 1:6	$4,226,094	$2,712,000	$1,514,094

*Four per station per day is defined as four anesthetics per anesthetizing location per day.

presents the same results, except on a per procedure or per patient basis.

Table 5. Per Procedure Results for Inpatient Surgery Setting

Model Four per Station per Day	Revenue Per Procedure	Cost Per Procedure	Revenue Minus Costs Per Procedure
Medical direction 1:4	$474	$267	$206
Medical direction 1:3	$474	$287	$187
Medical direction 1:2	$474	$339	$135
Medical direction 1:1	$474	$506	-$31
Anesthesiologist only	$443	$336	$107
CRNA only	$443	$170	$273
Supervisory 1:6	$352	$226	$126

The next scenario considers what may happen in an inpatient setting when demand is insufficient to support full utilization of the operating room schedule. This simulation is constructed so, on average, demand supports only two procedures per day at each station, compared to four per day in the previous case. Under these conditions, only the model in which CRNAs act independently is self-sustaining (see). All other models would require a subsidy.

Table 6. Inpatient Simulation with Below Average Demand (Results in Dollars)

Model Two per Station per Day	Yearly Total Revenue (12 stations)	Yearly Total Costs (12 stations)	Yearly Total Revenue Minus Total Cost (12 stations)
Medical direction 1:4	$2,939,415	$3,048,000	−$108,585
Medical direction 1:3	$2,945,765	$3,384,000	−$438,235
Medical direction 1:2	$2,948,422	$4,056,000	−$1,107,578
Medical direction 1:1	$2,943,579	$6,072,000	−$3,128,421
Anesthesiologist only	$2,742,690	$4,032,000	−$1,289,310
CRNA only	$2,742,690	$2,040,000	$702,690
Supervisory 1:6	$2,165,133	$2,712,000	−$546,867

Similar analyses were conducted but not reported here, for the outpatient and ambulatory surgical center settings. The overall conclusions regarding efficiency and economic viability were similar to those for the inpatient setting.

These results support the conclusion that the most cost-effective delivery model is CRNAs practicing independently. This model also produces the greatest net revenue. The supervisory model is the second lowest cost but reimbursement policies limit its profitability. The model would be almost as cost effective as CRNAs acting independently in settings where reimbursement is not an issue (e.g., veterans hospitals, military facilities). Other models, such as the medical direction 1:4 model, can do relatively well under conditions in which demand is sufficient to support full utilization. Under conditions when demand supports less than full utilization, almost all models will require a subsidy to remain viable. The CRNA acting independently is least likely to require a subsidy to remain economically viable. Moreover, we found in other experiments with the simulation model that when demand is highly variable, the net revenue of all models are adversely affected, but again the CRNA acting independently model is least likely to have negative net revenue. We also conducted sensitivity analyses around key model parameters, such as the salaries of the providers. The overall conclusions were robust across changes in key parameters of +/-10%.

Analysis of Claims Data

An analysis of claims data to compare the cost of providing anesthesia by provider type and by anesthesia delivery model was completed. Public and private insurance claims were used to estimate costs in inpatient and ambulatory surgery settings. The claims data identified surgical and non-surgical procedures for which anesthesia was performed and other anesthesia-related services. The claims data indicated provider type (CRNA vs. anesthesiologist) for directly providing the anesthesia services. Some of the data included enough information to identify the delivery model.

The Ingenix national database contains integrated medical and financial claims data from commercial payers. Claims from year 2008 were analyzed. This database included anesthesia modifier codes to identify anesthesia delivery models.

Two payment variables were analyzed: billed amount and allowed amount. The billed amount is the amount billed by a provider or facility. For anesthesia services this typically includes base units for the procedure plus time units multiplied by a conversion factor. The allowed amount is the portion of submitted charges covered under plan benefits, or the contracted amount agreed to by providers. This amount is after discounts and not covered/excluded expenses, and before member responsibility. The allowed amount better reflects the dollar amount the provider will receive for the service from commercial payers.

The results for the average billed amount for anesthesia per procedure (see), demonstrate that the CRNA-only model is less costly, on average, than other models, followed by the anesthesiologist-only model. The medical direction models are more costly.

Table 7. Billed Amount and Allowed Amount for Anesthesia per Procedure by Delivery Model

Delivery Model	N	Average Billed Amount	Average Allowed Amount
Anesthesiologist only	33,249	$1,087.15	$470.54
Medical direction 1:2–4	11,022	$1,434.19	$438.13
Medical direction 1:1	2,021	$1,544.36	$477.57
CRNA only	6,344	$1,059.34	$307.23

Using a regression model to control for patient gender, age, facility type, and base units of anesthesia procedures, the CRNA-only model has a lower billed amount than the other models and the lowest to highest remains the same. Anesthesiologist-only billed amount is almost 4% higher than the CRNA only model, and medical direction models have billed amounts 28%–37% more than the CRNA-only model.

The results for the average allowed amount for anesthesia per procedure, also shown in , indicate that the CRNA-only model is less costly on average compared to all other models. Moreover, anesthesiologist-only model is now as costly as the medical direction models.

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Using a regression model to control for patient gender, age, facility type, and base units of anesthesia procedures, the CRNA-only model has a lower allowed amount than the other models and the rank order from lowest to highest remains the same. The allowed amount for procedures when there is medical direction by an anesthesiologist of 2–4 CRNAs is 16% higher than the CRNA-only model. An anesthesiologist only and medical direction by anesthesiologist of one CRNA are 30%–33% higher than the CRNA-only model.

Summary

CRNAs acting independently provide anesthesia services at the lowest economic cost, and net revenue is likely to be positive under most circumstances. The supervisory model is the second lowest cost but reimbursement policies limit its profitability. In facilities where demand is high and relatively stable, the medical direction 1:4 model is better than the other medical direction models and can approach the net revenue benefits of the CRNA model. However, in areas of low demand, the medical direction models are inefficient. The medical direction 1:1 model is almost always the least efficient model.

CRNAs acting independently is the only model likely to have positive net revenue in venues of low demand, such as may be found in rural areas. Other models, including medical direction models where one anesthesiologist directs two to four CRNAs, are likely to require subsidies in cases where overall demand is not consistent with full utilization of facilities. Finally, analysis of claims data suggests CRNAs acting independently are the lowest cost to the private payer.

Undergraduate and Graduate Education Costs

The analysis of the cost effectiveness of CRNAs suggests they provide an economic means to deliver quality anesthesia services. The delivery model in which CRNAs are acting independently is the most cost-effective model and the model which is economically viable under the widest range of conditions. In this section, an examination of whether CRNAs are also cost effective to educate was implemented.

A key to estimating education costs for CRNAs and anesthesiolotion paths, and variants in those paths. A typical path for each is outlined briefly below.

- A CRNA must typically obtain a baccalaureate degree in nursing or relevant degree; must be licensed as a registered nurse; have at least 1 year of experience as an RN in an acute care setting; graduate from an accredited graduate-level nurse anesthesia educational program (average duration 28 months, may be as long as 36 months); and pass a national certification exam following graduation.
- An anesthesiologist must obtain a baccalaureate degree; spend 4 years in medical school leading to a degree in medicine (MD) or osteopathy (DO); complete a clinical base year residency; then complete 3 years of residency in anesthesiology. Board certification requires 4 years of residency in anesthesiology and passing the American Board of Anesthesiology exam.

The costs associated with traveling along those paths, both the direct costs and the opportunity costs (what the trainees could have been earning if they were not in an educational program), are estimated and included in this analysis. Also included is the productivity of the students which is estimated for the value of the student/resident services while being educated.

The literature on undergraduate and graduate education costs for CRNAs and anesthesiologists is presented in . Please note all estimates from the literature have been converted to 2008 dollars.

Table 8. Undergraduate and Graduate Education Cost Estimates from the Literature (2008 dollars)

	CRNA		Anesthesiologist	
Pipeline Stage	**Estimate**	**Source**	**Estimate**	**Source**
BA/BS/BSN	$53,696	National Center for Education Statistics (2009)	$53,696	National Center for Education Statistics (2009)
Medical school	▫	▫	$436,080	Gunn (1996)
▫	▫	▫	$1,070,000	Dodoo & Phillips (2008)
▫	▫	▫	$503,370	Rein et al. (1997)
PGY-1	▫	▫	$134,042	Gunn (1996)
CRNA education	$52,076 (direct cost)	Gunn (1996)	▫	▫
▫	$287,382 (social cost)	Fagerlund (1998)	▫	▫
	▫	▫	$321,000 (direct cost)	Dodoo & Phillips (2008)

Anesthesiology PGY 2–4	▪	▪	$301,178 (direct cost)	Franzini & Berry (1999)
	▪	▪	−$114,031 (direct plus productivity)	Franzini & Berry (1999)
	▪	▪	$245,969 (with opportunity cost added)	Franzini & Berry (1999) – modified by Hogan to include opportunity cost
	▪	▪	$229,267 (direct, before GME offset)	Pisetsky et al. (1998)
	▪	▪	−$213,000 (with productivity offset and GME subsidy)	Pisetsky et al. (1998)
	▪	▪	$146,940	Pisetsky et al. (1998) – with productivity offset with opportunity cost (Hogan)

Education Path Cost Estimates

Cost estimates of pre-anesthesia graduate education for CRNAs and anesthesiologists are taken from the literature. These include the costs of BA/BS/BSN degree, the cost of medical school for anesthesiologists, and the cost of a clinical base year residency for anesthesiologists.

Anesthesia Graduate Education Cost Model

An Education Path Cost Model for both CRNAs and MD anesthesiologists was constructed. For CRNAs, this estimate captures the average 28-month program that produces a CRNA. For anesthesiologists, the estimate captures the cost of the 3-year residency program in anesthesiology. The estimate is intended to capture the economic cost of education. This is the cost to society of obtaining an additional graduate. It is also constructed to approximate the additional costs that will be incurred to produce one more graduate. In that sense, it is an estimate of the marginal cost to society of producing a program graduate. The estimate consists of three major components:

- *Direct program costs*. This cost element consists of faculty salaries and benefits, liability insurance, and other direct costs of the graduate education program.
- *Student/resident opportunity cost*. This cost captures the value of the student's or resident's time while in the program. It represents what the student could be earning were the student not in the graduate program.
- *Student/resident productivity*. This is a measure of the value of the services the student or resident provides while in the graduate program. For example, the students and residents will be administering anesthesia. It is an offset to the other costs.

The graduate education cost model is driven by a number of key parameters: the student/faculty ratio, the salaries of faculty, the proportion of time the faculty allocates to instructing students or residents, the value of student's or resident's time (opportunity cost), the productivity of students or residents, program attrition, and program length.

Given these inputs, the model estimates the cost of a graduate from the program. provides the baseline inputs used to estimate the cost of program graduates.

Table 9. Baseline Values of Key Variables in the Anesthesia Graduate Education Model

Feature	CRNA	Anesthesiologist	Source

Program length	28 months	36 months	
Student/faculty ratio	7.4	2.2	AANA (2009); Franzini & Berry (1999)
Faculty salary	$158,587	$366,649	AANA (2008a); MGMA (2005)
Student opportunity cost at entry	$52,455	$120,000	Merritt Hawkins & Associates (2008); RN Magazine's 2009 Nurse Earnings Survey (Modern Medicine, 2009)
Attrition rate	7.3%/year	3%/year	AANA (2008a); Schubert (2007)

displays the pre-anesthesia costs taken from the literature and estimates of the cost per graduate from the CRNA and anesthesiologist programs derived from the cost model. The costs are in 2008 dollars, and are undiscounted. Therefore, all the estimates are in 2008 dollars, but the estimates do not take into account some costs were incurred up to 3 years before other costs. (We have also estimated costs that discount all costs incurred to the time of program graduation. This raises the total cost of both types of graduates by about 4%.)

Table 10. Marginal Cost of Pre-Anesthesia and Anesthesia Graduate Education (2008 dollars)

		CRNA	Anesthesiologist
Direct costs of education and clinical experience before entry into an anesthesia program	BA/BS/BSN	$53,696	$53,696
	Medical school		$436,080
	One year as acute care nurse	Required, but with no direct cost	
	First-year residency (PGY-1)		$134,042
Total Pre-Anesthesia		**$53,696**	**$623,818**
Anesthesia graduate education (GE)	Direct costs	$68,465	$494,420
	Student/Resident opportunity cost	$291,353	$897,793
	Productivity of students/residents	($251,704)	($775,073)
Total Anesthesia GE (less transfer payments)		**$108,113**	**$459,977**
Total Estimated Costs		**$161,809**	**$1,083,795**

Both the direct and indirect costs of education necessary to enter a graduate program and graduate education for CRNAs are lower than those costs for anesthesiologists, and by a substantial margin. Anesthesia graduate education costs for CRNAs are less than one-fourth the anesthesia graduate costs of anesthesiologists. Total costs, to include both undergraduate and graduate costs for CRNAs are about 15% of the costs of anesthesiologists. An implication of these estimates is that, at the margin, it will cost society less to increase the number of anesthesia providers by expanding CRNA education programs.

Conclusions

Simulations in this study indicated that delivery models using medical direction are not as cost effective as CRNAs acting independently and often are not financially sustainable without subsidies. CRNAs acting independently provide anesthesia services at the lowest economic cost. Net revenue is likely to be positive under most circumstances. The supervisory model is the second lowest cost but reimbursement policies limit its profitability. The medical direction

1:1 model is almost always the least efficient model.

In facilities where demand is high and relatively stable, the medical direction 1:4 model does better than the other medical direction models and can approach the net revenue benefits of the CRNA model. However, in areas of low demand, the medical direction models are inefficient. CRNAs acting independently are the only model likely to have positive net revenue in venues of low demand. Analysis of claims data suggest CRNAs acting independently are the lowest cost to the private payer.

Both the direct costs and the economic cost of educating CRNAs are lower than the cost of anesthesiologists. Economic costs of graduate education for CRNAs are about one-fourth of the cost of anesthesiologists. Costs of the entire education pathway for CRNAs are about 15% of anesthesiologists.

Anesthesiologists and certified registered nurse anesthetists provide high-quality, efficacious anesthesia care to the U.S. population. This research and analyses indicate that CRNAs are less costly to train than anesthesiologists and have the potential for providing anesthesia care efficiently. Anesthesiologists and CRNAs are interchangeable. They can perform the same set of anesthesia services, including relatively rare and difficult procedures such as open heart surgeries and organ transplantations, pediatric procedures, and others. CRNAs are generally salaried. Their compensation lags behind that of anesthesiologists, and they generally receive no overtime pay. As the demand for health care continues to grow, increasing the number of CRNAs, and permitting them to practice in the most efficient delivery models, will be a key to containing costs while maintaining quality care. **$**

Sidebar

Executive Summary

- Anesthesiologists and certified registered nurse anesthetists provide high-quality, efficacious anesthesia care to the U.S. population.
- This research and analyses indicate that CRNAs are less costly to train than anesthesiologists and have the potential for providing anesthesia care efficiently.
- Anesthesiologists and CRNAs can perform the same set of anesthesia services, including relatively rare and difficult procedures such as open heart surgeries and organ transplantations, pediatric procedures, and others.
- CRNAs are generally salaried, their compensation lags behind anesthesiologists, and they generally receive no overtime pay.
- As the demand for health care continues to grow, increasing the number of CRNAs, and permitting them to practice in the most efficient delivery models, will be a key to containing costs while maintaining quality care.

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