ECONOMICS

Anesthesiology
1998; 88:1350-6

A Method to Compare Costs of Drugs and Supplies among Anesthesia Providers

A Simple Statistical Method to Reduce Variations in Cost Due to Variations in Casemix

Franklin Dexter, M.D., Ph.D., David A. Lubarsky, M.D.,† Bill C. Gilbert, B.S., ‡ Christine Thompson§*

Background: **Comparison of costs among anesthesia providers using "cost per case" does not adjust for variations in casemix (such as the type of procedure and patient condition). The authors propose an alternative method for comparing costs using the American Society of Anesthesiologists' Relative Value Scale (ASARVS) system, which incorporates basic units (for the procedure), modifier units (for the patient's physical condition), "other" units (such as for the placement of invasive monitors), and time units (proportional to the case duration).**

Methods: **Data were obtained from a series of 3,340 anesthetics performed at a tertiary hospital. Administered and discarded drug, supply, and fluid costs were used.**

Results: **Costs expressed as dollars per ASARVS unit had 54% less variability than costs expressed as dollars per case ($P <$ 0.0001). Pearson correlations between demographic variables and cost per ASARVS unit ranged from −0.10 to 0.13. Total (*e.g.*, quarterly) costs for simulated sets of cases were predicted within 0.0 ± 2.3% by multiplying (1) their sum of units and (2) a like set of case's sum of costs divided by sum of units.**

Conclusions: **Costs of anesthetic supplies and drugs of a case were more accurately reported as "cost per unit" than as "cost per case." This method of calculating the cost of anesthetic drugs and supplies has several applications, including (1) comparison of costs among anesthesia providers and (2) benchmarking costs among hospitals and anesthesia groups. By design, anesthesia providers' time is quantified by their ASARVS units. Together anesthesia costs (personnel, supplies, and drugs) are better reported as "cost per unit" than as "cost per case."** **(Key words: Cost control; financial management; management information systems; medical practice management; relative value scales.)**

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 5A.

ANESTHESIOLOGISTS and hospital managers are working together to achieve cost control in the operating room environment. Electronic anesthesia records record each anesthesiologist's supply and drug use. The direct costs of anesthesia include costs that can be traced to specific anesthetics (*e.g.*, supplies and drugs).[1] Using a database of electronic anesthesia records, cost accountability can be established. Financial report cards to compare costs among anesthesia providers can be generated. Such feedback on relative financial performance may change anesthesia providers' practice patterns, encourage more appropriate use of resources,[2] or both. However, quoting from the American Society of Anesthesiologists' report on value-based anesthesia care, "cost . . . comparisons among anesthesiologists or institutions are presently unreliable because they depend on incompletely defined adjustments for the difficulties presented by different patients."||

The typical way to report direct anesthesia costs is to use "cost per case."[3] However, "cost per case" may be a poor measure of anesthesia providers' relative financial performance. Suitable provider financial review requires adjustment for casemix, including surgical procedure and patient demographics. For example, anesthesiologists who care for sicker patients who have longer operations may have higher costs than other anesthesi-

* Associate Professor, Department of Anesthesia, University of Iowa.

† Associate Professor and Vice-Chair, Department of Anesthesiology, Duke University.

‡ Arkive Systems Administrator, Department of Anesthesiology, Duke University.

§ Administrator, Department of Anesthesia, University of Iowa.

Received from the Department of Anesthesia, University of Iowa, Iowa City, Iowa. Submitted for publication June 9, 1997. Accepted for publication January 7, 1998.

Address reprint requests to Dr. Dexter: Department of Anesthesia, The University of Iowa, 6 JCP, 200 Hawkins Drive, Iowa City, Iowa 52242. Address electronic mail to: franklin-dexter@uiowa.edu

|| Johnstone RE: Value-based anesthesia care: maturing beyond cost containment. ASA Newsletter 1996; 60(10):7-8.

ologists. Although financial report cards should reflect variations in cost caused by provider inefficiency, report cards should exclude variations in cost resulting from variations in casemix. "Cost per case" does not do this. The goal of this study was to develop a simple method to compare the costs of drugs and supplies among anesthesia providers while reducing variations in cost caused by variations in casemix.

The American Society of Anesthesiologists' Relative Value Scale (ASARVS) system measures anesthesiologists' work.[4] Base units vary according to the operation that a patient undergoes. Modifier units account for variations in patients' physical conditions. "Other" units show the relative work needed to place invasive monitors. Time units are proportional to the duration of a case. Payments to anesthesiologists usually equal a dollar-per-unit fee multiplied by the sum of basic, modifier, time, and other units. We hypothesized that the variable costs of anesthesia may be better related to work performed than to numbers of cases. Therefore we wanted to determine whether "cost per unit" may yield a more accurate measure of anesthesia providers' cost performance than "cost per case," and thus whether ASARVS units can be used to reduce variations in cost resulting from variations in casemix.

Methods

We studied the database of anesthesia cost information at Duke University Medical Center. The Arkive automatic record keeping system and IDX billing system is used for each patient. Detailed information is recorded electronically in a database. Data were collected retrospectively using cases performed between November 1, 1995 and February 6, 1996. The following data were included in the study: (1) ASARVS basic unit value[4]; (2) ASARVS modifier units[4]; (3) ASARVS "other" units; (4) ASARVS time units[4]; (5) age; (6) American Society of Anesthesiologists (ASA) physical classification, including emergency status; (7) weight; (8) type of anesthesia (such as spinal); (9) estimated blood loss; (10) surgical service (such as cardiac and neurosurgery); and (11) length of hospital stay. The ASARVS time units equal the number of minutes from the start to the end of continuous anesthesia care divided by 15 min.[4] The anesthesia provider enters age, ASA physical classification, weight, type of anesthesia, and estimated blood loss manually into the Arkive automated anesthesia record. Patients who were discharged on the day of surgery were assigned a length of stay equal to zero. Arkive records were not made for obstetrical cases, cardioversions, electroconvulsive treatments, magnetic resonance imaging, or other satellite cases. Thus such cases were not included in our study. For some cases, costs or demographic information were not completely available. These cases were deleted. We analyzed 3,340 (63%) of the 5,325 procedures that required the services of an anesthesiologist during the study period.

Drug costs for each case, both administered and discarded, were determined from the Arkive record of drugs and intravenous fluids, fresh gas flow rates, and concentrations of inhaled agents, as entered by the anesthesia provider. A drug cassette was prepared for each case by a satellite operating room pharmacy. At the end of each case, when the cassette was returned to the pharmacy, the unused open vials were discarded. Drug costs were calculated by a validated computer program, as previously described.[2] The costs of blood products were excluded from our analysis of anesthesiology resource use. Drugs ordered under the direction of the surgeons, such as antibiotics, were also excluded.

Supply costs were calculated based on the type of anesthesia, as shown in table 1. Acquisition costs were added for all the disposable equipment routinely used during different types of anesthesia (such as general intubated or spinal). If a second anesthetic type was recorded, the appropriate additional costs were added. The costs for each recorded peripheral intravenous catheter site was calculated assuming the use of the standard intravenous tubing set and a 16-gauge angiocatheter. The Arkive record keeper automatically records invasive pressures for each case. Invasive monitoring costs were triggered by the presence of continuous, valid electronic data for that parameter. For arterial catheters, equipment included in the cost calculations included a 20-gauge intravenous catheter, pressure tubing, transducer, stopcock, and flush fluid. Equivalent calculations were done for central venous catheters, pulmonary artery catheters, and oximetric pulmonary artery catheters.

The ideal predictor of cost per case would be a value that is proportional to the true value of cost per case. Thus dividing cost per case by this value would yield the same number for all cases. Therefore the standard deviation of cost per case after adjustment by this ideal predictor would equal zero. Although the ideal predictor would have a standard deviation of zero, we cannot use the standard deviation. The number of ASARVS units for a case (*i.e.*, the predictor) is a positive number.

Table 1. Demographics of the 3,340 Cases

	Mean ± SD
Age (yr)	47 ± 23
Blood loss (ml · kg^{-1})	2.3 ± 5.5
Length of stay (days)*	5.8 ± 10.2
Weight (kg)	71 ± 27
Basic units	7.0 ± 4.5
Modifier units	0.51 ± 0.72
Time (mins)	183 ± 110
Time units	46 ± 28
Other units	2.3 ± 5.1
Total units	22 ± 15
Costs of supplies ($)	37 ± 58
Costs of drugs with discarded drugs ($)	34 ± 29
Costs of drugs administered ($)	24 ± 25
Costs of discarded drugs ($)	9.6 ± 8.3
Costs with discarded drugs ($)	70 ± 74
Costs per total units with discarded drugs ($)	3.2 ± 1.5

	%
Ambulatory	37
Anesthetic type	
General intubated	63
Monitored anesthesia	14
Nerve blockade	10
Epidural	5
Spinal	4
General mask	4
ASA classification	
1	18
2	39
3	30
4	12
5	1
Emergency	7
Surgical service	
Orthopedics	25
General	20
Cardiothoracic	11
Ophthalmology	9
Neurosurgery	7
Plastics	7
Otolaryngology	6
Urology	6
Gynecology	5
Pediatrics	3
Other	1

* The median and lower quartile of length of stay were 2 and 0 days, respectively.

The standard deviation of costs divided by the predictor would be smaller than the standard deviation of costs per case only because the mean value is smaller. A large predictor will yield a low standard deviation, regardless of how well it works as a predictor. For example, if a predictor was infinitely large, dividing costs by this predictor would produce a mean and standard deviation of zero. Therefore, the standard deviation must be scaled by the size of the predictor. The standard deviation, scaled by the size of the predictor, is the coefficient of variation. Therefore, to test the value of cost per case's ASARVS unit as a predictor, we compared coefficients of variation (*i.e.*, the ratio of standard deviation to the mean) before and after dividing by the case's ASARVS units.

We tested statistically whether the coefficient of variation of cost per case was different after dividing by each case's total number of ASARVS units. Our sample sizes varied from several hundred (when stratified by surgical service) to thousands (overall). Therefore we were able to use an asymptotic statistical method.[5] A two-sided statistical analysis was done using costs of supplies and all drugs, including waste. We thought *a priori* that the total number of ASARVS units might not be the best predictor of cost per case, so we also analyzed qualitatively changes in the coefficient of variation of cost per case after dividing by all combinations of ASARVS units. Other covariates, such as patient weight, may be able to predict adjusted cost per case. Thus we analyzed univariate correlations using Pearson's correlation coefficient. Data are otherwise reported as mean ± SD.

For the following analysis, "cost per unit" refers to a case's total costs divided by the case's total ASARVS units. We assessed the predictive value of "cost per unit" by randomly dividing the cases into two equally sized groups. For the first half (learning group), we calculated the mean cost per unit, the sum of costs, and the sum of units. We performed the same calculations for the second (test) group. We made four percentage comparisons. The rationale of each approach is explained in detail in the last paragraph of the Results section. Each comparison was designed to evaluate the predictive ability of "cost per unit." The four comparisons were (1) the (learning set sum of costs) ÷ (learning set sum of units) *versus* the test set's mean cost per unit; (2) the (test set sum of units) × (learning set mean cost per unit) *versus* the test set sum of costs; (3) the (test set sum of units) × (learning set sum of costs) ÷ (learning set sum of units) *versus* the test set sum of costs; and (4) the (test set number of cases) × (learning set sum of costs) ÷ (learning set number of cases) *versus* the test set sum of costs. For each of the four comparisons we obtained a percentage: 100 × ("true" − "predicted")/"true." We repeated the process of dividing the data into two groups and analyzing it for an additional 1,999 times, producing a total of 2,000 analyses. We calculated the mean and standard deviation of the 2,000 percentages. We choose 2,000 simulations to achieve a reasonable confidence interval for the standard deviation of the percentages.

Results

Data were analyzed for 3,340 cases. Table 1 gives the demographic features of the cases.

We evaluated the coefficient of variation of costs expressed as costs per sums of different combinations of ASARVS units (table 2). The total number of ASARVS units seems to have been as good a predictor of cost per case as was any other combination of ASARVS units (table 2). We therefore defined "cost per unit" to refer to a case's total costs divided by total ASARVS units. The coefficient of variation for cost per unit was 54% smaller than for the cost per case (table 2). Costs for a case's anesthetic supplies and drugs expressed as dollars per the case's ASARVS units (cost per unit) varied less than costs expressed as dollars per case ($P < 0.0001$).

Variations in casemix refer, in part, to variations in surgical procedure and patient demographics. When describing costs, costs were more accurately reported as "cost per unit" than as "cost per case" (table 2). We examined limitations of the method of using "cost per unit." We evaluated demographic variables and other characteristics of the cases to determine if they may predict cost per unit. Pearson correlations ranged from −0.10 to 0.13 (table 3). The mean cost per case differed 5.3 times among surgical services (table 4). However, cost per unit differed less (1.8 times). This decrease in cost variations among surgical services shows that "cost per unit" decreases variability *versus* "cost per case."

Some users of our method may limit their interest to one surgical service. For example, an anesthesia group may want to compare costs among its cardiac anesthesiologists. Should this hypothetical group compare "cost per unit" or is "cost per case" sufficient? To answer this question, we made comparisons after stratification by surgical service. For 7 of 10 surgical services, the coefficients of variation of cost per case significantly exceeded that of cost per unit (table 4). For the other three surgical services, the coefficients of variation did not differ significantly. These three surgical services had smaller means (<2 h) and standard deviations (<1.5 h) of time units than did the other seven services. Therefore cost per unit may not be better for reporting than cost per case for surgical services with relatively brief anesthesia times and concomitantly less variability in anesthesia times.

Table 2. Percentage Decreases in Coefficients of Variation of Cost per Case Achieved by Adjusting for Variations in Casemix

Sum of Units	Costs per "Sum of Units" (mean ± SD)	Percentage Decrease in Coefficient of Variation
None	70 ± 74	0
Basic	10 ± 7.0	36
Modifier	69 ± 58	21
Other	20 ± 11	46
Time	6.0 ± 4.3	32
Basic and modifier	9.7 ± 6.3	38
Basic and other	8.8 ± 4.9	47
Basic and time	3.6 ± 2.2	41
Modifier and other	26 ± 18	32
Modifier and time	5.7 ± 3.9	35
Procedures and time	5.2 ± 2.7	50
Basic, modifier, and other	8.4 ± 4.9	45
Basic, modifier, and time	3.5 ± 2.1	43
Basic, other, and time	3.2 ± 1.5	54
Modifier, other, and time	5.0 ± 2.6	50
Basic, modifier, other, and time	3.2 ± 1.5	54

Coefficients of variation are reported as percentages relative to the value for no units. "None" means, effectively, that the sum of units equals 1 for all cases. Basic units vary according to the operation that a patient undergoes. Modifier units account for variations in patients' physical conditions. "Other" units show the relative work needed for placement of invasive monitors. Time units are proportional to duration of a case. Coefficients of variation were calculated from cost per case divided by the sum of the American Society of Anesthesiologists' Relative Value Scale units specified. For example, consider a hypothetical patient undergoing resection of an abdominal aortic aneurysm. Costs for the case's drug, supply, and fluids might equal $125. Basic units for such procedures equal 15. Modifier units might equal 1, for an ASA 3 physical status. "Other" units might equal 3 units for arterial line plus 4 units for central venous catheter. Time units might equal 4 hours × (4 units per hour) = 16 units. The sum of basic, modifier, other, and time units would be 15 + 1 + 7 + 16 = 39 units. "Cost per unit" would then equal $125/39 = $3.2 per unit.

The above mentioned analyses are sufficient for two applications of our method. Cost per unit can be compared among anesthesiologists on the same and different surgical services. Further, the number of patients required in a clinical trial to compare cost per unit between groups would be less than in a trial comparing cost per case between groups. Additional applications of our method require additional testing, which we de-

Table 3. Effect of Demographic Variables and Characteristics of a Case on Cost per Case's ASARVS Units

Demographic Variable	Pearson's r
Age	−0.10
Blood loss	−0.05
Length of stay	−0.01
Weight	−0.03
Ambulatory case	0.13
ASA classification	0.03
Emergency case	0.07

Costs are reported as mean ± SD. The four negative correlation coefficients suggest that patients with increasing age, blood loss, length of stay, and/or weight may have lower "cost per unit." The three positive correlation coefficients suggest that ambulatory surgery, higher ASA physical status classification, and/or emergency cases may be associated with higher "cost per unit."

scribe below in the same order as in Methods section (*i.e.*, as comparisons 1-4).

Benchmarking is the use of data to make meaningful comparisons of performance among providers and hospitals. Hospitals can use "cost per unit" to track drug and supply expenditures over time, compare expenditures to targets, and compare results among hospitals. An information system may provide cost per unit for each patient. However, some anesthesia departments only have data for annual costs of drugs and supplies rather than of costs for each patient. Their billing database will provide the total number of ASARVS units for the cases done each year. Mean cost per unit can then be estimated by dividing the annual costs by the annual ASARVS units. We tested whether this approach would accurately predict mean "cost per unit." The errors for 2,000 sets of simulated cases had mean ± SD of −1.7 ± 1.9%. These simulations are labeled as comparison 1 in the Methods section.

Suppose an anesthesia group has been providing services at one site (such as a hospital) and wants to bid on a contract at a new site (such as a surgicenter). The group could predict total (such as annual) costs at the new site by multiplying (1) the annual numbers of ASARVS units at the new site and (2) the group's current mean cost per unit at their existing site. The latter may be obtained by having an information system provide mean "cost per unit" for the specific anesthesia providers who will work at the new site. When this approach was tested, the simulated error was 1.7 ± 1.8%. These simulations are labeled comparison (2) in the Methods section. Otherwise, total costs at the new site could be predicted by multiplying (1) the annual numbers of ASARVS units at the new site and (2) an estimate of the group's cost per unit calculated by dividing the existing site's annual budget for drugs and supplies by its annual numbers of ASARVS units. The simulated error was then 0.0 ± 2.3%. These simulations are labeled comparison (3) in the Methods section. We compared this error with that achieved using "cost per case." We estimated total costs at the new site by multiplying (1) the annual numbers of cases at the new site and (2) the group's annual budget for drugs and supplies divided by the

Table 4. Effect of Surgical Service on Cost per Case's ASARVS Units

	Mean ± SD		Coefficient of Variation (%)		
Surgical Service	Cost per Case	Cost per Case's ASARVS Units	Cost per Case	Cost per Case's ASARVS Units	*P* Value
Neurosurgery	63 ± 47	2.2 ± 1.0	75	46	<0.001
Ophthalmology	39 ± 15	3.0 ± 1.3	38	42	0.16
Plastics	49 ± 28	3.0 ± 1.3	58	44	0.001
Orthopedics	52 ± 27	3.0 ± 1.2	53	38	<0.001
Urology	57 ± 44	3.1 ± 1.4	76	46	<0.001
General	64 ± 63	3.1 ± 1.6	98	51	<0.001
Otolaryngology	47 ± 23	3.3 ± 1.7	50	52	0.65
Gynecology	53 ± 35	3.4 ± 1.8	66	54	0.03
Pediatrics	48 ± 23	3.7 ± 1.4	48	38	0.07
Cardiothoracic	207 ± 125	3.9 ± 1.9	61	47	<0.001
All services	70 ± 74	3.2 ± 1.5	105	48	<0.001

The values listed in the second and third columns of the last row are the same as the first and last rows of Table 2. The coefficient of variation (%) equals 100 multiplied by the ratio of the standard deviation to the mean. *P* value refers to the result of the two-sided statistical comparison of coefficients of variation between cost per case and cost per case's ASARVS units.

number of cases. The simulated error was 0.0 ± 3.5%. These simulations are labeled comparison (4) in the Methods sections. Use of "cost per unit" instead of "cost per case" decreased variability in the error by 48%, calculated as 100 × (3.5 − 2.3)/3.5.

Discussion

Applications of Our Method

We found that total anesthesia costs for supplies and drugs are more accurately reported as costs per ASARVS unit than as cost per case. The following examples show the potential use of reporting anesthetic costs as "cost per unit." First, the information system at Duke University allows the calculation of cost of anesthesia supplies and drugs for each patient. Although "cost per case" allows comparison of costs among anesthesiologists on the same surgical service, "cost per unit," in contrast, allows comparison among anesthesiologists on different services. Second, the number of patients required to be studied in a clinical trial depends on the variance for the effect being studied and the size of the difference to be detected. Because we found that the coefficient of variation for cost per ASARVS unit is 54% smaller than for cost per case (table 2), we anticipate that comparing "cost per unit" between groups instead of "cost per case" would require a smaller sample size. Third, assessment of anesthesia costs (supplies, drugs, and labor) as "cost per unit" may allow more accurate benchmarking of anesthesia costs among hospitals. Fourth, our method of assessing anesthesia costs may help anesthesia providers during contract negotiations.

Ethics and Utility of Comparing Costs among Anesthesia Providers

The premise of developing a method to permit accurate review of anesthesia providers' financial performance is controversial. Comparing cost per unit among anesthesia providers neglects the issue of quality. Low cost per unit may be achieved in a way that decreases the quality of medical care provided to our patients. The development of and adherence to good practice guidelines may help to decrease variability in important aspects of patient care without sacrificing quality.[6] Variations in cost per case among anesthesia providers is a reasonable economic scorecard. Regardless of the development of practice guidelines, it is inevitable that health-care costs, particularly anesthesia costs, will be evaluated frequently. Our goal was to develop a method that was scientifically sound, relatively easy to use, and fair to most anesthesia providers, regardless of their casemix. Voluntarily using cost comparisons among anesthesia providers to evaluate the costs of care and develop physician-driven care pathways is important. Some might argue that it is better to avoid the whole issue. However, the alternative to leading the economic analysis of our practice and controlling costs in a logical manner may be more stringent limits to hospital formularies. The latter approach eliminates anesthesia providers' ability to give certain drugs, even when they consider them to be the best options for their patients. When costs are to be compared among anesthesia providers, having a simple way to reduce variations caused by casemix may be advantageous to our patients and our specialty.

It is important to recognize that comparing drug and supply costs among anesthesia providers may be an inefficient strategy to achieve large percentage decreases in perioperative costs. Costs of drugs and supplies are only a small percentage of total costs of anesthetic management. Labor costs (such as in the operating room and postanesthesia care unit) account for most of perioperative hospital costs. Labor costs account for an even greater percentage of total perioperative costs (such as including the salaries of the anesthesia providers and surgeons).[7] Although our method predicts costs of drugs and supplies, we strongly recommend that managers concerned with perioperative costs focus predominantly on labor productivity.

Can We Do Better than Using Cost per Unit?

Our priority in developing our method was that it be sufficiently simple that nearly every hospital could start using it immediately. Costs for anesthesia supplies and drugs were better described as cost per unit than as cost per case given the analyzed information from Duke University. Some hospitals may have demographic information that could be used to further adjust for variations in casemix. Calculating a separate cost per unit for each surgical service may be helpful (tables 3 and 4).

Comparison of Our Method with Controlling for Surgical Service

Comparing drug and supply costs among cases with the same surgical service may be an approach to controlling for variations in casemix. Our method has some advantages. First, stratification of cost per case based on surgical service requires that a hospital knows how costs are distributed among surgical services. To do so requires that one of two criteria are met. Either the hospital (1) only cares for patients undergoing one type of surgery or (2) has a sophisticated automatic record-keeping system to measure each case's costs for drugs and supplies. In contrast, to calculate cost per unit, hospitals only need to know their monthly costs for drugs and supplies. An automated record-keeping system is not needed. Second, some anesthesiologists work primarily with one surgical service (such as a practice limited to cardiac or ophthalmologic anesthesia). Cost per unit permits cost comparisons among anesthesiologists with different subspecialties. However, cost per case stratified by surgical service would not. Third, some surgical services include cases with a wide range of case complexity (such as general surgery). Cost per unit adjusts for such variations in patients' physical status. However, cost per case does not.

Conclusions

Costs for a case's anesthetic supplies and drugs were more accurately reported as "cost per unit" than as "cost per case." The adjustment of cost per case for variations in casemix has several applications, including (1) comparison of costs among anesthesia providers (even if their patients' physical status or surgical services do not completely overlap) and (2) comparison of costs among hospitals and anesthesia groups. Further, by design, anesthesia provider's labor productivity (which is more important financially than costs of anesthesia drugs and supplies) is well quantified by their ASARVS units. Together anesthesia costs (personnel, supplies, and drugs) are better reported as cost per unit than as cost per case.

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