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Methodological Issues in Explaining Maternal Outcomes

Anesthesia Provider Characterizations and Resource Variation

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Anesthesia provider models were characterized based on responsibilities and technique privileges and the distribution of clinical resource and process variables using a survey of 1,135 hospitals offering obstetric care in eight representative states. The resulting models were then analyzed by resource availability. In the 40% of hospitals where certified registered nurse anesthetists (CRNAs) and anesthesiologists both practiced obstetric anesthesia, three models emerged based on consistency of privileges within the institution and permission to initiate procedures. Hospitals in which only anesthesiologists practice and those in which CRNAs practice was most restricted had more resources than other hospitals surveyed. Traditional characterizations of provider fail to capture differences in technique privileges. Clinical resource variables and the scope of technique privileges should be included in the study of anesthesia provider credentials on outcomes.

Keywords: *research design; maternal outcomes; outcome assessment; anesthesia*

One of the major policy issues related to anesthesia's improvement efforts is the extent to which quality is affected by whether this care is provided by anesthesiologists, certified registered nurse anesthetists (CRNAs), or teams in which CRNAs are supervised by anesthesiologists (M. Kane &

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Smith, 2004). Although there are a number of published studies on this issue (Abenstein & Warner, 1996; Silber et al., 2000), the results are subjects of continued discussion because of design limitations (Fleisher & Anderson, 2002; Smith, Kane, & Milne, 2004). Resolution of these design issues will improve the soundness of the findings generated by this area of health services research. This study explores two limitations.

Anesthesia Providers and Quality

Smith et al. (2004), based on their extensive literature review, concluded that because of the lack of high-level primary evidence it is not currently possible to draw conclusions regarding whether there are differences in outcomes that are a function of anesthesia provider type. They described anesthesia provider characterization as one challenge to achieving this high-level evidence. Accurate specification of a variable is a minimum requirement of any study. For example, in a drug study comparing several agents, the drugs are carefully defined in terms of chemical composition, dosage level, and regimen. Failure to specify fully the agents' composition could result in a study in which conclusions were reached about relative efficacy when, in fact, some of the agents administered represented quite different chemicals. The same problem can arise in defining variables in health services research.

Some studies have used model definitions that involved describing a hospital as using only anesthesiologists, only CRNAs, or a blended or care team model (anesthesiologists and CRNAs; Pine, Holt, & Lou, 2003; Simonson, Ahern, & Hendryx, 2007). This method superficially captured the overall provider types but it largely left the care team members' respective roles and what Smith et al. (2004) termed *certified registered nurse anesthetist (CRNA) supervision* unexplored. Other studies have tried to link the provider of record to the case or to describe the cases not conducted by an anesthesiologist alone using a variety of terms and definitions. Among these have been designations of "supervised" or "medically directed," the latter being most common in studies using Medicare and Medicaid data (Hoffmann, Thompson, Burke, & Derkay, 2002; Silber et al., 2000). These approaches have limited ability to differentiate based on the conditions of CRNA oversight and of CRNA practice privileges. This gap raises the possibility that anesthesia provider type is a proxy for technique privileges (e.g., permission to initiate or deliver epidural anesthesia) or the need for hand-off events between anesthesia providers, factors that could influence maternal outcomes during the period when timely initiation of a specific technique is vital for better outcomes.

A classic eighteenth century clinical example of how proxy variables could lead to the wrong conclusion was the observation that malaria only occurred in areas where there was warm, moist air and that the air, therefore, caused malaria. The presence of pathogen carrying mosquitoes, which is highly correlated with this type of climate, was unmeasured. Modern science has relied on the randomized experimental-control trial approach to avoid this type of correlation-as-causation mistake. In health services research, the challenge in determining the impact of anesthesia provider type stems from reliance on nonexperimental designs that use data sets developed chiefly for accounting purposes. Although the use of nonexperimental designs is unavoidable, given the almost impossible task of random assignment of patients, the data sets used in such studies have limited or no information about clinical facilities, processes, and human resources. If a variable in the data set (e.g., anesthesia provider model) is highly correlated with unmeasured variables (e.g., number and type of nursing support personnel, availability of obstetrical operating facilities 24 hours a day, or transport times for emergencies), detection of a strong relationship between the measured variable and the outcome could lead to the wrong conclusion about causation.

In other words, the predictor variable (such as provider type based on billing records) that appears self-evident may, in fact, represent other anesthesia, nursing, and medical resources that in themselves influence outcomes. To date, the extensive measurement of facility, process, and human resource variables within a single study has not been reported. Determination of the extent to which resources are distributed by anesthesia provider models would be a first step in ascertaining if these unmeasured variables are a threat to interpretation of the results of commonly used research designs.

Purpose

To address these gaps, this article explores (a) descriptions of anesthesia provider models based on responsibilities and privileges and (b) the distribution of clinical resource and process variables by anesthesia provider model. The findings will enable researchers to design better studies and interpret results already obtained. The results may also guide policy makers who use the results of such work in resource allocation and regulation.

We focus this initial work on obstetrical care and obstetrical anesthesia because the labor, delivery, and postpartum service experience is fairly discrete. Moreover, maternal outcomes are often directly attributable to care during this period, making it theoretically more likely that outcome producing variables can be identified (Panchal, Arria, & Labhsetwar, 2001). Almost all care immediately before, during, and after a delivery is the domain of nursing, medicine (including obstetrics, gynecology, and maternal fetal medicine), and anesthesiology, making a targeted study possible. Beyond these design advantages, maternal outcomes deserve examination because although U.S. maternal deaths and long-term disability are exceedingly rare (Poole & Long, 2004), there is room for morbidity reduction among the almost 4 million U.S. women who give birth annually (National Center for Health Statistics, 2005).

Method

All data collection was accomplished in compliance with the investigators' institutional review board policies.

Sample

We selected eight states (California, Florida, Kentucky, Ohio, New York, Texas, Wisconsin, and Washington) from which to survey hospitals because of their ability (a) to represent regions of the country and rural and urban populations, (b) to provide variation in economic and health service organization variables, and (c) to submit outcome data against which the variables could be examined in a subsequent study. Every hospital that reported at least one birth on the American Hospital Association Annual Survey for 1999 ($n = 1{,}135$) was sent a survey.

Instrument Development and Pilot Testing

We constructed and pilot tested a survey of anesthesia, nursing, and obstetrical medicine processes and resources in three stages using R. L. Kane's (1997) multifaceted definition of treatment. Anesthesia was conceptualized as processes and resources related to the delivery of anesthesia during an obstetrical event. Medicine was defined in terms of processes and resources related to the delivery of a child, that is, the service provided by family practice physicians, obstetricians, and nurse midwives.

In Stage 1, more than 20 medical, nursing, and anesthesia providers drawn from 10 states participated in group and individual discussions of variables potentially influencing outcomes. The states were chosen to provide diversity in terms of geographic location, hospital character, and patient demographics.

Table 1
Resource Conceptualization and Variables

General Conceptualization	Variable Examples
Timing	
Onset to treatment	Transport time to emergency cesarean delivery
Setting	
Facility type or mission	Teaching status; obstetric level
Support services	Dedicated fetal monitor observer; quality improvement structures
Provider characteristics	
Quantity	Number of persons to assist with typical cases
Availability	Anesthesia provider in hospital continuously
Workload	Patients per registered nurse per shift; registered nurse concurrent patient assignment
Preparation	Labor and delivery nurse manager education; board certification of obstetric providers
Scope of practice	Medical delivery privileges; anesthesia privileges
Span of control	Number of unit managers for labor and delivery
Schedule	Length of shifts; call hours
Physical resource availability	Obstetric operating room open continuously; labor, delivery, and operating room on same floor; cesarean delivery facilities in labor and delivery area

The investigators developed items for each variable by service (nursing, medicine, and anesthesia). Table 1 describes the general variables considered with specific examples of each.

An important finding was the anesthesia clinicians' agreement that emphasis should be on procedural initiation, especially during cesarean deliveries (regardless of anesthetic delivery technique), because initiation best objectively described the degree to which CRNA supervision existed. For example, in some institutions a CRNA might not begin anesthesia for a cesarean delivery but may provide continuing care after initiation. Procedural initiation (spinal, epidural, and general anesthesia) privileges were also judged as important to maternal outcomes.

Sixteen anesthesia, nursing, and medical providers attempted to complete the resulting items in Stage 2. Individuals were debriefed to determine face validity, data availability, and perceived item relevance to guide further survey revision.

In Stage 3, 20 surveys were distributed using convenience techniques to identify remaining wording, content, and data retrieval issues and to whom the survey should be addressed. The address designation item was key because the survey asked questions about facilities, resources, and practices in what are typically three hospital departments (nursing, medicine, and anesthesia) that often do not have information about one another. Stage 1 and 2 participants had suggested a variety of address approaches (hospital president; nurse manager of labor and delivery with instructions to ask other departments for help in completing items; and sending sections of the survey to nursing, medicine, and anesthesia). Of these, 15 surveys were returned. Response burden concerns required item trimming that was based on (a) completion rates, (b) potential impact on maternal outcomes, and (c) representation of the general variable elsewhere in the survey. Participants indicated that the nurse manager of labor and delivery was most likely to respond for nursing and to work to insure completion by other sources. Subsequent testing (100 hospitals) indicated adequate response rates and item completion.

Instrument

The final version of the survey used in the study consisted of 20 items related to the presence and extent of obstetrical nursing and medical resources and 10 items related to obstetrical anesthesia. A forced-choice or fill-in format facilitated completion.

Survey Administration Procedure

The survey was sent to the nurse manager of labor and delivery, who was asked to forward the medical and anesthesia sections to the department chairperson (response rate 16%). Nonresponding hospitals were divided into three approximately equal-sized groups using a convenience technique: (a) those sent a traditional repeat mailing, (b) those for which specific survey sections were sent to the nurse manager and to the head of anesthesiology, and (c) those not immediately sent a second survey to allow assessment of response rates from Groups 1 and 2. The second mailing produced a 21.6% response rate from Group 1 versus 54% from Group 2. The remaining nonresponders from Groups 1 and 3 were then surveyed using the specific survey method. Data collection was completed in 2004.

Response Rate

After omitting the 22 hospitals that reported discontinuance of obstetrical services and those hospitals that delivered fewer than five babies per year, the overall response rate was 56.1% (n = 613). Almost half (47%) provided information about all services; 38% provided medical and nursing information only, and 15% provided only anesthesia information. Typical respondents for the nursing section were the nurse managers of labor and delivery and anesthesia department heads. The medical questions were usually completed by the medical staff office or the department of obstetric medicine.

Data Quality

Data were subjected to standard cleaning programs for outliers and selected repeated entry (detected coding error rate of less than 1%). With the exception of one subsequently omitted item (on-call hours of anesthesia providers), responses did not vary from expected parameters.

Results

Respondents

Based on the authors' analysis of the American Hospital Association Annual Survey data, the responding hospitals delivered 47% of all births in their states and approximately one quarter of all U.S. births in 2000. Responders were likely to conduct slightly fewer annual deliveries and were less likely to be identified as for profit than nonresponders.

The resulting data set was closely representative of the nation's hospitals. Of participating hospitals, 18% versus 21% of all U.S. hospitals providing obstetrical care were medical school affiliates. Of participants, 22% were government facilities, 65% were nonprofit institutions, and 13% were for-profit institutions. The national distribution is 24, 63, and 13%, respectively. Of participating hospitals, 30% were in a metropolitan statistical area, a figure similar to the 33% of U.S. hospitals. The mean number of annual births was 1,167 (SD = 1,304); in all U.S. hospitals the mean was 1,076 (SD = 1,300). The average number of obstetric beds in a participating hospital was 17; the average in all U.S. hospitals was 16.3.

Anesthesia Provider Characterization

Of hospitals that completed the anesthesia section, 5% indicated that the provider types or policies regarding cesarean deliveries differed between the main operating room and the obstetric delivery area. For example, only an anesthesiologist could deliver obstetric anesthesia in the main operating room but the CRNA may have these privileges in the delivery area, or CRNAs could begin a cesarean delivery in the obstetric room without an anesthesiologist present but could not do so in the operating room. These hospitals were labeled *mixed*. (Given their small number and mixture of technique privileges, this group was omitted from the resource analysis.)

Hospitals using one type of provider throughout the institution for obstetrical anesthesia were designated as “anesthesiologist (ANES)” (30%) or “CRNA” (30%). The remaining 35% of hospitals reported that obstetrical anesthesia was provided by anesthesiologists and CRNAs and that CRNA privileges were consistent across the institution. There were differences in privileges (defined as ability to initiate anesthesia at planned cesarean deliveries and initiate spinal, epidural, and general anesthesia) across these hospitals. After pattern review, we divided these hospitals into two groups based on CRNAs privileges to begin anesthesia at a planned cesarean delivery. This produced almost equal size groups: ANES-CRNA I (18% of respondents) in which an anesthesiologist was required and ANES-CRNA II (17%) in which no anesthesiologist was required.

Next we examined items related to technique privileges for all obstetric patients regardless of cesarean status. There was some variation in technique privileges in the ANES-CRNA I group. In 58% of these hospitals CRNAs were allowed to begin epidurals, in 78% the CRNA could begin general anesthesia, and in 65% they could begin spinal anesthesia for at least some obstetric cases. These privileges differences were not consistent enough to allow meaningful division into subgroups. The ANES-CRNA II group was more consistent and liberal in granting CRNAs privileges to begin specific procedures: 85% allowed CRNAs to begin epidural, 93% spinal, and 89% general anesthesia. It is not possible to tell what restrictions, if any, applied to the initiation of each technique. Chi-square analyses indicated significant ($p < 0.001$) differences between the two models in the granting of epidural and spinal anesthesia initiation privileges but not ($p = 0.095$) in the initiation of general anesthesia.

Other providers (attending obstetricians and family practice physicians) were more likely to be allowed to conduct epidural (10% versus 3%), spinal (7% versus 1%), and general (7% versus 1%) anesthesia in the ANES-CRNA I hospitals than in ANES-CRNA II hospitals. These low overall rates precluded their incorporation into model characterization.

Provider Characterization and Institutional Characteristics

The distribution of institutional characteristics varied by provider model characterization (Table 2). Sixteen percent of the ANES-CRNA I, 8% of ANES and 3% of the ANES-CRNA II hospitals were members of the Council of Teaching Hospitals. None of the CRNA and mixed hospitals were members. Of CRNA hospitals, 86% provided Level 1 obstetric services versus 50% ANES, 35% ANES-CRNA I, 51% ANES-CRNA II, and 43% mixed. ANES-CRNA I hospitals were most likely to provide Level 3 obstetric services (26%).

Chi-square analyses indicated significant differences ($p < 0.001$) in control, council of teaching hospital membership, obstetric service level, and location by provider model. There were differences in the distribution of anesthesia models by state, particularly in the relative distribution of ANES-CRNA I and II hospitals. For example, in Florida the ANES-CRNA I model accounted for 68% of hospitals in which both provider types practiced but nearly the reverse was true in Texas where 61% were ANES-CRNA II hospitals.

Based on the 2002 American Hospital Association data regarding reported births at participating hospitals ($n = 686{,}062$), 40.8% of all births occurred at anesthesiologist, 6.12% at CRNA, 26.06% at ANES-CRNA I, 23.67% at ANES-CRNA II, and 3.32% at mixed hospitals. A comparison of births with available obstetric beds indicated that there were significant ($p < 0.001$) differences in annual deliveries per obstetric bed by model characterization. The overall ratio of annual births to beds at anesthesiologist model hospitals was 96.1:1. The overall ratio at the other types of hospitals was as follows: 48.1:1 CRNA, 75.2:1 ANES-CRNA I, 71.7:1 ANES-CRNA II, and 69.7:1 mixed.

Anesthesia Provider Characterization and Resources

To maximize the ability to describe resources by model, medical and nursing responses from hospitals that had omitted the anesthesia section (38% of respondents) were analyzed. If respondents indicated that an anesthesiologist (never a CRNA) was present at a planned cesarean delivery and no CRNA was ever routinely present at any type of birth, the attribution was an ANES model. If only a CRNA was reported routinely present at a planned section and no anesthesiologist was reported as being present at this or any other type of birth, the attribution was a CRNA model. A report that an anesthesiologist and a CRNA were present resulted in an ANES-CRNA I model attribution. A report that that an anesthesiologist or a CRNA was present led to an ANES-CRNA II attribution.

Table 2
Anesthesia Provider Characterization and Hospital Characteristics

	Control %			No. Annual Births				State %							
Characterization	Government	Not for Profit	For Profit	<301	302-730	732-1570	>1570	CA	FL	KY	NY	OH	TX	WA	WI
ANES	14	73	14	7	31	25	37	63	18	13	55	24	17	31	17
CRNA	38	54	8	74	15	9	1	12	8	22	3	18	37	29	50
ANES-CRNA I	13	73	14	4	17	39	40	6	43	9	20	26	17	4	14
ANES-CRNA II	26	60	14	20	28	31	21	17	20	56	20	31	27	35	17
Mixed	13	69	19	—	25	44	31	2	13	—	3	1	3	2	3

Note: ANES = anesthesiologist; CRNA = certified registered nurse anesthetist. ANES-CRNA I is used to characterize an institution in which anesthesiologists and CRNAs provide obstetric anesthesia and an anesthesiologist must be present at the initiation of anesthesia for every patient undergoing a cesarean delivery. ANES-CRNA II indicates an institution in which anesthesiologist and CRNAs provide obstetric anesthesia and an anesthesiologist need not be present at the initiation of anesthesia, for every patient undergoing a cesarean delivery. Mixed is a characterization indicating differences in provider types and technique privileges based on delivery site (obstetrical area versus main operating room) within the institution. In ANES-CRNA I and ANES-CRNA II institutions, the provider types and technique privileges were consistent within the institution regardless of delivery site.

To test this method's validity, a random sample of hospitals that completed all survey sections was subjected to this procedure with a resulting 96% accuracy rate when the attributed model was compared to that based on anesthesia department responses. The resource analysis is based on 596 hospitals with variation in the respondent number for individual items largely based on whether the institution completed the medical and nursing sections.

Statistically significant differences in resources by anesthesia provider characterizations were noted for some resources and processes (Table 3) but not others. Examples of the latter include presence of a dedicated fetal monitor observer; location of labor, delivery, and the operating room on the same floor; presence of a maternal intensive care unit; single management structure for labor and delivery; advanced neonatal life support certification required of delivery room registered nurses (RNs); 12-hour RN shift schedules; anesthesia staff weekend scheduling for more than 23-hour shifts; number of patients assigned concurrently to a labor and delivery RN; number of patients assigned to an RN per shift; the percent of total nursing hours supplied by RNs; and the number of personnel present at a vaginal delivery.

Post hoc analyses (Tukey's method) of the continuous variables attaining statistical significance indicated that the CRNA-only and ANES-CRNA II institutions had a significantly lower percentage of providers certified in obstetric medicine than did ANES and ANES-CRNA I hospitals. CRNA-only institutions had a significantly lower average number of personnel at planned cesarean sections than did any other hospital type. ANES model hospitals had significantly fewer personnel present for this type of delivery than did the ANES-CRNA I and ANES-CRNA II institutions. At emergency cesareans, CRNA-only hospitals had a significantly lower average number of personnel present than did ANES and ANES-CRNA I institutions. The dichotomous resource and process variables results (Table 3) also indicated that, for most variables in which there was a significant difference by provider type, CRNA-only hospitals were less likely to possess the resource. Two exceptions were advanced cardiac life support requirements for delivery room RNs and physicians.

Discussion

The Characterization of the Anesthesia Provider

The results strongly suggest that the traditional care team and supervision definitions fail to capture a small (5%) group of hospitals in which privileges vary by clinical setting within the hospital (mixed hospitals) and,

Table 3
Anesthesia Provider Characterization and Resources Significantly Different Among Groups ($p \leq .05$)

Resource or Process	Provider Characterization (% Reporting Resource Available)			
	ANES	CRNA	ANES-CRNA I	ANES-CRNA II
Continuously open obstetric operating room	79	49	85	71
Anesthesia provider in hospital continuously	31	12	47	20
Nonemergency cesarean deliveries performed in labor and delivery	72	34	87	65
Masters-prepared nurse manager	19	8	25	14
ACLS required of delivery room RNs	37	59	28	31
ACLS required of medical doctors	23	67	18	34
Neonatal resuscitation certification required of medical doctors	60	76	61	63
Obstetric area training site for				
Nurse midwifery students	10	3	17	15
Nursing students	35	19	16	27
Residents	22	16	42	21
Obstetric specialty residents	8	3	17	9
Obstetric fellows	5	1	16	4
Anesthesiology residents	13	2	15	4
Nurse anesthetist students	0	7	19	10
Anesthesia staff ≥ 24-hour shifts (weekday)	48	46	18	19
	M (*SD*)			
No. personnel at planned cesarean delivery	3.7 (1.3)	2.9 (2.0)	5.5 (1.4)	6.0 (1.6)
No. personnel at emergency cesarean delivery	3.9 (1.0)	3.4 (1.2)	4.1 (1.4)	4.0 (1.3)
% providers certified in obstetric medicine	70 (29)	44 (42)	68 (30)	60 (32)

Note: The number of personnel at the two types of deliveries listed in this table do not include the physician or nurse midwife conducting the delivery. ANES = anesthesiologist; CRNA = certified registered nurse anesthetist; ACLS = advanced cardiac life support; RN = registered nurse working in the labor and delivery area. Chi-square was used to test statistical differences of categorical variables. Analysis of variance was used for continuous interval variables. Only variables that were significantly different at the $p \leq .05$ level are included in the table.

perhaps more important, cannot detect marked differences in CRNA privileges in the 35% of hospitals using both CRNAs and anesthesiologists and having consistent policies across the institution. This supports Smith et al.'s (2004) assertion that supervised CRNAs may in fact be working under very different conditions. Moreover, the traditional methods do not capture the agent delivery methods (epidural, general, spinal) open to the CRNA in these hospitals. If the ability to initiate a procedure and deliver a variety of anesthesia methods in a timely way without needing to delegate care to another anesthesia provider directly influences outcomes, traditional provider characterizations cannot help explain outcome variation because they fail to discriminate between two major aspects of procedural privilege: to begin anesthesia at certain events and to choose from the full variety of anesthesia delivery methods. An example concerns women who suddenly develop the need for cesarean deliveries. Hospitals A and B use anesthesiologists and CRNAs in the delivery area. At Hospital A, a CRNA present at a delivery is not allowed to initiate the anesthesia technique required for a cesarean delivery but at Hospital B the CRNA is allowed to begin the procedure. Even a short initiation delay necessitated by the need to locate and orient an anesthesiologist to the case could result in poorer outcomes at Hospital A given the importance of timely intervention. Both hospitals would be classified as a team model if the traditional designation practice was used, leading to errors in determining the outcome causality.

The finding that the ANES-CRNA I and ANES-CRNA II models vary in distribution by state suggests caution in designing single-state studies that define hospitals that rely on both types of providers as team or supervised. There is a risk that these models represent very different procedural privilege sets.

A limitation of this study's provider characterization is that it accounts for the initiation of only three types of anesthesia delivery techniques and one (albeit major) obstetrical event that requires anesthesia. Future studies should collect information concerning management after initiation and about other obstetrical events. More models might emerge, especially in the ANES-CRNA I group where we observed that some initiation privileges varied but could not further classify them because of sample size issues. Future studies should examine an expanded list of individual provider process variables that were omitted from this project because of response burden issues.

The wide differences in resources by model suggests that future studies might identify the cause of such differences, especially given current national concerns about service disparities. One possibility might be the extent to which anesthesiologists are able to influence resource acquisition. Other possibilities include volume and obstetric service level.

Design and Interpretation of Outcomes Studies: Resource Distribution Patterns

Because of the finding that some clinically relevant resources are not equally distributed across anesthesia models, the results suggest that the attribution of large differences in outcomes like mortality to anesthesia provider type be made only when the research design addresses these resources (Fleisher & Anderson, 2002). Including these variables may be realistic if the research community works to influence state, federal, and accreditors' database requirements. An expanded database is more expensive but would result in more accurate results, an important consideration given the data's use in policy making.

These recommendations assume that the field will continue to conduct retrospective studies. Such approaches are necessary not only because of their cost and time advantages but because randomized control trials, the best ways to establish causality, are not feasible. The facility with which results from retrospective studies can be extrapolated to estimate lives saved and complications avoided is also appealing. There are many threats to correctly ascribing causality within retrospective studies beyond the two examined here (Cram, Rosenthal, & Vaughan-Sarrazin, 2005; Fleschler, Knight, & Ray, 2001; Hendryx & Teague, 2001; Iezzoni, 1997; Lee et al., 2005; Romano et al., 1995) but inclusion of resource relevant variables and the use of more sophisticated statistical models are interrelated design improvements. The inclusion of resource relevant variables would enable researchers to plan multilevel analyses such as those used in education and sociology (Goldstein, 2003). In education, such an approach allows one to determine if the best opportunities for quality improvement are at the student, classroom, or school level.

This study's results indicate that hospitals with greater numbers of deliveries are more likely to have many resources. In other words, volume and resource availability may be proxies for one another. Interpreting the association of outcomes and volume as causal without taking into account the relationship between volume and other resources can result in inappropriate or misleading conclusions. Many health care studies have examined the volume-outcome relationship in terms of diagnostic accuracy, surgical outcomes, and radiographic readings (Al-Khatib, Lucas, Jollis, Malenka, & Wennberg, 2005; Dimick, Cowan, Colletti, & Upchurch, 2004; Westvik et al., 2006). A common hypothesis in these studies is that volume is a proxy for staff expertise. Absent a randomized control trial, determination of the individual contributions of volume, anesthesia provider characterization and resource availability in explaining anesthesia outcomes requires a multilevel approach with preliminary causal modeling.

Research designs other than regression analysis of large data sets should also be considered. Work using simulators and observations in naturalistic clinical settings may better establish the elements that lead to favorable outcomes (Weinger, Reddy, & Slagle, 2004; Weinger, Slagle, Jain, & Ordonez, 2003). Use of these approaches could lead to the heart of what many would like to know: how to improve outcomes. In the interim, providers, professional organizations, and regulators need to be cautious in interpreting retrospective studies' results.

Another next step is to determine if the characterizations explain variation in maternal outcomes. Of special interest are hospitals that have multiple resource deficiencies. The effect on outcomes in these hospitals may be other than additive necessitating the creation of alternative variables that capture these situations. In addition, processes and resources may influence outcomes differentially. A study that includes infant outcomes could help determine this possibility because much of obstetrical care influences the mother and child simultaneously.

For now, studies of the obstetric anesthesia provider model that affect outcomes need to be acted on cautiously if at all. Our results are limited to obstetrical situations. Provider characterization and the determination of relevant resources and processes would be required anew before examining care outside this service area.

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