ANESTHESIA CARE TEAM TYPE AND HOSPITAL CHARACTERISTICS: ARE INCREASED LEVELS OF SUPERVISION ASSOCIATED WITH DIFFERENT ACUITIES AND OUTCOMES?

by

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ABSTRACT

IAN HEWER. Anesthesia care team type and hospital characteristics: are increased levels of supervision associated with different acuities and outcomes? (Under the direction of DR. CHRISTOPHER BLANCHETTE and DR. MICHAEL DULIN)

Anesthesia care in the United States is provided by a number of different practice models, that could involve nurses, physician's assistants, and physicians working in teams or alone. Much of the variation in care models evolved over time based on tradition, experience and political influences, rather than by design using evidence and cost-effectiveness analysis. In recent years, there has been increasing adoption of a team care model that requires less direct supervision from an anesthesiologist, as opposed to a physician led, medically-directed model. This model has lower labor costs, since it requires fewer, high-cost, anesthesiologists. In addition, this model allows for more flexible assignment of practitioners, based on the patient's risk. This dissertation analyzed the patterns of distribution across different hospital sizes and types, and 4 different care models: (i) all physician providers; (ii) a high physician supervision model; (iii) a low physician supervision model; and (iv) all nurse anesthetist. Nurse anesthetist only practices are heavily centered around small, rural hospitals, whereas most other models are found in large, urban areas. Both surgical complexity and comorbidity scores were higher in physician or physician-led groups, but by very small margins. Analysis of 48 hour mortality showed higher death counts by hospital for large and teaching hospitals, and either supervised model. Overall differences between surgical complexity, comorbidity, and perioperative mortality sometimes attributed solely to anesthesia models, are significantly related to hospital level characteristics, regardless of the provider.

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LIST OF ABBREVIATIONS

AHRQ: Agency for Health Care Research and Quality

AAAA: American Academy of Anesthesiologist Assistants

AHA: American Hospital Association

ASA: American Society of Anesthesiologists

AANA: American Association of Nurse Anesthetists

AA: Anesthesia Assistant

ACT: Anesthesia Care Team

CDC: Centers for Disease Control

CCI: Charlson Comorbidity Index

CRNA: Certified Registered Nurse Anesthetists

DRG: Diagnosis-Related Groups

HMO: Health Maintenance Organizations

ICD-9: International Classification of Diseases, Ninth Revision

NC: North Carolina

PSI: Patient Safety Indicators

RBRVS: Resource-Based Relative Value Scale

RVU: Relative Value Unit

TEFRA: Tax Equity & Financial Responsibility Act

US: United States

UNCC: University of North Carolina at Charlotte

VA: Veterans Administration

CHAPTER 1: INTRODUCTION

1.1 Historical background and development of billing policy

Despite the fact that the first demonstration of anesthesia in 1846 was by a dentist, at a renowned medical school, the practice of anesthesia in the late nineteenth and early twentieth centuries was largely in the hands of nurses. Explanations for this depend largely on the perspective of the narrator, but it seems clear that anesthesia was not considered a complex specialty deserving of physician attention, and a shortage of reliable providers were two of the most likely explanations. During the years following the discovery of ether, the job of providing anesthesia fell to anyone available at the time of surgery, and had little consistency (Bankert, 1989). Initially, that might fall to a medical student, or surgical resident, but there were also anesthesia technicians, who may or may not be nurses (Gunn, 1991). Any such nurses were unlikely to have received formal training, but instead would learn apprenticeship-style. It seems puzzling that a technique that was undoubtedly very dangerous was able to take root with only untrained and unskilled workers responsible for its administration. Perhaps some of the reasoning for this could be attributed to a factor that continues to this day, the pursuit of revenue. In the nineteenth century (and even beyond), it was rare for the anesthetizer to be paid anything for their services. Typically, a fee would be negotiated with the surgeon, who could choose to share a portion with the provider of anesthesia, but did not have any obligation (Bankert, 1989). Given the lack of income associated with anesthesia, it could be expected to hold little interest for a medical student or physician, except as a means to observe surgical techniques. In fact, it was not until the late 1920s that Ralph Waters set up the first academic department of anesthesiology at the University of Wisconsin (Bacon & Ament, 1995).

Nurses were an obvious choice as a reliable, trained, and possibly most importantly, salaried by the hospital, hence provided at no cost to the surgeon! Both Thatcher (1953) and Bankert (1989) have described in detail the contribution of nurses to the development of anesthesia in the late nineteenth and early twentieth century, but particular note is made of the work of Alice Magaw at the Mayo Clinic in Rochester, Minnesota. Magaw published a series of papers describing her work, culminating in 1906 with a review of over 14,000 anesthetics without an associated death, a remarkable achievement for that time (Magaw, 1906).

Thus, from the late 1800s to the early twentieth century, nurses gradually became the dominant provider of anesthesia services, although physician and non-trained providers continued to exist until after the Second World War. Although there were increasing numbers of nurses in the field, education continued to be sporadic, and inconsistent from facility to facility. According to Gunn (1991), plans to start a national training for nurse anesthetists were derailed by the start of the First World War, but interestingly, the military sent nurses for short intensive courses on administration of anesthesia at the hospitals with established training prior to being sent to the European theater.

The first formal anesthesia program for nurses was started in Oregon in 1909, and many others followed. Although basic standards for anesthesia training were set out by the AANA in 1935, it was not until 1945 that the first national certifying exam was given. The incremental advances in educational standards accompanied a difficult external environment, in which physicians and nurse anesthetists were increasingly at loggerheads over who "owned" the right to give anesthesia. This resulted in a series of lawsuits, essentially all of which were decided in favor of nurse anesthetists, and an alliance with the AHA who were likely concerned about a loss or drop in the number of anesthesia providers, should the legal status of nurse anesthetists change. Interestingly, physician anesthesiologists were also involved in a battle to be recognized as a specialty by their own profession, which followed a similar trajectory as nurse anesthetists, the establishment of educational programs and a national certification exam, the first of which was offered in 1937 (Waisel, 2001).

Following the Second World War, there was significant growth in the number of anesthesia residency programs, as well as nurse anesthesia training. Indeed, between 1940 and 1960, there was an approximately 400% in the number of nurse anesthetists, and a 600% increase in the number of physician anesthesiologists (Waisel, 2001). The dramatic increase in health insurance coverage, as well as increased hospital capacity was likely the root cause, due to the increased number of anesthetics being administered and hence need for more providers. However, despite the increased number and status of anesthesiologists, it was not until the 1960s that they began to follow the more traditional physician path of independent billing & practice. In the 1950s, most were salaried employees of a hospital, and it took aggressive maneuvering by the American Society of Anesthesiologists to persuade recalcitrant members to campaign for independent practice (what Curry [2005] calls "union tactics).

At some point from the 1950s to 1970s, there was a realization by the ASA that physicians could not administer all anesthetics without nurse anesthetists. In addition, it was clear that supervision of nurse anesthetists, a term which can have many meanings depending on who is using it, could be an additional source both of income and control of CRNAs (J. Cromwell, 1999). With this in mind, it is perhaps not surprising that after a period in which the apparent aim of anesthesiologists was the elimination of all nurse anesthesia training programs, there was a shift to the 1982 Statement on the Anesthesia Care Team (ACT), in which ASA established a position that there should always be an anesthesiologist involved in any anesthetic, which continues to this day.

Perhaps the ACT statement was an implicit recognition of what was to come in 1986, the establishment of the right of independent CRNAs to bill directly for anesthesia services. Additionally in the 1980s came another piece of legislation that directly affected anesthesia reimbursement, the TEFRA of 1982. TEFRA established guidelines for supervision of nurse anesthetists that ultimately capped reimbursement for a physician and CRNA working together at the same fee as either provider working alone. It also essentially established a new model of anesthesiologist supervision called medical direction, in which certain minimum standards were required, or reimbursement for the physician would drop dramatically. Interestingly, as Fassett and Calmes (1995) point out, the standards were not based on any objective analysis of data, instead likely arose from the ASA ACT definition. In their study of 358 anesthetics over a 4 week period at a single institution, both providers frequently felt that the standards were onerous, and unnecessary for more than 70% of cases. J. Cromwell and Rosenbach (1988) pointed out that a comparison of case complexity, as measured by anesthesia base units and modifiers, showed that there was little difference between anesthesiologists working alone, and those supervising multiple CRNAs. This would imply substitutability of providers, but economically speaking, the cost of an anesthesiologist is significantly higher. They also note the dramatic increases in the number of anesthesiologists, but a concurrent increase in the pay both absolute, and hourly, relative to other physicians, and significantly higher than the increase in the amount of surgery.

Another trend that was of great importance in the 1980s was the flattening out of growth in nurse anesthetists for the first time since the inception of the profession. Unsurprisingly, this was a direct result of the closure of many schools during this period, with a drop in graduates from 1100 to 600 in the mid 1980s (Gunn, 1991). The reasons for the dramatic drop were likely twofold: firstly, the change to tighter control of hospital reimbursement following enactment of the Prospective Payment System in 1983 resulted in pressure on hospitals to cut costs. Since many nurse anesthesia schools at that time were hospital-based, it was perceived by some as an unnecessary expenditure to maintain teaching staff. In addition, increasing numbers of anesthesiology residents resulted in displacement of nurse anesthesia students from academic medical centers, although there was little thought as to whether this was ultimately the most logical use of limited resources to train a more expensive provider (J. Cromwell, 1999).

The shift to a workforce with increasing numbers of anesthesiologists was not too last: by the mid 1990s, with health care costs continuing to escalate, there was a shift in priorities for the Federal Government, and the rise of managed care, both of which exerted downward pressure on anesthesiologists. Firstly, the decision of the Government to shift resources towards the training of primary care physicians, was a dramatic disincentive to graduating medical students to enter anesthesia. When added to drops in reimbursement associated with managed care, and the specter of a national health care system raised by the new Clinton presidency, the result was a precipitous fall in the number of domestic applicants to anesthesia residencies, and suggestions to cut back on training slots nationwide (Reves, Rogers, & Smith, 1996). Concurrently, CRNA graduates were already at a low level following the closures of the 1980s, however, by the 1990s, manpower forecasting suggested a need to increase supply significantly over the next twenty years (J. Cromwell, Rosenbach, Pope, Butrica, & Pitcher, 1991).

Essentially, the need to increase services and forecasts of personnel needs depended on which model was perceived as appropriate. Of course, those affiliated with anesthesiologists leaned towards models that had low ratios for physicians supervising CRNAs, and continuing solo practice MD providers contained within them, whereas CRNA affiliated groups suggested CRNA heavy workforces. Hence, predictions varied considerably. However, the reality was that there had never been any systematic calculation of the optimum mix of CRNAs and anesthesiologists, or even of the need for supervision at all (Jerry Cromwell & Snyder, 2000). As the provider market lurched between shortage and surplus during the 1990s, bitter opposition between the two camps persisted, basically continuing along the lines of quality vs cost that had originated in the early days of the explosion of anesthesiologist supply.

Interestingly, during the late 1960s, a new anesthesia provider called an anesthesiologists' assistant (AA) was created by the physicians that had similar characteristics to CRNAs, except it was explicitly designed through training and licensure to be only permitted to practice under the direct supervision of an anesthesiologist. In addition, nurse training and clinical experience was not required as a precursor to entry into AA school. Reimbursement is identical to CRNAs, with the significant exception that they can only bill using the medical direction model with a maximum ratio of 4 AAs to one anesthesiologist. The spread across the US has been successfully contested by CRNAs, as they are seen as a direct competitor. Currently, there are about 2000 AAs in the US compared with more than 50,000 CRNAs, in addition to which they are only permitted to practice in 16 states (AAAA, 2018).

During the 1990s, there was increasing realization that health care costs in general were again in danger of spiraling out of control. Managed care and the onset of HMOs had temporarily restrained costs, but now double digit inflation was commonplace; both politicians and health care economists alike were looking for techniques to manage costs, which typically involved decreased reimbursement. In addition, there was the beginning of an increased share of patients who were uninsured or reliant on government payers that lowered overall rates of recompense for providers. Navarro (1985) reported that the Government proportion of health expenditure was 42.7%, but by 2016, Himmelstein and Woolhandler (2016) reported that share had increased to 64.3%. In the case of anesthesia, one way to increase revenue in the face of lower income was to change the model of delivering care. From the anesthesiologists' perspective, regardless of whether they employed a nurse anesthetist or not, directing an increased number would result in higher income, since the physician retained 50% of the fee for each anesthetic, so simply increasing the ratio of supervision could add revenue. However, since Medicare reimbursement is currently approximately one third that of private payers, simply increasing the number of CRNA employees relative to physicians may not be enough to compensate for the loss of income. In addition, physician groups attempting to decrease supervision in a medical direction model, face onerous requirements that recent work has shown are almost impossible to meet even at a sub-maximal ratio of 1:3 (Epstein & Dexter, 2012). Failure to comply with Federal regulations risks multimillion dollar liability if detected.

One solution to this problem of attempting to increase supervision ratios while maintaining compliance, is to change from medical direction to QZ team billing. In this arrangement, the billing is 100% for the CRNA, with no proportion going to the physician, similar to an all-CRNA group working under the "supervision" of a surgeon. By transitioning to this form of billing, there are no rules regarding the involvement of an anesthesiologist, since they are not requesting reimbursement. The CRNA can work independently, or with an anesthesiologist, but neither approach is required. Given the economic pressures resulting from increasing share of governmental payors, it is unsurprising that this model is becoming increasingly popular (Byrd, Merrick, & Stead, 2011; Quraishi & Jordan, 2017). From the perspective of the professional associations, the response is mixed as the previous two authors illustrate. The physician viewpoint shows concern for an increased role for nurse anesthetists, with at minimum an implication that the role of an anesthesiologist is not required (Byrd et al., 2011). The CRNA approach applauds the increased involvement in anesthesia cases, but downplays the likely cause- increased physician/CRNA teams (Quraishi & Jordan, 2017).

Although the QZ team approach has the potential to increase billing for a single employer of both providers, if the physicians and CRNAs have different employers, it can be problematic. For example, a common employment arrangement is for the CRNAs to be hospital employees, and the physicians to have a separate group. In this case, using QZ billing could result in zero revenue for the physician group, with all the income going to the employer of the CRNAs, in this case the hospital. By comparison, if medical direction is used, the physician gets 50% of the revenue for each case, and the CRNA employer gets the other 50%. Thus, QZ billing would likely be associated with a single employer of both providers in the practice setting, whether that be the facility or an external corporation. Recently, there has been increasing consolidation apparent in the profession, with the formation of large, multistate groups, as well as an increase in the number of hospitals employing anesthesiologists (Maccioli & Johnstone, 2010). This consolidation increases the ease of transitioning to a QZ team billing approach.

Another solution to maintaining income is to seek another source apart from the patient. Increasingly, it has become common for anesthesia groups to be subsidized by the facility to provide coverage to a specified volume/time range of cases. Koch and Calder (2011) reported that in 2000, hospitals had started to provide subsidies to anesthesia groups, but by 2005, every hospital surveyed by ASA was giving one. Galinanes (2012) suggested subsidies of "up to $120,00 per anesthesiologist", O'Neill (2017) quoted $160,00 per full-time anesthesiologist. Reducing the number of anesthesiologists such as would accompany a QZ team model, could potentially decrease the subsidy required from an employer to maintain a fully functional operating room. Given both of these factors in the context of ongoing downward cost pressure, it is unsurprising that QZ billing is increasing in frequency.

1.2 Surgical complexity

By the end of the 1970s, it was becoming clear that surgical volume in the United States had increased dramatically without any significant control over its expansion, which led to questions over both necessity and quality (Blendon, 1971; Luft, 1980; C. B. Schoonhoven, W. R. Scott, A. B. Flood, & W. H. Forrest, 1980). Concurrently, hospitals and researchers were struggling to quantify more precisely the relative complexity of differing patients, by taking into account differing treatment options and acuities for the first time, in order to make better comparisons between providers and treatments. The development of the DRG system established a precise, encompassing system that could be used for precisely that purpose (Fetter, Shin, Freeman, Averill, & Thompson, 1980). Previous classification systems made little allowance for different treatment options for similar diagnoses- for example, surgical versus medical management of gall bladder disease- that could have significant effects on resource utilization in the hospital setting. Although this was a pioneering tool for an overall view of the patient population, it gave little attention to the surgical population specifically.

In order to analyze the necessity and quality of increased surgical volume, a way to measure surgical complexity was important. A suitable algorithm could serve both as a method to determine resource allocation, as well as a controlling factor when comparing outcomes. At this time, the existence of specialty training implicitly acknowledged that higher levels of education were required between disciplines, but there was incomplete knowledge and inconsistent assessment of specific operations. In a very interesting early work, Schoonhoven et al (1980) formulated an early approximation of complexity by simply surveying over 900 surgeons' and post-surgical nurses' opinions of a group of common surgeries. They focused their attention on complexity and uncertainty, and were also unique in their use of nurses as well as surgeons to attempt to quantify these categories. This followed the approach of Blendon (1971) in an earlier study.

In general, this technique of using expert opinion to determine the complexity of surgery, has continued essentially unchanged conceptually, although the method of collecting and perhaps analyzing data may have varied somewhat. Despite not being designed specifically for assessment of surgical complexity, the development of the Resource Based Relative Value Scale (RBRVS) in the late 1980s (Hsiao, Braun, Dunn, & Becker, 1988), was a similar idea. The scale was developed in response to a mandate from the Federal Government, in response to the rapid increase in both cost and volume of medical services. Using expert panels and mail surveys of physicians, the researchers established estimates of time required, and relative degree of expertise for a variety of services, using an inguinal hernia repair as a baseline constant to compare to other procedures. In the same issue of JAMA, Braun, Yntema, Dunn, and et al. (1988) compared different specialties by using “linking procedures” that made connections between different groups.

While not designed to measure surgical complexity per se, RBRVS were an intuitive proxy, since they were an attempt to quantify physician workload. Specifically, the work Relative Value Unit (RVU) portion of the total has been used by researchers as a substitute for complexity. Davenport, Henderson, Khuri, and Mentzer (2005) used work RVUs and NSQIP data to examine outcomes and costs, finding that work RVUS alone predicted 23% of total hospital costs, perhaps not surprising of itself, but interestingly, when combined with preoperative risk factors were a better predictor than complications. Similarly, Little et al. (2006) found an association between RVUs and operative time, although they did not report on outcomes, which could be considered more significant. A series of papers using early data from the National Surgical Quality Improvement

Program (NSQIP) found correlation between a number of different surgical complications and RVUs (Johnson et al, 2007; Neumayer et al, 2007; Virani et al, 2007). However, Shah et al. (2014) found poor correlation between RVUs and length of stay and operative time, and only moderate correlation with outcomes. Interestingly, they also used data from NSQIP, although with some methodological differences including removing patients who had complications when examining relationship between length of stay and RVUs.

Another similar, but perhaps more standardized, approach to assessing complexity has been developed by the Veterans Administration (VA), mostly in response to a need to allocate resources to hospitals that perform the most complex surgeries (Khuri et al., 1995). In this case, a group of specialists was asked to rank a subset of index operations into one of five categories, ranging from 1-5, where 5 was the most complex. This data was then used in combination with other preoperative factors to examine outcomes across the VA system. In two concurrent studies that looked at mortality and morbidity respectively, operative complexity assessed using this scale had little association with mortality, but had significant association with morbidity (Daley et al., 1997; Khuri et al., 1997). The studies were conducted in all 44 VA Medical Centers at the time, yielding a total of 87,078 non-cardiac procedures for analysis. Odds ratios for predicting mortality and morbidity for all operations were 1.36 (1.28-1.45) and 1.66 (1.61-1.70) and respectively, which was from low-moderate ranking when compared to other predictive variables, such as serum albumin. This early work at the VA became the basis of the National Surgical Quality Improvement Project (NSQIP), and was an important factor in the improvement of overall mortality and morbidity in the 2000s . Subsequently, it was adopted by the American College of Surgeons (ACS), and has been widely integrated into use nationally.

Though designed to help allocate more complex surgeries to resource-rich hospitals, the VA complexity matrix has also been used to as a controlling factor in research looking at surgical complexity and outcomes. Studnicki, Craver, Blanchette, Fisher, and Shahbazi (2014) examined a group of non-VA hospitals in Florida using the matrix, and found that there was appropriate stratification of complex surgery in the private sector, with smaller hospitals generally associated with less complex caseload. Only about 5% of the total discharges for that year (2009) involved complex surgery, but almost 50% of those were at hospitals in the fourth quartile. (Hospitals were split into quartiles based on the number of complex procedures). In further analysis, the researchers found no statistically significant differences in mortality rates between small and large hospitals, though length of stay was longer at fourth quartile centers. However, this was with the caveat that mortality rates were only compared across hospital quartile when the procedure was carried out at both institutions. Since there were few complex procedures performed at first quartile facilities, this limited the number of comparisons. In similar work, Aust, Henderson, Khuri, and Page (2005) found that operative complexity (derived from the VA system) accounted for part of the predictive capacity for perioperative complications, though patient factors were the larger influence.

It is well established in the anesthesia literature that the risk of perioperative complications that could be ascribed to anesthesia are increased with certain types of surgery. For example, the rate of myocardial infarction is significantly higher in the vascular surgery population than the general surgical one (Bursi et al., 2005).

Individually, providers consider this as part of their preoperative assessment of a patient, but there is no specific risk scoring related to surgery. However, although it is not used clinically, the method of billing in anesthesia has potential to be used as a proxy measure. As in other medical specialties, anesthesia is assigned a Relative Value based on the amount of work involved in performing the service, which in general terms is tied to specific surgeries. In anesthesia, this value is given in units, the unit being the basis of reimbursement by both private and Government insurance. The total number of billable units is derived from the sum of time units (one per 15 minutes) and base units (vary according to the surgical procedure). Given that base units are assigned based on the complexity of the surgery, they have been used by researchers as a proxy for surgical complexity. Dexter, Macario, Penning, and Chung (2002) used base units as a method to determine appropriate cases for a new outpatient surgery center, as a method to avoid high complexity cases. Dulisse and Cromwell (2010) examined 481,440 hospitalizations from Medicare data to compare different anesthesia providers. They found minimal difference between the incidence of mortality and complications, but found that anesthesiologists working alone had about one point higher base units per case, when compared with nurse anesthetists. They hypothesized that physicians were more likely to work in major urban centers, which in turn had increased likelihood of more complex surgery. In pragmatic terms, when examining anesthesia data, the ability to abstract base units from the same file as is used for other anesthesia modifiers has the potential to simplify data collection and analysis.

Closely tied to the concept of surgical complexity, is the existence of preexisting disease, and its relationship to perioperative morbidity and mortality. The likelihood of post-surgical morbidity is known to be related to pre-existing problems, but methods to assess this risk quantitatively have been varied in the anesthesia literature. There are a number of risk assessment tools for specific complications, such as the Goldman scale for non-cardiac surgery (Goldman et al., 1977), or the renal risk composite (Aronson et al., 2007), but these are useful only for specific system pathologies. Thus, in anesthesia literature, one is left with few available options for comparing perioperative morbidity.

For administrative data analysis in general, the Charlson Comorbidity Index (CCI) has been widely used since its introduction in the 1990s (Charlson, Szatrowski, Peterson, & Gold, 1994). The score is calculated from 17 conditions (original study called for 19), which each have weighted point assignment. With the advent of computerized database analysis, this task has become relatively straightforward, leading to variations on the original scoring algorithm (Quan et al., 2005). Results from this coding can then be used to stratify populations being studied, since higher scores are associated with increased risk of death (D'Hoore, Bouckaert, & Tilquin, 1996). Although not specifically designed for the perioperative population, it has been used successfully to predict poor outcomes (Froehner et al., 2003; Moodley, 2016). One disadvantage of the CCI, is its relatively restricted number of controlling variables; an alternative that takes account of this problem is the Elixhauser system (Elixhauser, Steiner, Harris, & Coffey, 1998). In this approach, there are 30 conditions that are used to adjust for population comorbidities; this increases potential accuracy, but can create difficulties with statistical modelling if there are not enough subjects to populate the conditions. van Walraven et al. (2009) created a scoring index as an alternate approach that is a useful alternative to CCI as a risk adjustment method, that with further testing could prove to be superior to Charleson's original approach.

A final algorithm that has been used for assessment of preoperative comorbidity, is the ASA Physical Status classification, originally designed in 1941 to act as an indicator of relative risk from anesthesia (Saklad, 1941). Froehner et al. (2003) found it was at least comparable to CCI as a predictor of survival after prostatectomy. Rauh and Krackow (2004) saw an association between postoperative mortality and ASA Class in elective arthroplasty surgeries. Hopkins et al. (2016) reported an association between perioperative mortality (48 hours) and ASA status, although differentiating between different classifications and relative risk was not undertaken. However, although ubiquitous in the profession, it is notoriously subjective, and has few objective guidelines for the provider to classify patients, so not surprisingly has only moderate inter-rater reliability (Sankar, Johnson, Beattie, Tait, & Wijeysundera), and hence is of limited use in large database analysis.

1.3 Outcomes

The analysis of outcomes has become increasingly vexing for anesthesia researchers over the last 50 years. What initially was a fairly clear cut question, focused around mortality rate, has developed into a complex array of imperfect measures, for two major reasons. Firstly, the dramatic increase in safety in the field has yielded substantial gains in mortality and morbidity across the spectrum. Secondly, the difficulty of separating what is an anesthetic complication, and what can be attributed to surgical risk is incompletely resolved.

From the advent of anesthesia in the late 19th century, it was clear that there was significant risk associated with surgery, and anesthesia. In the 1950s, there was a first attempt to try and catalog more completely the causes of the high rate of mortality. Beecher and Todd (1954) collated a large (ten University hospitals) sample of facilities, and collected data on any perioperative death that occurred over a period of five years. Using a panel of experts, they then attributed deaths to various anesthesia or surgical causes, finding a concerningly high average rate of 1:1560 that were solely related to anesthesia, which even at that time seemed extraordinarily high. Even the authors hesitated to call it a study, preferring the title "survey", which accurately reflects the subjective nature of its conclusions. They drew out a number of factors that seemed related to the high mortality, most of which are of purely historical interest, but in their comparison of nurse and physician anesthetists, there was no notable difference between the two groups. As the authors pointed out, that rate was higher than the mortality associated with polio, at the time a significant national health hazard. The study was a landmark, arriving at a time when national certification standards for both nurse anesthetists and anesthesiologists had finally become standard. However, the huge amount of time and effort involved in a multicenter study (over 550,000 surgeries were captured) in an era before large computerized databases, meant it was unlikely to be replicated.

The general consensus in the intervening decades was that there was a huge improvement in mortality and morbidity, probably related to better anesthetics and monitoring techniques. Dripps, Lamont, and Eckenhoff (1961) found no mortality related to anesthesia, either spinal or general, in healthy patients, although in patients with severe coexisting disease undergoing spinal anesthesia rates were as high as 1:16. Marx, Mateo, and Orkin (1973) studied mortality at a teaching hospital in New York, and found overall perioperative mortality of 1:53, though anesthesia related was lower at 1: 1265. In another early study, Bechtoldt (1981) retrospectively examined all surgical deaths in North Carolina over a five year period, then based on expert analysis, attributed some as anesthesia-related. They calculated a rate of approximately 1:24,000, and did not find any difference between physician and nurse providers, though again, statistical analysis was little more than rudimentary. Emphasizing the small impact of anesthesia on overall perioperative complications, Cohen, Duncan, and Tate (1988) retrospectively examined surgical deaths over 100,000 anesthetics, and found that while certain anesthesia techniques did predict increased mortality, overall patient factors, type of surgery, and emergency (rather than elective) procedure had much greater influence.

An ideal example of the improvements over time are two large retrospective studies carried out in France in 1986 and 2006 respectively. A comprehensive analysis of all death certificates, and follow up with health care providers involved in identified cases, allowed for in depth analysis. Tiret, Desmonts, Hatton, and Vourc'h (1986) only analyzed deaths within the first 24 hours after surgery, unlike the later study, but observed a mortality rate of 1:2956. In the more recent work, deaths at least partially related to anesthesia were 5.4 per 100,000, a fairly dramatic decrease (A. Lienhart et al., 2006).

Although most authors are consistent in their assessment of improving mortality, Lagasse (2002) is less convinced. As could be intuited from some of the data already presented, establishing a causal relationship between anesthesia and perioperative mortality is difficult, given that anesthesia is merely a service performed in order to undergo surgery, which in itself has the potential to cause significant morbidity. For example, a patient undergoes an aortic aneurysm repair with extensive blood loss, then 24 hours later has a myocardial infarction. This might be attributed to the surgery, due to the large blood loss, or anesthesia, for not correcting the ensuing anemia. It could also be related to management in the immediate perioperative period, which may include surgery, anesthesia, or neither depending on local preferences.

In addition, methodological differences make comparison problematic, as exemplified by the two French studies in which different time periods were used for inclusion of anesthesia-related mortality in the respective studies (M. D. A. Lienhart et al., 2006; Tiret et al., 1986). Li, Warner, Lang, Huang, and Sun (2009) found a tiny number of anesthesia-related deaths, by analysis of the ICD-9 coding designed specifically for anesthesia toxicity, or other direct complication, only 8.2 per million hospital discharges. Although interesting conceptually as an attempt to combine all the anesthesia codings together, the accuracy of specific anesthesia complication identification in the chart is not known. The absence of this kind of data, not to mention database, also makes it problematic to compare with earlier studies. As with many infrequent complications, the value of using retrospective data that could contain incomplete, missing, or miscoded variables, as opposed to the daunting task of conducting a large-scale prospective study, has to be balanced, with the scale frequently swinging in favor of historical claims data for cost reasons if nothing else.

Nevertheless, the broad consensus is that anesthesia (and surgical)-related mortality has substantially reduced over time. According to AANA (2009), a decision by the Centers for Disease Control (CDC) to compare mortality rates between CRNAs and physicians in the early ‘90s was abandoned after a pilot study revealed no difference, and costs for a full-scale investigation were estimated at over 15 million dollars. Using a meta analysis technique, Bainbridge, Martin, Arango, Cheng, and Evidence-based Peri-operative Clinical Outcomes Research (2012) found a gradual decline in mortality from the pre-1970s period to the 2000s, at least in the developed world. The incidence of mortality that could be solely attributed to anesthesia decreased from 357 per million anesthetics to 34 per million. Overall perioperative mortality showed a similar tenfold decrease from 10,467 to 1095 per million.

As well as the many studies that have examined overall mortality, more recent work has attempted to compare providers in terms of their respective outcomes. In a study carried out in Washington state, Simonson, Ahern, and Hendryx (2007) examined 73 hospitals that cared for obstetric cases. They found no significant difference between the rate of maternal anesthetic complications (including death), using specific anesthesia coding on discharge summaries, between all CRNA and all physician hospitals. Importantly, they noted that of the 17 total deaths in their sample of over 100,000, only one was coded as anesthesia related in the discharge data making it unusable as a comparator between groups. Using mortality alone, regardless of whether it was coded as an anesthesia death in the discharge data, did not detect any differences between groups

In a similar, but larger, one year retrospective study across seven states of over a million discharges, Needleman and Minnick (2009) found a death rate of only 0.007 percent across the sample, with no statistically significant difference between hospitals with either team or all CRNA/physician practices. Mortality was established from discharge coding, so was all cause, and not specifically anesthesia related. Although the mortality rate was very low, this was expected given that was conducted in the same, very healthy population with typically low mortality: pregnant women. A similar result was found for anesthetic complications, again using discharge coding alone to detect occurrence of the variable. This result was regardless of the anesthesia model used to deliver care.

Although data from obstetrics is useful, the extremely healthy nature of the population makes it difficult to extrapolate across a wider population. For this reason, other researchers attempted to look at surgical groups more specifically. Silber, Williams, Krakauer, and Schwartz (1992) used small sample of patients undergoing routine surgeries across seven states to compare mortality rates and complications between “directed” (cases in which an anesthesiologist billed for medical direction of a nurse anesthetist or resident, or provided care personally) or “undirected” (a nurse anesthetist working alone or with a non-anesthesiologist physician supervisor). They also introduced a new concept that they called “failure to rescue”, which essentially measured the number of deaths after a complication occurred. Although such a measure could potentially detect lower quality care by counting when adverse events were not treated properly, critics pointed out that the potential for a long delay between the administration of an anesthetic, and the occurrence of “failure to rescue” (for example, a myocardial infarction occurring a week after a hip replacement), made it difficult to tie all such events to anesthesia specifically. Supporters argue that subtle consequences of substandard anesthesia delivery could take longer time periods to develop, such as sepsis related to line placement, or complications arising from intraoperative hypothermia. In this study, and a subsequent study (Silber et al., 2000) the authors found that increased numbers of Board–

certified anesthesiologists were associated with decreased incidence of these events. The latter research was carried out using a much bigger population, but in one state (Pennsylvania). In both studies, a potentially problematic methodological assumption was made, that cases without anesthesia billing data should be assigned to the non-anesthesiologist group- in the more recent research, that was almost 2/3 of the non-anesthesiologist directed group. Another troubling decision was to allocate patients having a series of operations during one stay solely to the undirected group, if any of the procedures were classified as undirected. Both studies found increased rates of failure to rescue to be associated with undirected care. Although the studies controlled for comorbidity and hospital characteristics to some degree, there was limited allowance for the fact that increased numbers of Board certified physicians was likely to be associated with bigger hospitals, with access to greater resources to carry out high standard perioperative care.

Pine, Holt, and Lou (2003) examined Medicare data across 22 states, taken to represent a broad spectrum of rural and urban practices, over a period of three years. In addition, they only investigated 8 different surgical procedures that represented a broad spectrum of general and vascular surgery, but excluded cardiac or complex neurosurgery. This generated a total of 404,196 cases for analysis, after exclusions for missing codes, which they fit into a stepwise logistic regression model. Using risk adjusted models that accounted for hospital and patient characteristics, they found no effect on surgical mortality by type of provider model. Unfortunately, is unclear how surgical mortality was defined by the authors.

In one of the largest analyses of the effect of provider on outcome, Dulisse and Cromwell (2010) found no increase in mortality rate when comparing solo nurse anesthetists with both solo anesthesiologists and team-based care models. In fact, the odds ratio was lowest in the CRNA group, followed by the team, and highest amongst physicians working alone. The study also compared mortality and complications over time, in order to attempt to measure the effect of a significant rule change by Centers for Medicare Services (CMS), the so-called “opt out”. This rule allows a state to completely opt out of requiring any physician supervision of CRNAs; currently, CRNAs can work without an anesthesiologist, but instead must be supervised by another physician or dentist. Although a surgeon cannot realistically supervise a nurse anesthetist in matters of anesthesia, and has been shown many times to carry no additional liability for technically being responsible for CRNA supervision, the opt out rule allows this lack of direct involvement to be codified in billing regulations.

As well as examining mortality, Dulisse and Cromwell (2010) also counted the incidence of complications using Patient Safety Indicators (PSI) designed by the Agency for Health Care Quality and Research (AHRQ). These indicators are designed to detect iatrogenic complications in large databases using software that scans ICD-9 codes and controls for preexisting morbidity. Although PSIs have not previously been used in anesthesia related research, though they have been suggested as a useful method to examine the quality of surgical care (Cima et al., 2011). Dulisse and Cromwell (2010) found either no difference or a decrease in the incidence of complications when comparing nurse anesthetists with physicians. Team care anesthesia showed similar results. As with the Silber study cited earlier (Silber et al., 2000), the difficulty of separating complications related solely to anesthesia, and not either preexisting morbidity or the nature of the surgical procedure, is significant. While there are certain complications that can be specifically related to anesthesia such as recall, post-operative nausea or sore throat, they are either too difficult to detect, or too rare to utilize for useful analysis.

1.4 Conclusion

Anesthesia has a long history of conflict between its two main providers as to the most efficient and safest model of care. Although there is consensus that mortality has decreased over time, there is disagreement over the precise cause. Claims by physicians that their involvement has resulted in significant improvements in patient outcomes have been contested. The last decade has shown an increase in the use of less supervised team models, but there has been no work to date examining the characteristics and outcomes of this model. The burgeoning cost of the US health care system mandates that choices made for delivery of care be based on the most cost-efficient method, not upon historical or political reasons. By examining all models of anesthesia care delivery, including low supervision, the aim of this research is to add to the research showing the best models for anesthesia care delivery based on safety and cost. . The research provided in this dissertation examines three novel questions: (i) What is the distribution of anesthesia providers across varying types of hospitals?; (ii) What differences exist in surgical complexity and comorbidity of the patients receiving care through the alternate anesthesia models?; and (iii) are there differences between anesthesia models when examined at the level of the hospital where practice is based? By answering these questions, we seek to help guide policy development for anesthesia services in the coming decade.

Article 1: Distribution of anesthesia cases by practice model in the United States: A changing paradigm

Introduction

The cost of healthcare in the United States continues to be dramatically higher than comparable systems, with no discernible improvement in outcomes. With this in mind, researchers should strive to identify inefficient processes that could be managed more effectively by lower cost providers if the outcome is the same. Anesthesia care in the United States is provided by a variety of different practice models with significantly different costs (Hogan, Seifert, Moore, & Simonson, 2010), that could involve nurse anesthetists, physicians' assistants, and physicians in teams or working alone. Much of the variation can be explained by tradition and political influences, rather than by any kind of cost or quality analysis. Although in the early twentieth century solo providers were the norm, by the 1950s and 1960s, there was a growing in the number of "team" practices, in which nurse anesthetists were supervised or directed by anesthesiologists. Determination of the ratio of physicians to nurses developed in response to billing regulations created in the 1980s. These recommendations have remained essentially unchanged to the present day without any systematic examination as to the need for better understanding of their impact. In 1982, the American Society of Anesthesiologists (ASA) codified a statement on the Anesthesia Care Team (ACT), that stated a physician should be involved in every anesthetic administered in the United States. This position continues to this day, and is opposed by the American Association of Nurse Anesthetists (AANA). To date, attempts to discern differences between models of anesthesia delivery have largely focused on comparing anesthesiologists with nurse anesthetists working alone. Despite the increase in the number of practices using a QZ (light supervision) team model, there has been no work comparing the two dominant team models, likely because of the lack of a distinct billing code to easily differentiate between the two arrangements. Using the Physician Compare database, we determined the distribution of likely practice arrangements in a national sample of hospitals treating Medicare patients, along with the demographics of this population.

Background

Historically, anesthesia was initially delivered mostly by nurses, and it was not until the 1930s, and more significantly, after the Second World War, that the number of physicians began to significantly increase. Indeed, between 1940 and 1960, there was an approximately 400% increase in the number of nurse anesthetists, and a 600% increase in the number of physician anesthesiologists (Waisel, 2001). The precise reason for this change is unknown, but it does coincide with an increase in the prevalence of health insurance, and increasing reimbursement for anesthesia services. During the initial advent of anesthesiology as a medical profession in the 1920s, there were numerous unsuccessful legal attempts to bar nurse anesthetists from delivering anesthesia at all, on the grounds that it was the practice of medicine (Gunn, 1991). It was the position of physicians that they should be the only ones administering anesthesia. The failure of a legal remedy for the physician anesthesiologists was doubtless aided by the opposition of a great many of their surgical colleagues. This was perhaps because of their established, successful relationships with nurse anesthetists, but also likely related to the fact that nurse anesthetists posed little threat to both the surgeon's economic well-being, and status as "captain of the ship" in the operating room. In any case, despite the dramatic increase in numbers of physicians in the post-War years, it was clear that there would not be enough physicians alone to cover the rapidly expanding surgical volume in the United States. Instead, many physicians began working as a team with nurse anesthetists. In this approach, there was the political win of involvement in more anesthetics, as well as an increase in revenue as insurance billing regulations were lenient on payment requirements. The ASA described a model called the Anesthesia Care Team (ACT) in 1982, in which the physician was always the head of the team, and in which non-physician professionals were "directed" in the provision of anesthesia care. Interestingly, physician residents are "supervised" in this model- despite the fact that the physician student would likely need more direction than a fully qualified nurse anesthetist.

Concurrently to the ASA ACT statement, Congress was legislating stricter requirements for reimbursement of physicians involved in anesthesia, which culminated in TEFRA of 1982. Medicare began restricting physician reimbursement by limiting the number of anesthetists that could be directed (the most lucrative model) to a maximum of four. Initially, it was possible for the fee for a team model to be greater than that of a physician working alone, but over the next 15 years, the government tightened overall team reimbursement to the same as if the case were done by a solo practitioner, split evenly between the physician and nurse anesthetist. In conjunction with the allocation of the fee, were seven rules that specified the precise tasks that had to be completed in order to be in compliance. The conditions were:

1. Perform a preanesthetic examination and evaluation

2. Prescribe the anesthetic plan
3. Personally participate in the most demanding procedures in the anesthesia plan, including induction and emergence
4. Ensure that any procedure in the plan that is not done personally is done by a qualified individual
5. Monitor the course of anesthesia administration at regular intervals
6. Remain physically present and available for treatment of emergencies
7. Provide indicated postanesthesia care

Perhaps reflecting the stricter terms, this model was named medical direction, and has remained essentially unchanged to the current time. Though stricter than earlier models, it still allowed for potentially lucrative employment of nurse anesthetists by physician groups. Although a group would have to pay CRNA salaries (typically 2-3 times lower than physician pay), a physician directing four CRNAs in their employment could result in 400% of the revenue compared to doing a case alone (since the CRNA signs over billing rights and the physician employer thus retains fees for both providers). Even if the hospital employed the CRNAs, directing four cases could result in 200% of the fee compared to doing one case alone (physician retains 50% of the fee for each case). Clearly, the lower the number of cases directed, the less efficient the model becomes, at least in purely financial terms.

In more recent times, the medical direction model has become economically problematic for two major reasons: increasing CRNA salaries and decreasing insurance reimbursement. As CRNA salaries became higher, it was more difficult for physician groups to profit from employment. One solution to this problem was to offload employment of CRNAs to hospitals, in which case income would be solely from the physician portion of the fee. As long as reimbursement was adequate, this solution worked well, but decreasing rates from private insurance, combined with increased overall proportion of government (Medicaid or Medicare) payors at substantially lower rates than commercial payers, has made this model more difficult to sustain without maximizing the ratios of CRNA to MD. As ratios become higher, it is increasingly difficult to meet all the requirements of the TEFRA regulations and run an efficient operating room, of critical importance in today's market. A landmark paper by Epstein and Dexter (2012) spelled out this difficulty by identifying supervision lapses in the medical direction model to occur on approximately 35% of days with a 1:2 supervision model. With higher ratios, they predicted much higher rates of lapsing supervision, yet as already described, profitability was hindered by these conditions.

One increasingly popular solution to this problem is to use a different labor model (Thomas R. Miller, Amr Abouleish, & Nicholas M. Halzack, 2016). Although it is not clear when this began, as there is no distinct billing code or survey data to identify it, the QZ team approach allows for flexibility in staffing, while maintaining billing revenues. Originally, QZ was an anesthesia modifier that indicated a nurse anesthetist working alone, without medical direction, typically used where a surgeon is acting as the "supervisor". However, should an ACT choose to bill using the QZ modifier, the CRNA would get 100% of the fee, without the need to comply with any of the seven TEFRA requirements. Should the physicians choose to follow any of the requirements, that would be optional, as far as compliance with Medicare regulations. Clearly, while maintaining income and presence of anesthesiologists in many surgical cases, it also diminishes the level of supervision, which has been identified by some as a political problem for physicians (Byrd et al., 2011). From the nurse anesthetist perspective, there is interest in identifying the increased involvement of CRNAs, as documented by growing numbers of QZ modifier surgical cases, although there is little mention of the fact that many of these cases may also involve an anesthesiologist (Quraishi & Jordan, 2017)

To date, almost no work has examined the breakdown of QZ cases between all CRNA and MD/CRNA teams, and none has looked for differences, if any, between the types of practice environment. In this paper, we describe demographics and distribution of cases by hospital associated with the different anesthesia labor models.

Methods

Although the QZ modifier is listed in Medicare Provider Limited Data Sets (LDS), there is no method to distinguish if QZ refers to a CRNA working alone, or in an ACT using the modifier in order to maintain lighter levels of supervision. Following the work of Thomas R. Miller et al. (2016), we used the 2014 Physician Compare Database to identify anesthesiologists' affiliation with hospitals. (The 2014 file was used for our planned analysis of 2013 Medicare data since it is estimated to take 3-6 months for providers to be added to the file.) Physician Compare was created in 2010 from an initiative in the Affordable Care Act, and is primarily intended as a means to compare quality of providers. Access is free to the public, and permission is not required. Of relevance to our work, information includes NPI number and practice location, but also has outcome data for some quality measures. If a physician worked at more than one facility, we assigned a fraction to the facility, based on the number of facilities worked at. For example, if there were four practice locations, each would be assigned 0.25 fraction. Then, we summed the fractions to create the total number working at each location, which we named Full Time Approximation (FTA) to indicate similarity but not equivalence, with the more usual FTE acronym. We considered each provider as full-time, although it is possible that some of the listed physicians could be working part-time. Using this method, we divided the data into two groups of hospitals, those with an FTA of 1.0 or less, and those with an FTA of greater than 1. In our later analysis of QZ billed cases, we assigned an FTA of 1.0 or less to CRNA only practice, and greater than 1.0 to low supervision team. The decision to assign an FTA value of one or less to the CRNA only group was based on the fact that it would not be possible to be in attendance for a complete operating room schedule with only one FTA. In some rural facilities, an anesthesiologist is employed in a quality improvement/administrative role, for which they are not required to be involved in any anesthetic. This would explain the low FTA assignment which would only cover approximately 40 hours per week, certainly not enough to cover evenings, weekends, nights and vacations.

Prior to examination of the data, approval was obtained from the UNCC Internal Review Board to proceed with the research (study # 17-0291, classified as exempt). Initially, we created a subset of claims that involved administration of anesthesia from the 5% National Sample Medicare Provider Limited Data Set (LDS). This was determined by identifying those that had anesthesia modifiers attached (AA, AD, QK, QX, QS, QY, QZ). By merging with the Medicare Denominator File, we were able to identify race, age and gender characteristics of the population, and for subsequent analyses, death rates. We then merged this file with the National 5% Sample Medicare Inpatient LDS, but excluded long term, psychiatric facilities, and further restricted analysis to those patients age 65 or greater.

We then combined this file with our Physician Compare data by facility, allowing us to assign an FTA value to each facility in the Medicare combined file. Within this analytical file created, flags for analysis were created: anesthesiologist working alone (AA), high supervison (medical direction- QK with QX or QY), light supervision (QZ with an FTA assignment of greater than 1), and all CRNA (QZ with an FTA assignment of 1 or less). The QS group (a modifier for Monitored Anesthesia Care, typically a form of sedation) was discarded because of its small size (9). Similarly, the AD modifier (theoretically designed for supervision of more than 4 anesthetists, but rarely used owing to lower overall reimbursement) was considered of insignificant size to merit further analysis alone (632), but was added to the light supervision group since by definition it is used only where a physician is supervising more than four CRNAs.

Using the 2013 National Hospital File, we were able to determine the characteristics of the hospitals represented in the sample. Specifically, we determined the breakdown by rural/urban designation, number of beds, and teaching status.

Results

Although theoretically inclusive of all providers who bill for Medicare patients, after separating out from Physician Compare, there were only 19,010 anesthesiologists when compared with 49,201 cited in recent literature (Quraishi & Jordan, 2017). The reason for this is not known. In addition, there was a small group of 1345 (7.1%) who did not have any hospital locations associated with their entry. This could be because they were in office practice only, unlikely in anesthesia, but possible if there was a freestanding outpatient pain clinic. Alternatively, the provider could have no fixed practice location (working as locum tenens full-time), or be retired and not in active clinical practice. The total number of hospitals associated with this group was 3267, 2523 with FTA of greater than 1.0, and 744 with less than or equal to one. Clearly, since all physicians are not represented, all hospitals are unlikely to be identified by this method; it is expected to result in fewer hospitals in the QZ group to analyze, since the other labor models can be identified by the anesthesia modifier alone without further sorting by database merging.

A total of 790,684 anesthesia claims were initially abstracted from the 2013 Provider file. After selecting only those 65 and older who had an inpatient procedure, we were left with 122,645 claims for analysis. Table 1 shows the number of anesthesia cases by labor model, either physician only, physician/CRNA team with high supervision (medical direction), physician/CRNA team with light supervision (QZ team), or CRNA only. Initial analysis showed the most common model is all MD, followed by medical direction. The smallest group is all CRNA. However, there were 7526 cases that had one of the two modifiers present for medical direction. With this model, there are two codes required, one for the physician, and one for the CRNA in the Provider file. There were 4002 cases with missing CRNA codes, 3025 with missing physician codes, and 499 cases missing CRNA codes for a 1:1 supervision case. Similar issues have been noted by other researchers (Dulisse & Cromwell, 2010; Silber et al., 2000), and arbitrary decisions made to assign these cases to specific provider groups. Initially, our plan was to assign these missing cases to the medical direction model, however, the possibility existed that a case that should be counted as one, could be counted twice if it had one line for CRNA and another for physician. Closer examination, in an attempt to count only single cases, found several examples of cases billed under the same claim number and date, with different CPT codes. Given the potential for error, it was decided to completely exclude cases with missing/incomplete coding.

Table 1.1: Number of cases by anesthesia labor model (number in parentheses=% of total cases)

	PHYSICIAN ONLY	**HIGH SUPERVISION**	**LOW SUPERVISION**	**CRNA ONLY**
NUMBER OF CASES	48270 (41.9)	45161 (39.2)	18068 (15.7)	3620 (3.1)

Table 2 shows the breakdown of cases in each model by race, age stratum and gender. The mean age is highest in the all CRNA group (76.6), but the range of means is only from 75.6-76.6. Although there is a statistically significant difference between the groups, the clinical relevance is unlikely to be important as the differences are small.

Table 1.2: Demographics of cases within each labor model

	PHYSICIAN ONLY	**HIGH SUPERVISION**	**LOW SUPERVISION**	**CRNA ONLY**	**TOTAL CASES,%**
MALE (% OF TOTAL MALE, % OF TOTAL CASES WITHIN MODEL)	22546 (40.3, 46.5)	20247 (42.4, 45.0)	8103 (14.5, 44.8)	1488 (2.7, 41.1)	52,384 (45.5)
WHITE (% OF TOTAL WHITE, % OF TOTAL CASES WITHIN MODEL)	41631 (39.0, 86.2)	39443 (42.9, 87.3)	16082 (15.1, 89.0)	3286 (3.1,90.1)	100,442 (87.3)
BLACK (% OF TOTAL BLACK, % OF TOTAL CASES WITHIN MODEL)	3283 (39.1, 6.8)	4285 (42.8, 9.5)	1294 (15.4, 7.1)	235 (2.8, 6.5)	9097 (7.9)
OTHER RACE (% OF TOTAL OTHER, % OF TOTAL CASES WITHIN MODEL)	3086 (64.2, 6.4)	1212 (21.3, 2.7)	614 (12.8, 3.4)	89 (1.8, 2.5)	5001 (4.3)
MEAN AGE (STD DEV)	76.0 (7.6)	75.8 (7.5)	75.9 (6.8)	76.6 (6.2)	75.9 (7.6)
65-74 (% OF TOTAL 65-74, % OF TOTAL CASES WITHIN MODEL)	23093 (39.1, 47.8)	21979 (37.2, 48.7)	8622 (14.6, 46.8)	1600 (2.7, 44.2)	55,294 (48.0)
75-84 (% OF TOTAL 75-84, % OF TOTAL CASES WITHIN MODEL)	17522 (39.3, 36.3)	16407 (36.8, 36.3)	6685 (15.0, 36.7)	1363 (3.1, 37.7)	41,977 (36.5)
85+ (% OF TOTAL 85+, % OF TOTAL CASES WITHIN MODEL)	7655 (40.5, 15.9)	6775 (35.9, 15.0)	2761 (14.6, 15.3	657 (3.5,18.1)	17,848 (15.5)

Tables 3 and 4 show the distribution of anesthesia cases by hospital type and size across the different labor models. In addition, Table 5 shows the demographic characteristics of each hospital type alone, and by labor model. The dominant model in teaching hospitals is clearly high supervision or physician only, whereas in rural hospitals, the CRNA only model is more common proportionally, although not in absolute numbers. Less than 10% of all CRNA cases are conducted in a teaching hospital as opposed to over 60% of high supervision cases. Our data also shows almost 60% of CRNA only cases are conducted in a rural hospital, as compared with 5% of physician only, or around 10% of any type of supervision cases. Similarly, almost 60% of CRNA only cases are at small to medium sized hospitals, as opposed to under 10% for all other models.

Table 1.3: Demographics of cases by different hospital types

	TEACHING	**NON-TEACHING**	**RURAL**	**URBAN**	**SMALL**	**MEDIUM**	**LARGE**
MALE, N (% OF GROUP)	28846 (46.3)	23542 (44.5)	4611 (43.9)	47777 (45.7)	1175 (41.0)	3120 (42.5)	48049 (45.8)
BLACK, N (% OF GROUP)	5815 (9.3)	3283 (6.2)	595 (5.7)	8503 (8.1)	86 (3.0)	301 (4.0)	8710 (8.0)
AGE, MEAN (SD)	75.7 (7.5)	76.2 (7.6)	76.5 (7.7)	75.8 (7.6)	74.9 (7.2)	76.2 (7.7)	75.9 (7.6)

Table 1.4: Distribution of cases by anesthesia model in different hospital types (% of total cases for each model)

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY	TOTAL CASES (%)
RURAL	2601 (5.4)	3735 (8.3)	1892 (10.5)	1273(58.2)	9501 (8.4)
URBAN	45669 (94.6)	41426 (91.7))	16176 (89.5)	1351 (41.8)	104,186 (91.6)
TEACHING	26177 (54.2)	27630 (61.2)	8153 (45.1)	113 (5.2)	62,073 (45.9)

Table 1.5: Distribution of cases by anesthesia model across varying hospital sizes (% of total cases for each model)

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY	TOTAL CASES (% OF TOTAL)
SMALL (<50 BEDS)	1104 (2.3)	508 (1.1)	516 (2.9)	398 (18.2)	2526 (2.2)
MEDIUM (50-100 BEDS)	2664 (5.5)	2188 (4.9)	1175 (6.5)	674 (30.8)	6701 (5.9)
LARGE (>100 BEDS)	44502 (92.3)	42465 (94.1)	16377 (90.6)	1116 (51.1)	104,460 (91.9)

Discussion

Historically, the QZ modifier was only used for all CRNA practices, and only accounted for a small portion of total anesthesia billing. However, in recent years, there has been a trend to increased utilization, which has been noted as a cause of concern for physician professional organizations, likely because it indicates increasing utilization of CRNAs rather than physicians, regardless of whether they are operating independently or not (Byrd et al., 2011). Along these lines of concern, Thomas R. Miller et al. (2016) identified that anesthesiologists are involved in many QZ cases, using the Physician Compare to identify physician practice locations (this study replicates their method), but did not speak to the likely diminished level of involvement in this labor model. Similarly, Quraishi and Jordan (2017) identified an increase in QZ billed cases from 10.9% to 21.7% over the period 2000-2014, but did not discuss the underlying causes of the trend. Our data shows 18.8%, which is lower, but excludes outpatient procedures that were included in the other analysis, . Perhaps not surprisingly, different labor models appear to have little influence on the demographic characteristics of their respective populations. Although significant differences exist at the statistical level, clinically speaking, these are unlikely to have impact.

Previous work and survey analysis suggests that all-CRNA practice may be centered around rural and/or critical access facilities (Liao, Quraishi, & Jordan, 2015). However, little work has accurately described the distribution of other anesthesia models. Our work supports this description of all CRNA practice, and adds to knowledge of other labor models. We found that over 60% of the CRNA only caseload was rural, and over 60% was in small-medium size hospitals. However, although the rural caseload of high supervision practices is only 9% of their total volume, it does represent 41% of the total number of rural cases, followed by physician only with 23% of the total number. Hogan et al. (2010) have pointed out that medical direction is associated with the highest costs of administering anesthesia. In a below average demand setting, such as might be expected in a rural setting, the estimated annual revenue based on an all CRNA setting is $702,000, whereas in a medical direction model, there is always a loss ranging from $108,000 to over $3 million. Although not specifically addressed in their model, based on the numbers from their simulation, even staying with a team model, but moving to a low supervision QZ approach could be expected to have revenue of around $30,000 (assuming CRNA only revenue, but supervisory costs).

Currently in the United States, it has increasingly become part of the healthcare landscape to provide a subsidy to maintain anesthesia coverage. Koch and Calder (2011) reported that every hospital surveyed by the ASA in 2005 was providing financial support to anesthesiology services, and more recently, O'Neill (2017) cited average subsidies of $160,000 per anesthesiologist. In a trade newsletter, HPS (2009) reported results averaging $1.2 million per facility from a national survey of hospitals with 112 results. In a medical direction model, the physician need not necessarily administer any anesthesia, since their role is purely a supervisory one. Multiple researchers have concluded that there is either no difference, or none can be detected, between the safety of anesthesia given by physicians or CRNAs (Dulisse & Cromwell, 2010; Lewis, Nicholson, Smith, & Alderson, 2014; Pine et al., 2003). Given this background of increasing cost to maintain anesthesia services, and a typical annual salary in the region of $500,000, the need to maintain any supervision of CRNAs by anesthesiologists should be questioned. At the minimum, the need for high versus low levels of supervision is not subject to any rules or national standards regarding differentiation between the two. In our analysis, we showed a similar pattern of distribution between the two team models when comparing location and size of hospital, but a preponderance of high supervision in teaching hospitals. It could be expected that these centers, which are dominated by academic physicians, might hew to a more rigid interpretation of the ASA guidelines of anesthesiologists being involved in every case. Interestingly, that does not appear to extend to anesthesiologists actually administering the anesthetic, which would be the highest level of involvement.

Limitations

Our work has several limitations. There are a number of limitations to our work. Firstly, our method of determining which hospitals are CRNA-only as opposed to low supervision team relies on the assumption that an FTA of one or less indicates all CRNA. Clearly, there could be scenarios in which this is incorrect: firstly, we have no way of knowing if when a physician works at more than one hospital, how their time is split between each. For modelling purposes, we assumed it was even, but it could be uneven which would alter the fraction assigned to each practice location, and ultimately the determination of FTA. Secondly, having a value of more than one FTA does not explicitly confirm that the labor model is a team. The authors are aware of models in which physicians and CRNAs work in the same facility, but the CRNAs practice independently. Conversely, even if there is only one physician assigned for 40 hours or less per week, they could still operate within a team model consistently, negating our facility assignment to independent CRNA practice. Also related to the determination of FTA, the list of anesthesiologists in Physician Compare only contains approximately 50% of the national total. Thus, it is likely that some facilities are not represented in our sample, and hence we have undersampled the true rate of QZ claims. Our total number of hospitals derived from the Physician Compare sample was 3266, of which 2523 were determined to be a team model, and 744 were all CRNA. It is important to note, that after merging with the provider file, hospitals with a physician FTA of one or less could actually be solo physician, as described by the billing modifier AA. Similarly, team model could be assigned to QZ team (low supervision), or medical direction (high supervision) depending on the modifier attached to the hospital. According to the American Hospitals Association in 2017, there are around 4800 acute care community hospitals in the United States, which would include both inpatient and outpatient (not analyzed for this study) facilities, but exclude federal government centers

There are a small number of AAs practicing throughout the US, so we may have attributed some medical direction cases to CRNAs, when they were in fact AAs. Given that AAs represent a tiny proportion of the anesthesia workforce overall, and that they can only bill for services as medical direction, we anticipate the effect, if any, would be very small.

As with any secondary data, there is the possibility of errors in coding or entry. In particular, the possibility of missing or inaccurate anesthesia billing information could alter the composition of any of the four billing groups used in the analysis. Our assumption is that most providers strive to enter such information as quickly and as accurately as possible to maximize revenue. We know that CRNA only data is likely undercounted, since critical access hospitals have the ability to bill for CRNA services through Part A, which would not be identified by our analysis. In addition, the use of Medicare data in an elderly population limits the number and type of cases included in the analysis.

Conclusion

Low supervison practices account for almost 16% of Medicare volume in the United States. The distribution of this model is across all types and sizes of facility, though primarily urban, and larger hospitals. Given the significantly lower cost associated with this model, and the failure of previous research to show differences in outcomes between providers, more widespread adoption of this approach seems worthy of attention.

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Article 2. Surgical complexity and comorbidity: how do different practice models compare in anesthesia?

Introduction

Unlike other medical specialties, anesthesia is unusual in that it commonly uses two providers to do one job. The providers, Certified Registered Nurse Anesthetists (CRNAs) and anesthesiologists, have both completed post graduate training in the specialty, and are educated in essentially the same techniques and knowledge base. Even though either professional can work alone, the commonest practice setting is a pairing of CRNA and physician in which the CRNA remains with the patient for the whole surgery, while the physician has only an intermittent presence. The determination of the frequency of presence may be related to patient characteristics, billing requirements, or possibly local factors such as operating room needs or staffing. Previous work has attempted to examine differences in outcomes between CRNAs or physicians working alone, and teams of both working together, but little research has focused on the types of surgery and patient characteristics that could justify need for additional providers (Dulisse & Cromwell, 2010; Pine et al., 2003; Silber et al., 2000).

Background

Defining surgical complexity for both health care researchers and administrators, has proven somewhat problematic to achieve. Attempts to measure complexity began in the 1970s, as surgical volume began to rise dramatically (Blendon, 1971; Luft, 1980; C. B. Schoonhoven, W. R. Scott, A. B. Flood, & W. H. Forrest, Jr., 1980). Both researchers and insurers wanted a way to define both quality, and appropriate volume, hence there was a need to allow for the varying degrees of difficulty that might require extra skill, or reimbursement, as well as affecting outcomes. In addition, hospitals and the Federal Government wanted a way to assess the relative workload of physicians in order to create equitable but fair payment schedules for physicians. The creation of DRGs quantified the resources needed for a particular grouping, such as a normal delivery or appendectomy, but gave little specific attention to surgery itself (Fetter et al., 1980). However, this was soon followed by the RBRVS, which was designed to look more specifically at different physician specialties and compare them for payment purposes (Hsiao et al., 1988). Although not specifically designed for surgical complexity, some researchers saw value in using RBRVS as a proxy since it quantified physician workload, and as complex cases could be expected to require more work, the two would logically be correlated. Aside from the interest of billing agencies, researchers also wanted to define complexity. Using RVUs, a component of RBRVS, Davenport et al. (2005) found they accounted for 23% of the total cost of hospitalization, and when combined with preoperative risk factors, were a better predictor of cost than complications. Little et al. (2006) found that increasing RVUs were associated with increasing operative time, but unfortunately did not analyze outcomes. Subsequently, and often in association with the National Surgical Quality Improvement Project (NSQIP), other researchers have detected a correlation between RVUs and complications (Johnson et al.; Neumayer et al.; Virani et al.) On the other hand, Shah et al. (2014) found no association between RVUs and either operative time or complications.

In looking for other ways to assess complexity, a common approach involves surveying a group of experts. Blendon (1971) asked 80 University affiliated surgeons and anesthesiologists to rate a list of common surgeries, since he considered this to be the most expert group to make a determination. Using a similar technique, C. B. Schoonhoven et al. (1980) used over 900 providers to determine levels of complexity by questionnaire, with special focus on procedures associated with uncertainty or difficulty. Unlike most subsequent work, they used nurses as well as physicians in their analysis, and the ratings derived from each group were very similar. Both studies found similar levels of agreement on what could be considered complex.

The concept of using a peer group to define levels of complexity has also been adapted by the Veteran's Administration (VA) for internal use in identifying system needs for allocation of resources (Khuri et al., 1995). Initially developed as part of a larger Surgical Risk study, the classification (a five level scale for inpatient surgeries) is used to determine whether individual VA hospitals have the resources available to carry out specific surgeries; each hospital has a specific designation. Subsequent work within the study has found complexity level as a useful predictor variable for various outcomes, such as mortality or postoperative morbidity (Davenport et al., 2005; Khuri et al., 1997). In addition to the VA system, the complexity classification has been used as a predictor variable in other hospital settings. Aust et al. (2005) validated the VA Surgical Risk Study by studying discharges within one University hospital system, and found operative complexity to give additive predictive value for mortality risk, although it was most useful at grades three and above (out of five). More recently, Studnicki et al. (2014)

examined discharges in non-VA hospitals in Florida, and found that there was good association between large hospitals and more complex classification levels.

Another possibility for assessment of complexity is using anesthesia base units, assigned to specific CPT codes on the basis of procedural complexity. Base units vary according to the estimated difficulty of the anesthetic management, for example, surgery on the lens of the eye is four units, whereas heart/lung transplant would be 20 units. Dexter et al. (2002) evaluated the suitability of using base units to determine acceptable case loads for a new surgery center, and found it to be a helpful tool for identification of appropriate case load. Dulisse and Cromwell (2010) used base units as a control measure for their large retrospective study of CRNA and physician anesthesiologist outcomes. There are several advantages to this method. Firstly, the ease with which base units can be abstracted from both Medicare and private payor billing data for use in analyses. Secondly, the range and linear nature of the scale potentially allows it to give more accurate data as opposed to categorical scales with limited divisions.

As well as comparing complexity, assessment of patient comorbidity may help us understand differences between surgical populations, and therefore help make more accurate comparisons between providers. The Charlson Comorbidity Index (CCI), while not designed for surgical populations specifically, has been widely used since its inception in the early 1990s (Charlson et al., 1994). While initially complex to calculate, owing to the requirement of data from 17 different conditions, the advent of computerized analysis has dramatically increased the feasibility of use, and allowed for variations of scoring from the original (Quan et al., 2005). CCI is also known to be correlated with increased risk of death, and can be used to stratify populations, or as a control variable. In the perioperative population, it has been used to predict poor outcomes (D'Hoore et al., 1996; Froehner et al., 2003; Moodley, 2016). Elixhauser et al. (1998) developed a similar but potentially more accurate system that uses 30 conditions to adjust for patient comorbidities, assuming the sample is sufficiently large. Since it was designed primarily for stratification, there initially was no score associated with application, another potentially limiting factor. However, van Walraven et al. (2009) developed an algorithm to assess a numerical value using the Elixhauser conditions, which has potential for creation of a predictive score.

Methods

Although it is relatively straightforward to identify physicians working alone as well as highly supervised anesthesia teams (medical direction), simply by using Medicare billing modifiers, it is much more complex to differentiate between CRNAs working independently, and anesthesia teams with low supervision. In this situation, both use the QZ modifier with no additional coding to distinguish between models. Thus, in order to determine which model is being used when the QZ modifier is used, we merged the Medicare Provider Limited Data Set for 2013, with a file that allocates a physician Full Time Approximation (FTA) for each hospital calculated from the publicly available Physician Compare dataset. Prior to examination of the data, approval was obtained from the UNCC Internal Review Board to proceed with the research (study # 17-0291, classified as exempt). Our method was based on one described by Thomas R. Miller et al. (2016), and uses the listed practice locations to determine the number of physicians assigned to each hospital, which we named a FTA based on the fact that it is comparable to, but not the same as, Full time Equivalent (FTE). Specifically, since the exact division of time cannot be ascertained for a given physician, we cannot say with certainty, for example, that four physicians assigned to hospital A actually means it has four FTE. Having found the FTA for each hospital, we assigned QZ hospitals with an FTA of greater than one to a team model, and less than or equal to one to an all CRNA group. We used a value of one because it is not uncommon for CRNA only groups to employ a single physician in a Quality Improvement or administrative function, even though they may have little or no direct clinical involvement. In addition, with only one physician, it is not feasible to operate a labor model with supervision continuously, allowing for off shift work and vacation coverage, which makes it extremely unlikely it could be assigned to that group.

Separately, we created a subset of claims that involved administration of anesthesia from the 2013 National 5% Sample Medicare Provider Limited Data Set (LDS). Anesthesia claims are identified by seven modifiers, AA, AD, QK, QX, QS, QY, QZ, which indicate the type of provider that administered and/or supervised the anesthetic. Subsequently, by merging with the 2013 Medicare Denominator File, we were able to identify race, age and gender characteristics of the population, and date of death if applicable. We then merged this file with the National 5% Sample Medicare Inpatient LDS, but excluded long term and psychiatric facilities, then further restricted analysis to patients 65 and older.

We then combined the file obtained from Medicare data with our Physician Compare subset by facility, allowing us to assign an FTA value to each facility in the Medicare combined file. Within this analytical file, we were able to create variables for each anesthesia labor model: anesthesiologist working alone (AA), medical direction (QK with QX or QY), light supervision (QZ with an FTA assignment of greater than 1), and all CRNA (QZ with an assignment of 1 or less). The QS group (a modifier for Monitored Anesthesia Care, typically a form of sedation) was discarded because of its small size (n=9). Similarly, the AD modifier (theoretically designed for supervision of more than 4 anesthetists, but rarely used owing to lower overall reimbursement) was considered of insignificant size (n=632) to merit further analysis alone, but was added to the light supervision group, since by definition it is used only where a physician is supervising more than four CRNAs. Using information from the 2013 Medicare Limited Data Set, we were also able to create variables for hospital characteristics, including size (by total number of beds), location (rural/urban), and teaching hospital designation.

Surgical complexity was assessed using the proxy measure of anesthesia base units, which is included for every case that has an anesthesia modifier in the Carrier file. Preexisting comorbidity was assessed using Charlson scores (Charlson et al., 1994), which were calculated from ICD9 codes found in the inpatient file, creating a Charlson Comorbidity Index (CCI).

Results

After beginning with a sample of 790,684 anesthesia claims from the Carrier file, we excluded outpatient surgery, patients 64 or younger, and non-acute care facilities. This left us with an analysis file of 113,687 claims. Owing to an incomplete listing of physicians in the Physician Compare Database, some hospitals were not captured in the analysis. After sorting Physician Compare, the total number of physicians was 19,010, lower than the expected number of around 50,000. It is uncertain why all physicians are not listed, since the website language implies that participation is mandatory for those involved in Medicare billing. Using this group, there were a total of 3267 facilities identified as practice locations, of which 744 had an FTA of one or less, implying an individual model, and the remainder (2523) had an FTA of greater than one, implying a team model. Table 1 shows the demographics of each anesthesia labor model. Using an ANOVA, these groups have a statistically significant difference, however, the clinical significance is difficult to determine, in terms of anesthetic management and outcomes. For example, mean age ranged from 75.6 to 76.6, and the relative share of male, white, and black patients was essentially constant across each group.

Table 2 shows the breakdown of cases by type of hospital, rural/urban or teaching, across the different types of models. Our data was consistent with previous researchers who have shown CRNA only practices are concentrated in rural areas (Liao et al., 2015).

While absolute numbers show high supervision as the dominant model with 4755 cases, that number represented 9% of the total high supervision model; CRNA only cases numbered 2268, but were 63% of the total model. Similarly, models that have a high physician involvement (physician only and high supervision) had both larger absolute numbers and proportions of cases in teaching hospitals (Table 3). Size of hospital had a similar pattern, with the CRNA only model concentrated in small hospital settings.

Table 2.1: Demographics of cases within each labor model

	PHYSICIAN ONLY	**HIGH SUPERVISION**	**LOW SUPERVISION**	**CRNA ONLY**	**TOTAL CASES (%)**
MALE (% OF TOTAL MALE, % OF TOTAL CASES WITHIN MODEL)	22546 (40.3, 46.5)	20247 (42.4, 45.0)	8103 (14.5, 44.8)	1488 (2.7, 41.1)	52,384 (45.5)
WHITE (% OF TOTAL WHITE, % OF TOTAL CASES WITHIN MODEL)	41631 (39.0, 86.2)	39443 (42.9, 87.3)	16082 (15.1, 89.0)	3286 (3.1,90.1)	100,442 (87.3)
BLACK (% OF TOTAL BLACK, % OF TOTAL CASES WITHIN MODEL)	3283 (39.1, 6.8)	4285 (42.8, 9.5)	1294 (15.4, 7.1)	235 (2.8, 6.5)	9097 (7.9)
OTHER RACE (% OF TOTAL OTHER, % OF TOTAL CASES WITHIN MODEL)	3086 (64.2, 6.4)	1212 (21.3, 2.7)	614 (12.8, 3.4)	89 (1.8, 2.5)	5001 (4.3)
MEAN AGE (STD DEV)	76.0 (7.6)	75.8 (7.5)	75.9 (6.8)	76.6 (6.2)	75.9 (7.6)
65-74 (% OF TOTAL 65-74, % OF TOTAL CASES WITHIN MODEL)	23093 (39.1, 47.8)	21979 (37.2, 48.7)	8622 (14.6, 46.8)	1600 (2.7, 44.2)	55,294 (48.0)
75-84 (% OF TOTAL 75-84, % OF TOTAL CASES WITHIN MODEL)	17522 (39.3, 36.3)	16407 (36.8, 36.3)	6685 (15.0, 36.7)	1363 (3.1, 37.7)	41,977 (36.5)
85+ (% OF TOTAL 85+, % OF TOTAL CASES WITHIN MODEL)	7655 (40.5, 15.9)	6775 (35.9, 15.0)	2761 (14.6, 15.3	657 (3.5,18.1)	17,848 (15.5)

Table 2.2: Distribution of cases by anesthesia model in different hospital types (% of total cases for each model)

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY	TOTAL CASES (%)
RURAL	2601 (5.4)	4755 (9.0)	1891 (10.5)	2268 (62.7)	11,515 (9.4)
URBAN	45669 (94.6)	47937 (90.5)	16173 (89.5)	1351 (37.3)	111,130 (90.6)
TEACHING	26177 (54.2)	32673 (62.0)	8151 (45.1)	349 (9.6)	55,295 (45.1)

Table 2.3: Distribution of cases by anesthesia model across varying hospital sizes (% of total cases for each model)

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY	TOTAL CASES (% OF TOTAL)
SMALL (<50 BEDS)	1033 (2.1)	481 (1.1)	510 (2.8)	843 (23.3)	2867 (2.5)
MEDIUM (50-100 BEDS)	2664 (5.5)	2188 (4.9)	1175 (6.5)	1312 (36.2)	7339 (6.4)
LARGE (>100 BEDS)	44502 (92.3)	42465 (94.1)	16377 (90.7)	1465 (40.5)	104,809 (91.1)

The mean number of anesthesia base units for the sample was 7.31 (SD 3.75). Table 4 shows the breakdown of base units by anesthesia labor model. The highest number of units were associated with the most physician intensive models. Similarly, the average CCI score was highest in the most physician intensive models, and lowest in the CRNA only. The differences were statistically significant using anova, however, when comparing the two team models, the mean difference was only 0.23 base units and 0.03 in CCI score.

Table 2.4: Base units and CCI in different anesthesia labor models (*p<.001; $^{+}$p<.001)

	PHYSICIAN ONLY	**HIGH SUPERVISION**	**LOW SUPERVISION**	**CRNA ONLY**
BASE UNITS (SD)	7.78 (4.33)*	7.05 (3.24)*	6.82 (3.06)*	6.23 (2.50)*
CCI SCORE (SD)	2.51 (2.57)$^{+}$	2.42 (2.55)$^{+}$	2.39 (2.53)$^{+}$	2.17 (2.32)$^{+}$

We also examined average base units and CCI score in different hospital types, shown in Tables 5-10. As might be expected given the higher resources associated with urban, teaching or larger hospitals, average base units were higher in these facilities across all models, with the exception of CRNA only models in large facilities. In that scenario, small hospitals had the highest base units, large had the lowest. Interestingly, for all models, base units were lower at mid-size hospitals than at small ones . Similarly, CCI scores were highest in hospitals expected to have a greater concentration of resources, although the differences were often very small. Comparing rural to urban facilities yielded a difference of from 0.04-0.22, teaching to non-teaching ranged from 0.24-0.35. The exception to this was when comparing hospitals of varying size, when the difference ranged from 0.74-1.40. In this category, another observation of note was that the CRNA only model had the highest comorbidity with an average CCI of 1.76, other anesthesia models ranged from 1.07-1.28.

Table 2.5: Average CCI score (SD) in hospitals with different characteristics, by anesthesia labor model

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY
RURAL	2.30 (2.42)	2.30 (2.49)	2.36 (2.44)	2.27 (2.43)
URBAN	2.52 (2.58)	2.48 (2.57)	2.40 (2.54)	2.37 (2.37)
TEACHING HOSPITAL	2.62 (2.59)	2.57 (2.61)	2.51 (2.56)	2.89 (2.50)
NON-TEACHING	2.38 (2.54)	2.30 (2.49)	2.30 (2.50)	2.28 (2.40)
< 50 BEDS	1.26 (1.87)	1.26 (1.94)	1.06 (1.47)	1.79 (2.05)
50-99 BEDS	2.07 (2.25)	1.90 (2.18)	1.98 (2.22)	2.26 (2.50)
100 OR MORE BEDS	2.57 (2.59)	2.51 (2.59)	2.47 (2.57)	2.53 (2.44)

Table 2.6: Average base units (SD) in hospitals with different characteristics, by anesthesia labor model

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY
RURAL	6.84 (3.55)	6.62 (2.84)	6.22 (2.32)	6.15 (2.21)
URBAN	7.83 (4.36)	6.97 (3.25)	6.89 (3.12)	6.72 (3.33)
TEACHING HOSPITAL	8.23 (4.70)	7.02 (3.28)	6.96 (3.22)	6.53 (3.07)
NON-TEACHING	7.24 (3.78)	6.82 (3.11)	6.71 (2.91)	6.38 (2.73)
< 50 BEDS	7.62 (2.97)	7.22 (2.48)	7.82 (2.49)	7.04 (3.31)
50-99 BEDS	7.08 (3.47)	6.63 (2.46)	6.39 (2.12)	6.16 (2.33)
100 OR MORE BEDS	7.82 (4.40)	6.95 (3.26)	6.82 (3.12)	6.30 (2.73)

Previously, we noted that physician intensive models were concentrated in large, urban and teaching hospitals. Other researchers have noted that these hospitals are more likely to have complex surgeries, and patients with more preexisting disease, which could potentially be acting as a confounding variable with anesthesia labor model. Hence, we constructed a multiple regression model including anesthesia labor model, age, CCI, type (rural/urban), size, and teaching status of hospital for both surgical complexity and comorbidity. For complexity, all values were significant (p<.05), as shown in Table 7.

Table 2.7: Regression model for surgical complexity (base units)

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	PR> |T|
INTERCEPT	12.39	0.16	<.0001
URBAN HOSPITAL	0.41	0.04	<.0001
ANESTHESIA MODEL	-0.49	0.01	<.0001
CCI	-0.11	0.00	<.0001
AGE	0.06	0.00	<.0001
HOSPITAL SIZE	-0.08	0.03	0.01
TEACHING HOSPITAL	0.46	0.02	<0.001

We noted that teaching or urban designation of hospital had a positive association with surgical complexity, but age, CCI, hospital size and decreasing physician involvement in the anesthesia model had a negative relationship. Typically, more complex surgical cases could be expected to be referred to teaching hospitals, or urban centers. The negative association of age and CCI could be related to lower likelihood of undertaking complex surgery on older and sicker patients.

Table 2.8: Regression model for comorbidity (CCI

VARIABLE	**PARAMETER ESTIMATE**	**STANDARD ERROR**	**PR> |T|**
INTERCEPT	1.27	0.11	<.0001
URBAN HOSPITAL	-0.04	0.03	0.15
ANESTHESIA MODEL	-0.06	0.01	<.0001
BASE UNITS	-0.06	0.00	<.0001
AGE	0.00	0.00	0.01
HOSPITAL SIZE	0.52	0.02	<.0001
TEACHING HOSPITAL	0.18	0.02	<0.001

As with surgical complexity, it could be expected that CCI might increase with bigger, urban hospitals, as they are frequently referral centers for smaller, rural centers. This was somewhat demonstrated in our data (Table 8), with a positive, statistically significant association between size and teaching hospital designation. Age was also positively associated with CCI which is anticipated owing to increasing comorbidity burden with advancing age. However, in our analysis, CCI was negatively associated with urban hospitals (relative to rural), as was increasing proportion of CRNAs in anesthesia labor model and surgical complexity.

Discussion

Congruent with previous researchers, we found practices with physician involvement to be more common in urban, large and teaching hospitals. When comparing surgical complexity between models, as measured by our proxy indicator of anesthesia base units, there was a statistically significant difference between mean base units across labor model. The number of units was most with physician only (7.78 +/- 4.33), and least with CRNA only (6.23 +/- 2.50), and trended down as the level of physician involvement decreased. However, this does not take account of hospital level factors that could influence complexity. Using regression analysis, model, hospital size, location, and teaching status all had effects on complexity, along with CCI and age. Secondly, while the difference between physician only and CRNA only (the largest variation) was 1.55 units, between high supervision and low supervision models was 0.23 units, an extremely small margin. The range of base units for a procedure is from three to twenty five, with a mean value in our data for all CPT codes of 6.67, so clearly there is minimal clinical difference between the two team models, in terms of complexity.

We saw a similar pattern when examining pre-existing morbidity, as measured by CCI in our work. Average score showed statistically significant differences between each labor model, age, hospital type (teaching/non; rural/urban; small/medium/large size), base units. However, the absolute difference between models was small; the complete range was 0.34 from physician only to CRNA only, but between high and low supervision groups it was 0.03. Certainly, CCI scores are biased towards the low side of the scale, with a large number of scores from 0-1, but this work shows very small differences of likely minimal significance in the clinical environment. In other words, when controlling for hospital type, each type of anesthesia model cares for patients with similar levels of co-morbidity when presenting for surgery.

It appears that there are small differences between alternate labor models in terms of the complexity of surgery, and the acuity of the patients cared for. In particular, for facilities that use an ACT model, there is a striking similarity between high supervision and low supervision models, despite the fact that the cost implications are substantial. Hogan et al. (2010) estimated the annual *loss* of revenue using medical direction (high supervision) to be between $108,000 and $3 million; a low supervision (QZ billing) model could be expected to make profit of $30,000 annually, using their numbers. In addition, the low supervision or CRNA only model permits more flexible use of expensive operating room time by eliminating the need for two providers to be involved at mandatory points in the anesthetic, as opposed to just when warranted by patient need. In this study, there is no examination of outcomes using different models, however, multiple previous researchers have found either no difference, or determined it is not possible to detect a difference, between providers (Dulisse & Cromwell, 2010; Lewis et al., 2014; Pine et al., 2003).

Limitations

Our work has several limitations. Identification of low supervision is imperfect; while being able to ascertain practice locations, we cannot establish how much time is spent at each facility, to truly establish FTE status. In addition, there are a large number of physicians missing from the Physician Compare database, which could mean there are additional facilities that are operating in a low supervision mode. There are a small number of AAs practicing throughout the US, so we may have attributed some medical direction cases to CRNAs, when they were in fact AAs. Given that AAs represent a tiny proportion of the anesthesia workforce overall, and that they can only bill for services as medical direction, we anticipate the effect, if any, would be very small.

As with any secondary data, there is the possibility of errors in coding or entry. In particular, the possibility of missing, or inaccurate anesthesia billing information could alter the composition of any of the four billing groups used in the analysis. Our assumption is that most billers strive to enter such information as quickly and as accurately as possible to maximize revenue. We know that CRNA only data is likely undercounted, since critical access hospitals have the ability to bill for CRNA services through Part A, which would not be identified by our analysis, though this is not required if revenue through Part B is adequate.

Conclusions

Our work has potential implications for planning of anesthesia services. Hospital factors have significant associations with surgical complexity and patient comorbidity, whereas we find small, and likely clinically insignificant, differences between surgical complexity and comorbidity in patients cared for in diferent anesthesia models. With this in mind, especially as anesthesia providers increasingly become employed by large health groups, hospitals should carefully examine the optimum provider mix based on matching skills with patients’ risk.

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Article 3: 48 hour mortality after surgery: variations between anesthesia practice model and hospital type

Introduction

Mortality in anesthesia has shown dramatic improvements since the beginnings of the profession in the late nineteenth century. The explanation for this is likely a combination of high quality education, technological advances in patient monitoring, and safer anesthetic agents. In the last few decades, as health care costs have continued to escalate, there has been increasing pressure on anesthesiologists to justify their continued support of a team model, which requires two professionals with similar training to complete the same tasks that can demonstrably be achieved with one. Concurrently, as economic pressures on a two provider model increase, there has been a shift towards a looser form of supervision, with less direct physician involvement Byrd et al. (2011). This newer model has not been studied directly, probably because of difficulties in identification in large data sets needed, as well as a political disinclination to examine an approach that calls for decreased physician presence. Our study examines this group in comparison to other, traditional, anesthesia labor models, and considers hospital level factors that may influence outcomes.

Background

Since the early days of anesthesia administration, providers have been concerned with perioperative mortality (Bankert, 1989). Initially, death at the hands of unskilled providers was relatively common, and perhaps not surprising given the cavalier manner in which the task of anesthetist was delegated to almost anyone available. However, as educational programs for both nurse anesthetists and anesthesiologists began to become both more rigorous, and more common, attention began to be paid to precise investigation of the causes of unexpected death, and what could be done to prevent them (Bacon & Ament, 1995).

One of the earliest studies of anesthesia-related mortality was carried out by Beecher and Todd (1954). In their oft-cited work, they examined all perioperative deaths that occurred in ten University hospital settings over a period of five years. By using a panel of expert anesthesiologists, they designated death as related to surgical or anesthesia causes, concluding that 1:1560 were related solely to anesthesia, a sobering number. Many of the reasons they cited for the high mortality rate were historical in nature, but of note is that they did not find any notable differences between physicians and nurse anesthetists. Certainly, the methods were not scientific, and even at the time, the authors described it as more of a "survey" than a research study, however, it was a huge wake-up call to the profession, especially coming at a time of burgeoning surgical volume. Over subsequent decades, continued research of varying quality and depth showed overall decreasing mortality rates. Bechtoldt (1981) found a dramatically lower rate of 1:24,000, with no differences noted between physician and nurse providers in a five year study in North Carolina. Though not in the United States, two French studies with similar, detailed approaches found large decreases in perioperative mortality over 20 years (M. D. A. Lienhart et al., 2006; Tiret et al., 1986). Globally, Bainbridge et al.

(2012), in an extensive meta-analysis, estimated deaths to have dropped from 375 to 34 per million anesthetics over three decades, in the developed world.

Some have contested the attribution of improvements, instead pointing out that outcomes are more likely related to either patient or surgical factors which carry far heavier weight than anesthetic management, perhaps, in itself, a testament to the quality of education of providers, and the extremely safe nature of anesthesia. Cohen et al. (1988) claimed that the most important factors associated with increased mortality were patient related, type of surgery, and emergency (vs elective) operations, and anesthesia had relatively little influence. Lagasse (2002), in an extensive review of mortality data, came to a similar conclusion. Perhaps part of the reason for some contention is that there is a wide variety of methodological approaches in the research. In addition, the low incidence of death makes it difficult to study prospectively without large, prohibitively expensive numbers. According to an AANA review (AANA, 2009), the CDC declined to pursue such a study in the 1990s after initial pilot data suggested it would require almost 300 hospitals at a cost of over 15 million dollars, at that time. From survey, to expert panel, to database review, approaches are diverse, as are definitions of anesthesia-related death. Li et al. (2009) used billing coding to define anesthesia-related which resulted in only one death per 8.2 million discharges, a notable outlier in rates. Other studies range from examining intraoperative deaths only, to any death after surgery. However, while common in the perioperative literature to look at 30 day mortality, confounding factors are only likely to multiply as time between the event (in this case, anesthesia) and death increases.

When examining differences between providers, the literature is largely consistent in discerning no difference. In addition, some research is simply unable to detect a difference, owing to the previously mentioned factors of rare occurrence and problems with the accuracy of attribution to anesthesia specifically. In the most recent work comparing providers, Dulisse and Cromwell (2010) found lower odds of death in CRNA providers working alone, across two time periods, in the early 2000s, when compared with either physicians working alone, or in a team model with CRNAs. This was in concurrence with earlier work that looked at different regions, specialties, and sample sizes (Needleman & Minnick, 2009; Pine et al., 2003). Lewis et al. (2014) reviewed multiple sources internationally, and were unable to detect increased mortality with non-physician providers. A notable exception to this work, is that of Silber (Silber et al., 2000; Silber et al., 1992). In two studies, they came to similar conclusions, that directed care, or increased numbers of Board-Certified anesthesiologists, resulted in lower death rates. Although there were some significant methodological problems in terms of assignment of patients with incomplete billing data, they did introduce an interesting concept, "failure to rescue", which examined mortality in those who experienced a complication. In their work, they tied this failure to decreased numbers of anesthesiologists, even though the "rescue" could occur days after the initial surgery. Although this may seem implausible, of note for our work is the implicit identification of hospital level factors that could affect outcomes, which has rarely been addressed.

Clearly, the use of perioperative mortality as an assessment of anesthesia quality is associated with a number of issues, including difficulties of measurement, definition, and attribution specifically to anesthesia. However, other potential quality measures are fraught with complication too. Many outcomes that could be used, such as nausea, or postoperative pain, are ethereal in terms of identification in third party payor databases, and prone to measurement error due to the subjective nature of their assessment. While many anesthesia groups are active measuring such variables in terms of Quality Improvement markers, to our knowledge, there is no large-scale research currently underway using these short-term outcomes. In an innovative approach, Dulisse and Cromwell (2010) used AHRQ PSIs to measure complication rates after anesthesia, however, their method of choice of PSIs was not clearly described, and the incidence was so low, in a database of over 480,000 that they had to pool all the indicators together to make a variable simply for complications. In that context, mortality remains a concrete, measurable outcome that can be compared to previous research, with the caveats already discussed.

Methods

In our study, we aimed to identify mortality rates associated with each kind of anesthesia model. Prior to examination of the data, approval was obtained from the UNCC Internal Review Board to proceed with the research (study # 17-0291, classified as exempt). We began with the 2013 Medicare Limited Data Set Provider files, which identify billing for all health care professionals. By using anesthesia modifiers, it is straightforward to identify anesthesia provided in a medically directed setting, and by anesthesiologists working alone as they have unique billing codes. However, since the QZ modifier can be used for both CRNAs working alone, and anesthesia care teams with low supervision, an alternate method is required to discriminate between the two. We used an approach based on that described by T. R. Miller, A. Abouleish, and N. M. Halzack (2016), using the publically available Physician Compare database. The database contains a list of all Medicare providers (includes CRNAs as well), and their practice locations. If a physician worked at more than one facility, we assigned a fraction to the facility, based on the number of facilities worked at. For example, if there were four practice locations, each would be assigned 0.25 fraction. Then, we summed the fractions to create the total number working at each location, which we named Full Time Approximation (FTA) to indicate similarity but not equivalence, with the more usual Full-Time Equivalent (FTE) acronym. We considered each provider as full-time, although it is possible that a small number of the listed physicians could be working part-time. Using this method, we divided the data into two groups of hospitals, those with an FTA of 1.0 or less, and those with an FTA of greater than 1. In our later analysis of QZ billed cases, we assigned an FTA of 1.0 or less to CRNA only practice, and greater than 1.0 to low supervision team. The decision to assign an FTA value of one or less to the CRNA only group was chosen since a single full-time physician could not be in attendance for a complete operating room schedule, covering nights, weekends, and vacations. The explanation for any physician assignment is that, in some rural facilities, an anesthesiologist is employed in a quality improvement/administrative role, for which they are not required to be involved in every anesthetic. This would explain the low FTA assignment which would only cover approximately 40 hours per week or less, certainly not enough to be available to supervise all anesthetics administered.

Having created a subset of claims that involved administration of anesthesia from the 2013 National 5% Sample Medicare Provider Limited Data Set (LDS) (as identified by seven modifiers, AA, AD, QK, QX, QS, QY, QZ, which indicate the type of provider that administered and/or supervised the anesthetic), we merged it with the 2013 Medicare Denominator File. We were now able to identify race, age and gender characteristics of the population, and date of death, if applicable. For patients who underwent surgery at the end of 2013, date of death is included up until the first quarter of 2014. We then merged this file with the National 5% Sample Medicare Inpatient LDS, but excluded long term and psychiatric facilities, and further restricted analysis to patients 65 and older. In this file, we had previously created variables for hospital characteristics, including size (by total number of beds), location (rural/urban), and teaching hospital designation from information also obtained from the 2013 Medicare Limited Data Set. In order to take into consideration pre-existing patient morbidity, we also calculated CCI scores using ICD-9 coding from the Inpatient File (Charlson et al., 1994). Higher scores on the CCI are known to be associated with increased risk of death. To allow for variations in type of procedure that could affect mortality risk, we used anesthesia base units which are allocated based on surgical complexity.

We then combined the file obtained from Medicare data with our Physician Compare subset by facility, allowing us to assign an FTA value to each facility in the Medicare combined file. Within this analytical file, we were able to create variables for each anesthesia labor model: anesthesiologist working alone (AA), medical direction (QK with QX or QY), light supervision (QZ with an FTA assignment of greater than 1), and all CRNA (QZ with an assignment of 1 or less). The QS group (a modifier for

Monitored Anesthesia Care, typically a form of sedation) was discarded because of its small size (9). Similarly, the AD modifier (theoretically designed for supervision of more than 4 anesthetists, but rarely used owing to lower overall reimbursement) was considered of insignificant size to merit further analysis alone, but was added to the light supervision group, since by definition it is used only where a physician is supervising more than four CRNAs, and is not required to be present at critical points during the anesthetic. Finally, we created a hospital level analysis file, which contained the number of deaths within 48 hours after surgery for each facility, as well as the number of anesthesia cases, mean CCI score, mean age, anesthesia model, and hospital characteristics.

Results

Initial analysis was at the provider level, and began with 790,684 claims from the 2013 Medicare Limited Data Set Provider files, 5% sample. We began with this set to identify anesthesia claims only, and retained all that had any of the seven anesthesia modifiers that indicate different labor models, in addition to QS, a rarely used indicator for sedation (AA, AD, QK, QX, QY, QS, QZ). Subsequently, we merged the file with the 2013 Medicare Denominator file, which contains a complete listing of all patients including date of death (if applicable) and demographic details. We included patients 65 and older who were seen at acute, inpatient facilities, which left a sample of 123,175 cases. However, owing to incomplete billing data, such as CRNA modifier missing for a medical direction billing code from physician, we were left with 115,119 cases. Tables 1-4 show distribution of cases by anesthesia model across different types of hospitals.

Table 3.1: Number of cases by anesthesia labor model (% of total cases

	PHYSICIAN ONLY	HIGH SUPERVISION (MEDICAL DIRECTION)	LOW SUPERVISION (QZ TEAM)	CRNA ONLY
NUMBER OF CASES	48270 (41.9)	45161 (39.2)	18068 (15.7)	3620 (3.1)

Table 3.2: Distribution of cases by anesthesia model in different hospital types (% of total cases for each model)

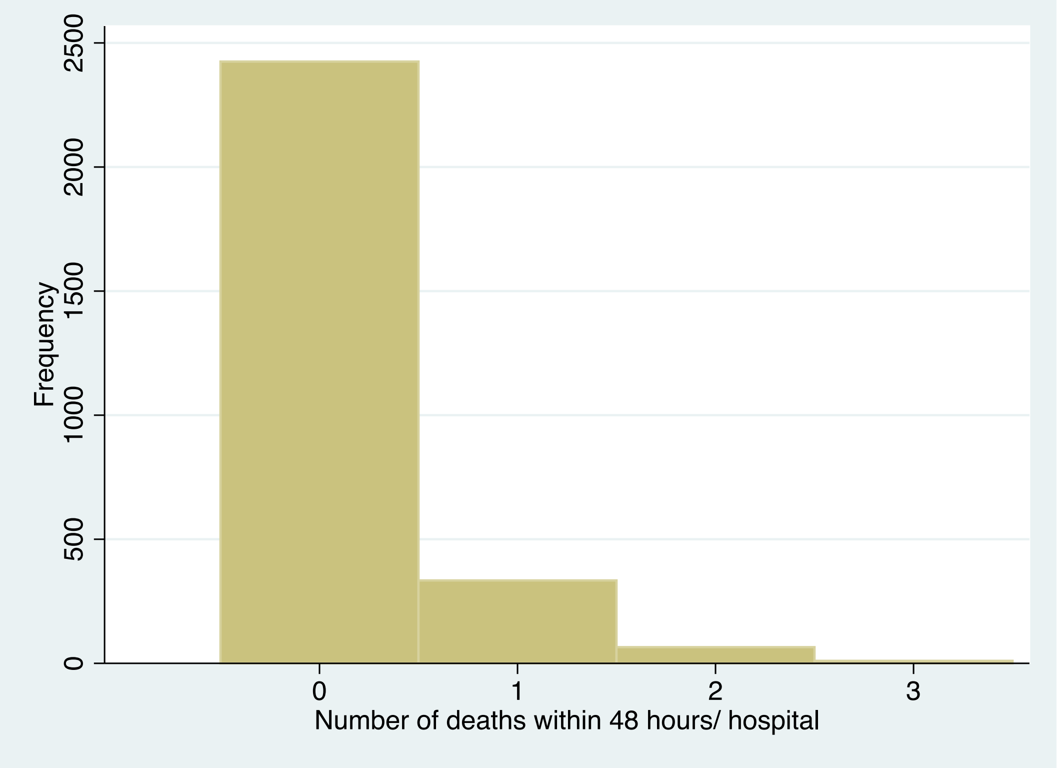
	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY	TOTAL CASES (%)
RURAL	2601 (5.4)	3735 (8.3)	1892 (10.5)	2269 (62.7)	10,497 (9.1)
URBAN	45669 (94.6)	41426 (91.7))	16176 (89.5)	1351 (37.3)	104,622 (90.9)
TEACHING	26177 (54.2)	27630 (61.2)	8153 (45.1)	349 (9.6)	52,810 (45.9)

Table 3.3: Distribution of cases by anesthesia model across varying hospital sizes (% of total cases for each model)

	PHYSICIAN ONLY	HIGH SUPERVISION	LOW SUPERVISION	CRNA ONLY	TOTAL CASES (% OF TOTAL)
SMALL (<50 BEDS)	1033 (2.1)	481 (1.1)	510 (2.8)	843 (23.3)	2867 (2.5)
MEDIUM (50-100 BEDS)	2664 (5.5)	2188 (4.9)	1175 (6.5)	1312 (36.2)	7339 (6.4)
LARGE (>100 BEDS)	44502 (92.3)	42465 (94.1)	16377 (90.7)	1465 (40.5)	104,809 (91.1)

The file used for death rate analysis was organized by hospital, with a total of 3358 facilities. This reflected 93,516 patients, as some had surgery on more than one occasion. Unfortunately, a significant number of facilities had to be eliminated owing to lack of anesthesia cases from the carrier file, leaving a final count of 2834 hospitals in the file used for count analysis. Fig 1 shows the 48 hour death rate counts over the sample. The mean count was 0.1743 with a standard deviation of 0.4594. As expected, zero was the commonest value by far, given that death after surgery is rare.

Figure 1: Number of deaths within 48 hours of anesthesia, per hospital



We considered both Poisson and negative binomial regression as a method of analysis. Since the mean of our dependent variable- the count of deaths within 48 hours after surgery over a one year period- was 0.174, and the variance was 0.211, we concluded that there was no overdispersion, and Poisson would be the best fit. Given the large number of zero counts, a zero-inflated Poisson model could be an option; however, the choice of this model requires that there be a grouping within the population who always score zero for reasons other than that predicted by the Poisson distribution, for example, patients who did not have surgery. In our analysis, this is not the case, and modelling with zero-inflated Poisson produced non-significant matching with our data (p= 0.992).

Using anesthesia labor model, hospital characteristics, age, surgical complexity, CCI, and number of cases as predictor variables, many variables were significant (see Table 4). In comparison to the physician only model, which we used as a referent group, either form of supervision had increased counts of death, though not CRNA only. There was no difference between rural and urban, but large hospitals had much higher predicted counts than other sizes, with a rate ratio three times higher than small hospitals. Similarly, teaching hospitals are predicted to have higher counts than non-teaching. Given that CCI has been shown to predict mortality, it was not surprising to see a rate ratio of 1.21, reflecting 21% additional deaths per year for every one unit increase in the average CCI score per hospital. Increased age, surgical complexity (base units), and number of cases all had slightly higher than predicted counts of death.

Table 3.4: Incident rate ratios (IRR) for predictor variables with outcome of death within 48 hours ([1]referent group=physician only;[2]referent group=rural hospital; [3]referent group=small hospital;[4]referent group=non-teaching hospital)

	IRR	**STD ERROR**	**Z**	**P>|Z|**	**95% CI**	
HIGH SUPERVISON[1]	1.42	0.22	2.21	0.03	1.04	1.93
LIGHT SUPERVISION[1]	1.77	0.27	3.69	0.00	1.31	2.39
CRNA ONLY[1]	1.45	0.31	1.75	0.08	0.96	2.21
URBAN HOSPITAL[2]	1.09	0.23	0.45	0.65	0.73	1.65
MED. SIZE HOSPITAL[3]	1.44	0.69	0.76	0.45	0.56	3.71
LARGE HOSPITAL[3]	3.35	1.42	2.86	0.00	1.46	7.69
AGE	1.04	0.02	2.23	0.03	1.01	1.08
BASE UNITS	1.08	0.04	2.05	0.04	1.00	1.17
CCI	1.21	0.06	3.64	0.00	1.09	1.33
CASES	1.01	0.00	10.01	0.00	1.01	1.01
TEACHING HOSPITAL[4]	1.44	0.17	3.04	0.00	1.14	1.82

It is important to remember that our model reflects change at the hospital level, not patient, so IRR for continuous values such as age or CCI are based on the mean for that variable at a given hospital.

Discussion

Historically, there is little question that anesthesia is extremely safe, and most researchers have found no, or minimal, difference in mortality rates between different providers (Dulisse & Cromwell, 2010; Lewis et al., 2014; Pine et al., 2003). To date, however, limited attention has been paid to practice type and location while conducting these analyses. Previous researchers have chosen to aggregate patients grouped by anesthesia model, but this does not fully allow for the possibility that there are other, hospital-level, factors that could be influencing perioperative mortality. In addition, it does not consider the fact that anesthesia models likely have characteristic patterns of dispersion by types of facility. While controversial owing to a number of methodological errors, Silber et al. (2000) identified "failure-to-rescue" as a possible etiology for increased death rates. They tied this concept to anesthesiologist intervention, but there is little reason to expect that an anesthesiologist would be involved with medical management of a perioperative patient 48 hours after surgery. However, it seems plausible that there could be variation between facilities in the level of intervention by other medical or nursing specialties, to the extent that it could affect outcomes. Our initial analysis showed the largest individual factor in increased 48 hour mortality rates to be hospital size, specifically large hospitals (> 100 beds) which had an Incident Rate Ratio of 3.35 compared with the referent small hospital group (<50 beds). Interestingly, that would suggest that while larger hospitals may have access to greater resources, that alone is not enough to reduce perioperative mortality. The factors that are causing this increase are unknown, but clearly significant since this was the largest value seen in our model. Similarly, teaching hospitals, that might be expected to have more complex surgeries and sicker patients, but a more extensive, and highly trained staff, had an IRR of 1.44 when compared with non-teaching facilities.Although our model attempted to control for morbidity and surgical complexity, it is possible that our measures did not accurately represent these factors. We also found an increased IRR in both supervised anesthesia models, 1.42 and 1.77 for high and low levels respectively. This would suggest that less supervision is associated with increased mortality, however, CRNAs working with no supervision had non-significant changes in IRR for death counts. Perhaps addition of another provider does not increase safety, but has the potential to add complication by creating two strands to clinical decision making, or risks omission of key tasks due to incomplete assignment of responsibility, our data is unable to detect the precise reason. Importantly, although physician-dominant models are clearly dominant in urban and larger hospitals, there was no collinearity noted between anesthesia model and hospital characteristics. It is unknown from this analysis if there are other factors associated with the use of different models across hospitals that may be affecting mortality rates after anesthesia. Studnicki et al. (2014) have shown that complex surgeries tend to be associated with larger hospitals, and that mortality rates are similar on that basis. However, they were unable to address low volume complex surgeries carried out in smaller hospitals. In the context of a specialty that is known to have extremely low mortality rates, if particular anesthesia models were associated with hospitals that had low volume, high-risk surgery with limited post-surgical resources, there is potential for significant inflation of the mortality rate, as an example.

Limitations

Our work has several limitations. Identification of low supervision is imperfect; while being able to ascertain practice locations, we cannot establish how much time is spent at each facility, to truly establish FTE status. In addition, there are a large number of physicians missing from the Physician Compare database, which could mean there are additional facilities that are operating in a low supervision mode. There are a small number of AAs practicing throughout the US, so we may have attributed some medical direction cases to CRNAs, when they were in fact AAs. Given that AAs represent a tiny proportion of the anesthesia workforce overall, and that they can only bill for services as medical direction, we anticipate the effect, if any, would be very small. Although we essentially counted all deaths as anesthesia related, it is possible that some had no connection to anesthesia, and were a result of surgical mishap, or traumatic injury, for example. In that respect, we potentially overcounted deaths attributable to anesthesia.

As with any secondary data, there is the possibility of errors in coding or entry. In particular, the possibility of missing or inaccurate anesthesia billing information could alter the composition of any of the four billing groups used in the analysis. Our assumption is that most providers strive to enter such information as quickly and as accurately as possible to maximize revenue. We know that CRNA only data is likely undercounted, since critical access hospitals have the ability to bill for CRNA services through Part A, which would not be identified by our analysis.

Conclusion

Our data shows perioperative anesthesia mortality rates are not only higher in large hospitals than small, but that this factor has the largest predicted effect. In addition, we noted increased mortality with supervised models compared to unsupervised, but the reason for this is unknown. It could possibly be process-related to having two providers, or an unmeasured hospital characteristic associated with the distribution of models. Given that multiple previous studies have been unable to show significant differences in mortality between providers, and that hospital characteristics have larger effects on predicted mortality counts, future work might focus on hospital-level factors as a source of increased death rates after surgery rather than ratios of anesthesia providers.

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Overall Conclusions

Anesthesia is often likened to the airline industry, owing to its careful focus on safety. A large body of research over many decades has shown a pattern of decreases in patient mortality, with improved quality of care for more short-term outcomes such as post-operative pain and nausea. However, as the US healthcare system expenditures climb inexorably higher, it is not enough to simply demonstrate good results: instead, providers must also be conscious of the cost of achieving high quality care. Quraishi and Jordan (2017) have identified that there has been an increasing trend in the use of CRNAs, in recent years, but it is unclear whether this is as part of a loosely supervised team, or working independently (Byrd et al., 2011). In this work, we sought first to identify the distribution of cases between team practices, and independent, CRNA or physician only groups. Additionally, although it has been shown that CRNAs live and so presumably work in rural areas at greater rates than physicians, we were able to describe the practice patterns of all four major anesthesia labor models in terms of multiple hospital characteristics. We identified that close to 16% of anesthetics given in 2013 to the elderly, Medicare population were within a loosely supervised team, as opposed to 39% in a highly supervised one. The remainder of cases were administered by either physicians or CRNAs working alone. We also noted that race and age showed similar dispersion regardless of anesthesia model, though the CRNA only group was slightly older and whiter than the others. The biggest difference was in hospital characteristics: CRNA only cases were carried out 63% of the time in rural hospitals, as compared to 5% for physician only. Likewise, physician only cases in teaching hospitals were 54% of total, as opposed to CRNA only who administered over 90% in a non-teaching facility.

Finally, all CRNA models carried out 23 % of their cases in small hospitals, whereas high supervision groups were around 1%. In general, the supervised settings were similar to physician-only in their practice characteristics, whereas the all CRNA model was predominantly found in rural and small hospital settings.

Secondly, another area that has not previously been studied in depth, is the kind of patients being taken care of by different anesthesia models, which was described by anesthesia base units (a proxy for surgical complexity), and CCI (to represent comorbidity). As had been shown by other researchers (Dulisse & Cromwell, 2010), anesthesia base units were highest in the physician only model; a new result was to show that CCI scores were also increased. However, the differences, while statistically significant were small: about 1.5 units for complexity, and 0.34 for CCI was the largest difference between groups, but some were as small as 0.23. Such a small difference could reasonably be questioned as to its clinical significance, in particular when considered in the context of the skewing of physician only or physician directed cases to urban, large, teaching hospitals that might reasonably be expected to have more complex surgeries, and sicker patients. Hence, multiple regression was used to get a sense of the association of different factors with both surgical complexity and comorbidity, first with individual independent variables, and then with the addition of interaction variables between hospital characteristics and anesthesia model. There was no association found between anesthesia labor model and either surgical complexity or comorbidity, when interactions were considered. Our work suggests there is little overall difference between either the acuity, or the surgical complexity of patients cared for based on the anesthesia model used.

Finally, we examined outcomes for different models, as measured by 48 hour mortality after anesthesia. Given that our earlier analyses suggested significant hospital level variation in the distribution of different models, the analysis took a different approach from previous work, which has been patient level, and examined it from a hospital perspective. Again, once hospital level characteristics were accounted for, there was no difference in death counts between anesthesia models, and even without accounting for these effects, only supervised models showed increases in mortality.

Future research

Although using Physician Compare was a useful start to determining the type pf anesthesia staffing, the technique is prone to several potential errors: firstly, it is not a complete listing of all physicians, and secondly, there is no way of knowing how much time is apportioned to each practice setting. In the ideal world, the creation of a new modifier that would indicate team care with low levels of supervision, would allow for easy identification, however, this is not likely in the foreseeable future. Alternatively, a larger scale study that could survey practices regionally, and confirm the type of practice directly would allow for certainty in categorization of models, and consequently, more accurate data. In addition, a longer time period would allow for a larger sample, and more accurate predictions. Possibly, one could consider a natural experiment, such as is about to occur locally in Charlotte, NC, in which a major health system transitions from a medically directed model to low supervision, allowing for analysis prospectively of the new system, while using existing records to examine retrospective data.

It would also be helpful to have better comorbidity data: while CCI is universally acknowledged as a risk stratification tool, it is not a common approach to perioperative research. The wide spread of potential scores, while simultaneously aggregating around the lower range, risks overlooking the contribution of sicker patients at certain facilities. Another possibility would be to use the van Walraven modification of the Elixhauser scoring system, which might give more accurate data, but is more complex to use (van Walraven et al., 2009). Similarly, the use of an alternate system of assessing surgical complexity, such as the VA categorization, could validate the results seen in the second paper.

There is purposefully no analysis of outpatient anesthesia in this study, since that population is healthier, and consequently less prone to complications in general, mortality in particular. However, a larger study could examine this population too, since it is larger proportion of all surgery carried out in the United States, and hence has more implications for the system as a whole. At the other extreme, closer analysis of high risk surgery, such as cardiac, could prove fruitful owing to the higher incidence of mortality, although the perennial problem of separating anesthesia issues from surgical could prove especially thorny in this field.

Policy implications

At this time, anesthesia labor models are close to a critical juncture: in addition to the spotlight on expenditure on health care spending in general, there is an ongoing consolidation of employment, by a combination of large health care systems, and for profit national medical groups (Galinanes, 2012). When both CRNAs and anesthesiologists are employed by the same entity, who does not have a vested interest in protecting the income or power of either, there is an opportunity to experiment with new staffing models. There has been little convincing data at any time, but during the last few decades in particular (when techniques have become more sophisticated), to suggest that there are significant differences in outcomes between the two major providers of anesthesia care in the United States, and these results are confirmed by this analysis. In addition, there is little evidence of significant differences in the patient population cared for, regardless of the level of physician involvement. However, the research carried out in this dissertation suggests that there are significant differences between the distribution of providers across hospitals, and these differences, or other as yet unmeasured properties, may be the more important contributor to alterations in perioperative mortality. The financial implications of moving to an anesthesia workforce with fewer physicians are significant (Hogan et al., 2010); if there is no logical reason to maintain current numbers, the recommendation of this study is to move to a system with higher utilization of CRNAs in all settings.

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