

# Differentiating among Hospitals Performing Physiologically Complex Operative Procedures in the Elderly

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**Background:** The authors previously showed how a statewide discharge abstract database could be used to quantify for stakeholders how surgical practices differ among hospitals. The two pediatric hospitals in Iowa differ from other hospitals in Iowa based on their providing a more diverse, comprehensive, and physiologically complex selection of procedures in younger patients. Physiologically complex surgery performed in children aged 0–2 yr has been regionalized to a few high-volume facilities.

**Methods:** The same inpatient discharge abstract database was used to quantify physiologically complex operative procedures performed throughout Iowa in patients aged 80 yr and older during January through June 2001.

**Results:** In contrast to earlier results with pediatric patients using the same database, hospitals performing physiologically complex procedures in the elderly could not readily be differentiated from one another based on the numbers and types of procedures performed ( $P < 0.001$  when comparing geriatrics vs. pediatrics in terms of the distributions of numbers of procedures, the distributions of numbers of different types of procedures, or the distributions of numbers of rare procedures performed at different hospitals). Additional analyses showed that one hospital did perform relatively more rare procedures in geriatric patients and had a relatively larger percentage of patients who traveled beyond their local county to reach it.

**Conclusions:** Results observed for geriatric patients provide further evidence of the validity of these methods and the usefulness of discharge abstract data for comparing surgical practices among facilities. A hospital can use discharge abstract data to assist governmental agencies, charitable organizations, philanthropists, insurers, etc., in appreciating the unique contributions of individual hospitals to surgical care.

THE vibrancy of an anesthesia group is inextricably linked to the financial strength of the hospitals where its providers practice. Financially strong hospitals can make capital improvements (e.g., buy anesthesia information management systems), grow thriving surgical practices (e.g., provide sustained business to the anesthesia group), provide poorly compensated community benefits (e.g., support research), and give institutional financial support to professional practices (e.g., academic anesthesia training programs<sup>1</sup>). Anesthesiologists in lead-

ership positions can participate in efforts to maintain the financial strength and volume growth of hospitals by assisting in hospital marketing efforts.

Hospitals providing surgical care to patients often market themselves directly to customers and stakeholders. Stakeholders include not only patients and referring physicians, but also governmental agencies, charitable organizations, philanthropists, insurers, and others who may provide financial support. As part of their marketing efforts, hospitals may want to differentiate themselves by showing that their services or physical facilities are unique or in some way differ from those of other hospitals.

We previously<sup>2</sup> described how a surgical facility can analyze and use discharge abstract data to provide stakeholders with supportive data showing how it differs from other facilities and how it uniquely serves the healthcare needs of its community. We found that (1) 98% of physiologically complex operative procedures in infants and young children in the State of Iowa were naturally regionalized to only three facilities, two of which are pediatric hospitals; (2) the two pediatric hospitals in Iowa could be differentiated from the other 117 hospitals and hospital-affiliated ambulatory surgery facilities in the state based on their providing a more diverse, comprehensive, and physiologically complex selection of procedures; (3) the two pediatric hospitals could be differentiated from one another and were no more similar to each other in the relative volumes of each type of procedure than they were to other hospitals in the state; and (4) one hospital, the larger pediatric hospital, was clearly dominant, performing 64% of all physiologically complex procedures in infants and young children statewide.

To provide a further test of the usefulness of discharge abstract data for this application and the validity of the methodology used to analyze the data, we performed a similar analysis of the same 6 months of data on a different age group, geriatric patients. We chose the geriatric age group because we expected the results to differ from those obtained previously.

Because of barriers to regionalization of care in elderly citizens, we predicted that more surgery would occur at locations closer to patients' homes and that no single hospital would be as dominant in performing a large fraction of physiologically complex procedures statewide. Barriers to regionalization include primary care

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physicians' referrals to local surgeons<sup>3</sup> and older patients' reluctance to travel.<sup>4-6</sup> For example, many elderly patients undergoing pancreatectomy would prefer to have surgery locally, even if travel to a regional center would lead to a lower operative mortality risk.<sup>5</sup> Thus, the geriatric data provide a good test of the applicability of these methods to a broad range of data.

In addition, we extended the methodology used previously to examine additional criteria that a hospital might use to differentiate itself from other hospitals: rare procedures and traveling distances. Use of these additional criteria enhances the utility of discharge abstract data for generating information a hospital can use to set itself apart from other hospitals within its region.

## Methods

Some of the methods have been reported previously for the analysis of pediatric data (ages 0–2 yr).<sup>2</sup> Use of rare procedures and traveling frequencies are reported for the first time.

### Databases

As in the pediatric study, we used the State of Iowa inpatient and outpatient discharge abstract databases, January 1, 2001, to June 30, 2001. The discharge abstract databases included the cases performed in every nonfederal hospital and hospital-affiliated outpatient surgery center statewide. Procedures and diagnoses were coded by each facility using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). The databases included county of patient residence.

### Operative Procedures

We analyzed 8,584 inpatient admissions and 6,947 outpatient visits among patients aged at least 80 yr with an operating room or anesthesia charge (see table 1 for descriptive statistics from the database). As in the pediatric study, we analyzed only "operative procedures." Diagnostic procedures (ICD-9-CM 87.0 and greater) were excluded. Like the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System,<sup>7</sup> we added the requirement that an incision be made for a procedure to be operative (e.g., cardiac catheterization [37.23] and cardiopulmonary bypass [39.61] were excluded).

### Physiologic Complexity of Procedures

Because the pediatric data showed that hospitals could be differentiated based mainly on the physiologically complex procedures they performed,<sup>2</sup> only procedures considered physiologically complex were included in this analysis. A procedure was considered physiologically complex if it had 8 or more basic units according to the American Society of Anesthesiologists (ASA) Relative

**Table 1. Summary of Geriatric and Pediatric Discharge Data**

	Geriatrics	Pediatrics
Operative procedures	15,556	5,671
Physiologically complex procedures	2,399 (25)	242
Different types of physiologically complex procedures	124 (6)	70
Admissions involving at least one physiologically complex procedure	1,894 (4)	145
No. of facilities performing one or more physiologically complex procedures	62 of 119	6 of 119
< 13 procedures	39	3
13–28	0	1
29–50	6	0
51–100	9	1
> 100	8	1
Rare physiologically complex procedures	376 (22)	231

Description of dataset for patients aged 80 yr and older derived from the State of Iowa inpatient and outpatient discharge abstract databases, January 1, 2001, to June 30, 2001. Pediatric data for children aged 0–2 yr from the same databases are shown for comparison; some of the pediatric data have been published previously.<sup>2</sup> Numbers in parentheses represent operative procedures and corresponding admissions whose physiologic complexity could not be determined. A physiologically complex procedure was considered rare if it was performed fewer than 125 times in the entire state during the 6-month period for all ages combined, equivalent to once per working day.

Value Guide<sup>8-10</sup> (RVG). For example, laparoscopic cholecystectomy (7 units) was not included. Hip replacement (8 units), carotid artery bypass (10 units), lung lobectomy (13 units), and abdominal aortic aneurysm resection (15 units) were all included.

The ASA Crosswalk provides ASA RVG basic units based on Current Procedural Terminology (CPT) codes. Because the discharge abstracts use ICD-9-CM procedure codes, ICD-9-CM codes were first converted to CPT codes as described previously.<sup>2</sup>

Although each ICD-9-CM code frequently corresponded to multiple CPT codes, almost all relevant CPT codes had either 7 or fewer basic units or 8 or more ASA RVG basic units. Thus, the physiologic complexity of a given procedure was usually clear.

When the physiologic complexity of a procedure was not clear, physiologic complexity could usually be determined using the patient's other procedure codes or diagnosis codes. For example, vagotomy (ICD-9-CM 44.0) would not be considered physiologically complex if performed through an abdominal approach (CPT 64760) but would be physiologically complex when performed using a transthoracic approach (CPT 64752). If concomitant procedure codes involved gastric or bowel surgery, we assumed the approach was abdominal and considered the procedure to have been not physiologically complex.

For some procedures, physiologic complexity could not be determined from the discharge abstract database because insufficient information was available. An exam-

ple is removal of heart assist device (ICD-9-CM 37.64). Corresponding CPT-4 codes range from percutaneous removal of intraaortic balloon assist device (33968, 3 ASA RVG basic units) to removal of intraaortic balloon assist device from the ascending aorta, including repair of the ascending aorta, with or without graft (33974, 15 ASA RVG basic units). If additional information describing the exact procedure was not available, physiologic complexity was unknown.

The number of procedures whose physiologic complexity could not be determined is shown in table 1. These procedures were not included in the values reported in the Results. However, all statistical results for comparisons between groups were repeated with the inclusion of these additional procedures and the assumption that they were all physiologically complex. All comparisons of geriatric *versus* pediatric patients remained  $P < 0.001$ , and all comparisons among hospitals remained  $P < 0.05$  (multiple-comparison adjusted).

#### *Number of Different Types of Procedures and the Internal Herfindahl Index*

The diversity or comprehensiveness of the types of procedures performed at a facility can be quantified by the internal Herfindahl index.<sup>2,11</sup> The internal Herfindahl index equals the sum of the squares of the proportions of all procedures at a facility that are accounted for by each type of procedure. That is, it equals the probability that if two procedures are selected at random, both will be of the same type.

For example, suppose that a facility performed three types of procedures in relative proportions of 50%, 40%, and 10%. Then the internal Herfindahl index would equal 0.42, where  $0.42 = (0.50)^2 + (0.40)^2 + (0.10)^2$ . If a facility performed three types of procedures in relative proportions of 93%, 5%, and 2%, the internal Herfindahl index would equal 0.87, where  $0.87 = (0.93)^2 + (0.05)^2 + (0.02)^2$ . Although both facilities performed the same number of different types of procedures, the second facility is less diverse because the proportions of each type of procedure are less balanced.

#### *Distribution of Procedures among Hospitals and the Herfindahl-Hirschman Index*

The degree of concentration of discharges among hospitals in a given market is often quantified using the Herfindahl-Hirschman index.<sup>12</sup> This is identical to the internal Herfindahl described above but is applied externally rather than internally. We used the Herfindahl-Hirschman index to compare the concentration of physiologically complex procedures in pediatric patients *versus* geriatric patients among hospitals. The index for each group of patients was calculated by summing the squares of the proportions of all physiologically complex procedures statewide that were performed at each facil-

ity. The index is thus a larger number when procedures are concentrated at fewer facilities.

#### *Rare Physiologically Complex Procedures*

A physiologically complex procedure was considered rare if it was performed less than 125 times in the entire state during the 6-month period for all ages combined. We thus studied procedures that were performed an average of less than once per working day at all hospitals in the entire state, assuming 250 elective working days per year. Because there were almost 217,700 operative and nonoperative procedures performed statewide in the 6-month period, a frequency of 125 times in 6 months represents 0.06% of all procedures.

#### *Frequency of Patient Traveling*

We quantified the percentage of patients who had physiologically complex surgery in Iowa but outside of their home county or a county contiguous to their home county. Unlike estimating travel distances or times based on using zip codes, this statistic is not highly skewed by patients who travel particularly long distances.<sup>13</sup> In addition, it was not affected by censoring or by missing values arising from patients traveling from another state into Iowa for their surgery.<sup>14</sup>

#### *Statistical Analysis*

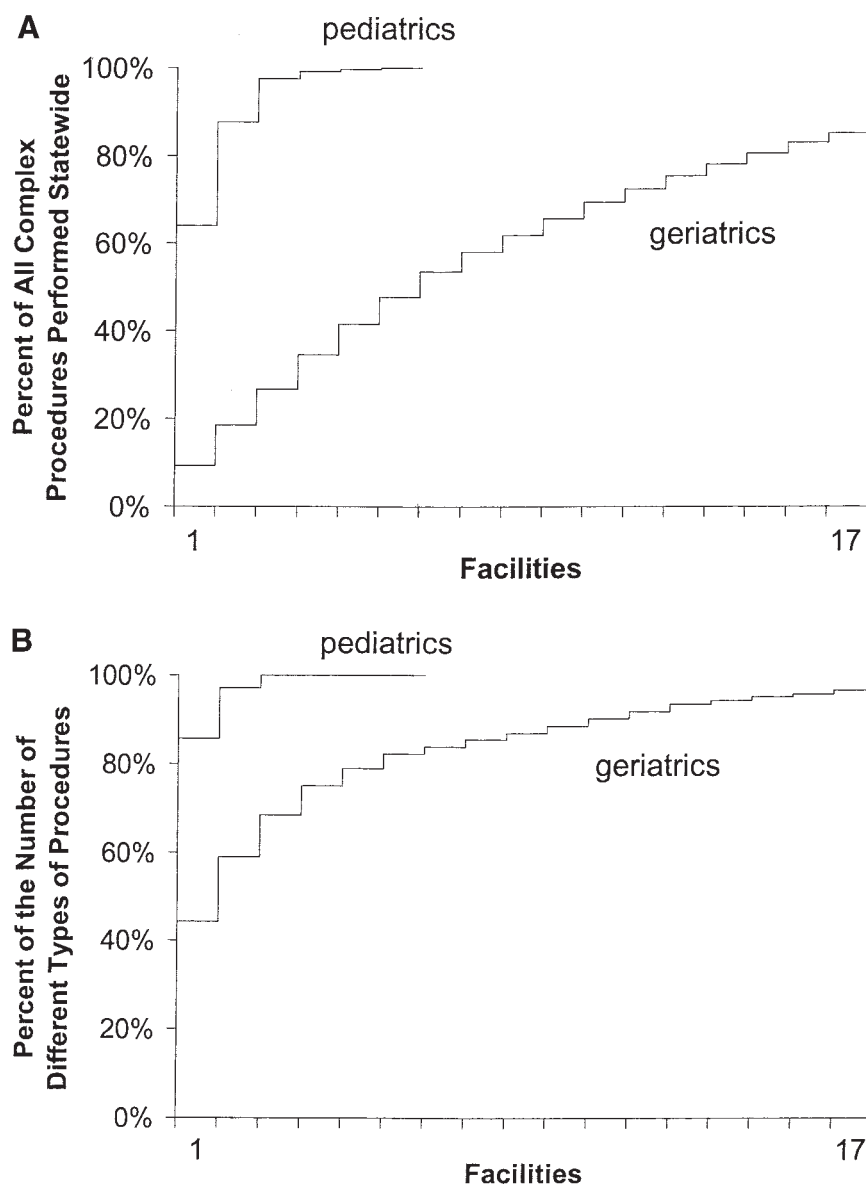
StatXact-5 was used for all calculations (Cytel Software Corporation, Cambridge, MA). All  $P$  values were calculated using exact methods.

The Kolmogorov-Smirnov method was used to compute two-sided  $P$  values comparing geriatrics and pediatrics in terms of the percentages of physiologically complex surgeries statewide that were performed at the different facilities. This method compares the cumulative probability distributions (*i.e.*, the analysis is not paired by hospital but uses two independent groups). The same analysis was used to compare the proportions of the number of different types of procedures and the proportions of rare procedures performed at the different facilities.

Specifically, we used the Kolmogorov-Smirnov method to compare the two age groups based on the 17 facilities performing the highest volume of physiologically complex surgery, the 17 facilities that combined to perform the greatest number of different types of procedures, and the 17 facilities performing the greatest number of rare procedures. For each comparison, the same 17 facilities were used for each age group. Seventeen was chosen because that is the number of hospitals that performed 50 or more physiologically complex procedures in geriatric patients. For pediatrics, the 17 facilities included 6 hospitals that performed physiologically complex surgery and 11 hospitals that performed no physiologically complex procedures in pediatric patients. For



Fig. 1. (A) Cumulative distributions showing the number of physiologically complex procedures performed at each facility as a percentage of the total number performed in the entire state.  $P < 10^{-5}$  when comparing geriatrics and pediatrics based on the cumulative distribution of procedures (top 17 facilities in each group). If the 25 geriatric procedures of unknown complexity were included in the figure, the plot would be indistinguishable from that shown. (B) Cumulative distributions showing the number of different types of physiologically complex procedures performed at each facility as a percentage of the total number performed in the entire state. For geriatrics, data are shown for the 17 hospitals that combined to perform the greatest number of different types of procedures; 15 of these 17 hospitals also performed 50 or more physiologically complex procedures. For pediatric patients, all types of physiologically complex procedures were performed at only 3 hospitals.  $P < 10^{-5}$  when comparing geriatrics and pediatrics based on the cumulative distribution of number of different types of procedures (top 17 facilities in each group).



clarity, those 11 hospitals are not shown on the cumulative distribution plots of figures 1 and 2.<sup>‡</sup>

The SEs of the Herfindahl-Hirschman index and  $P$  values for comparing age groups were calculated as derived by Taplin.<sup>15</sup>

One-sided  $P$  values comparing hospital G to the other

<sup>‡</sup> In the figures showing cumulative distributions, plotting the 17 hospitals that performed the greatest number of procedures in each category along the horizontal axis and numbering them 1-17 is equivalent to plotting a percentage of the number of hospitals. Calculation of percentages simply divides all values by a fixed number. Regardless of whether that fixed number is chosen to be 119, 62, or 17, the graph is unaffected. Only the labels on the axis would change.

§ Barnard's test compares proportions from multiple groups (*i.e.*, different hospitals) with one control group (*i.e.*, hospital G). The  $P$  value adjustment was used because of the multiple comparisons made with one hospital. Previous simulation studies<sup>17</sup> showed that the resulting  $P$  values are conservative estimates.

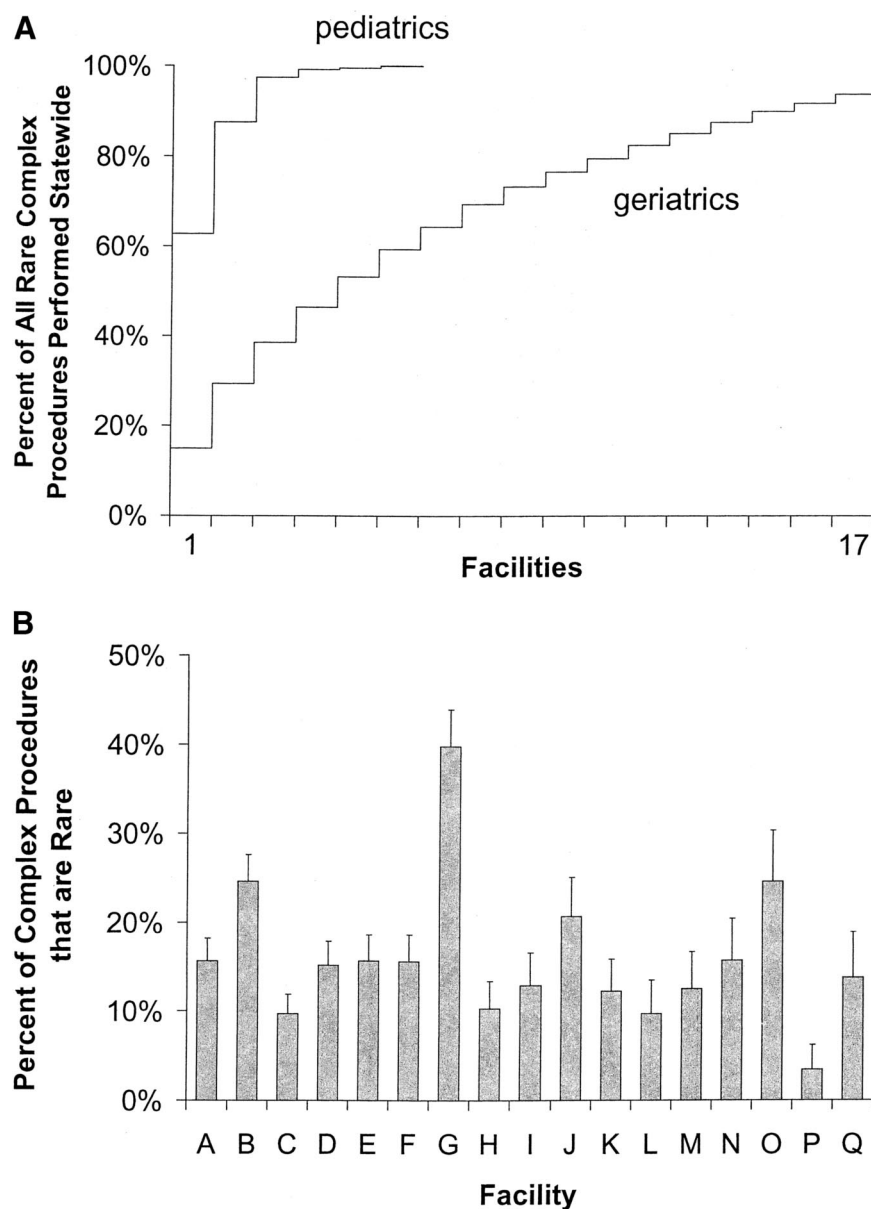
|| A one-sided test was used because the question was whether hospital G performs a disproportionately large percentage of rare procedures *versus* other hospitals. A disproportionately small percentage would be of no relevance.

16 hospitals performing 50 or more physiologically complex procedures were calculated by applying the Bonferroni-Holm adjustment procedure<sup>16</sup> to Barnard's<sup>17</sup> test. § Hospital G was chosen for comparison|| because it is the same facility as the larger pediatric hospital that was so unique in the pediatric study.<sup>2</sup> The same analysis was used to compare hospital G to other hospitals with respect to the percentage of patients traveling to each hospital for physiologically complex surgery from a county not contiguous to that hospital's county.

## Results

Basic findings and statistics describing the data are presented in table 1.

Of Iowa's 119 hospitals and freestanding hospital-affiliated outpatient surgery centers, 62 hospitals performed



**Fig. 2.** Physiologically complex procedures that are also rare (*i.e.*, performed an average of less than once per working day statewide in any age group). (**A**) Cumulative distributions showing the number of rare physiologically complex procedures performed at each facility as a percentage of the total number performed in the entire state. For geriatrics, 16 of the 17 hospitals shown also performed 50 or more physiologically complex procedures.  $P < 10^{-3}$  when comparing geriatrics and pediatrics based on the cumulative distribution of procedures (top 17 facilities in each group). (**B**) The number of rare physiologically complex procedures performed at each facility, reported as a percentage of the total number of physiologically complex procedures performed at that facility. The 17 hospitals that performed 50 or more physiologically complex procedures in geriatric patients are labeled A–Q and are listed in decreasing order of the total number of physiologically complex procedures performed. For hospital G, adjusted  $P < 0.05$  when compared to each of the other hospitals. Vertical bars are  $\pm$  SE.

at least one physiologically complex procedure during the 6-month period in elderly patients (aged  $\geq 80$  yr). Seventeen hospitals performed 50 or more physiologically complex procedures, accounting for 85% of all such procedures statewide.

#### Numbers of Procedures

The highest volume hospitals all performed a comparable number of procedures. In figure 1A, the total number of physiologically complex procedures performed statewide is shown cumulatively for the 17 hospitals performing 50 or more such procedures in geriatric patients. For each group, the total percentage is shown combined as each successive hospital is added to the total. As expected, procedures for geriatric patients were distributed uniformly among multiple hospitals

throughout the state, with no one or two hospitals dominating.

These results provide a striking contrast to the pattern observed for pediatric patients. For comparison, figure 1A also shows data for all of the hospitals performing physiologically complex procedures in pediatric patients (aged 0–2 yr). For pediatric patients, only a few hospitals statewide performed any physiologically complex surgery, and one hospital performed the majority of physiologically complex procedures (64%) ( $P < 10^{-5}$  when comparing geriatrics and pediatrics based on the cumulative distribution of procedures using the top 17 facilities in each group, including 11 hospitals for pediatrics that performed no physiologically complex procedures; the 17 facilities compared were the same for both age groups).

The Herfindahl-Hirschman index<sup>12</sup> provides another method for quantifying the distribution of procedures among hospitals. Larger values of the index mean that the concentration of procedures is greater (*i.e.*, more procedures are performed at fewer hospitals). The unbiased estimator<sup>15</sup> for the Herfindahl-Hirschman index was  $0.073 \pm 0.001$  for geriatric surgery and  $0.48 \pm 0.03$  for pediatric surgery ( $P < 10^{-5}$ ) based on the 17 hospitals performing at least 50 physiologically complex procedures in geriatric patients. The  $P$  value was also less than  $10^{-5}$  when comparing all 62 hospitals performing physiologically complex surgery or all 119 facilities in the state performing surgery.

### *Different Types of Procedures*

Not only did multiple hospitals throughout Iowa perform physiologically complex procedures on elderly patients, but those hospitals also performed a variety of different types of procedures. The internal Herfindahl index is a useful measure of the diversity and comprehensiveness of the types of procedures performed. Rather than providing a simple count of the number of different types of procedures, the internal Herfindahl index also considers the number of times each procedure was performed. The smaller the index, the greater is the number of different procedures performed and the more balanced are the proportions of the different procedures. Sixteen of 17 hospitals performing 50 or more physiologically complex procedures in elderly patients had index values less than 0.2, indicating they performed many different types of procedures, each at a relatively low frequency. For all types of pediatric surgery, only the larger pediatric hospital had an internal Herfindahl index less than 0.2. In fact, the highest volume facility for pediatric patients performed only 7 different types of procedures, compared with 181 for the hospital that performed the most different types.<sup>2</sup>

A total of 124 different types of physiologically complex procedures were performed statewide in geriatric patients. No one or two hospitals accounted for the majority of different types of procedures, and many hospitals performed types of procedures that others did not. Figure 1B shows the cumulative distribution of the number of different types of procedures performed at each hospital relative to the number of different types performed in the entire state. The total percentage is shown combined as each successive hospital is added to the total, where each successive step represents the number of different types of procedures done at that hospital that were not done at any of the hospitals shown to the left of it. The cumulative distribution among hospitals of the different types of physiologically complex procedures differed significantly between geriatric and pediatric patients ( $P < 10^{-5}$  based on the top 17 facilities in each group, including 14 hospitals for pediatrics that performed no types of physiologically

complex procedures not performed elsewhere; the 17 facilities compared were the same for both age groups). For pediatric patients, 86% of the different types of physiologically complex procedures were all performed at a single hospital. For geriatric patients, only 44% of all the different types of procedures performed statewide were performed at one hospital.

### *Rare Procedures*

Rare procedures provide another means by which a hospital can differentiate itself from other facilities. A cumulative distribution plot shows that rare physiologically complex procedures in the elderly were distributed relatively uniformly among multiple hospitals (fig. 2A). No one or two hospitals performed most of the rare physiologically complex surgeries statewide. This distribution differed significantly from that for pediatric surgery, also shown in figure 2A, for which 63% of all rare physiologically complex procedures were performed at one hospital ( $P < 10^{-3}$  for the cumulative distributions based on the top 17 facilities in each group, including 11 hospitals for pediatrics that performed no rare physiologically complex procedures; the 17 facilities compared were the same for both age groups).

The unbiased estimator<sup>15</sup> for the Herfindahl-Hirschman index was applied to the number of rare physiologically complex procedures at each hospital. Results were  $0.091 \pm 0.005$  for geriatric surgery and  $0.47 \pm 0.03$  for pediatric surgery ( $P < 10^{-5}$ ) based on the 17 hospitals performing the greatest number of rare physiologically complex procedures in each age group. The  $P$  value was also less than  $10^{-5}$  when comparing all 62 hospitals performing physiologically complex surgery or all 119 facilities in the state performing surgery.

Even though a hospital does not perform a much greater number of rare procedures than other hospitals, a relatively high percentage of procedures performed at that hospital may still be rare. At hospital G, 40% of its physiologically complex procedures were rare (fig. 2B), which was a much greater percentage than all of the other 16 facilities performing at least 50 such procedures (all adjusted  $P < 0.05$ ).

### *Traveling for Surgery*

Elderly patients usually visited a nearby hospital for their physiologically complex surgery instead of traveling to regionalized centers. Of Iowa's 99 counties, 78% contain or are contiguous with a county containing a hospital that performed an average of at least one physiologically complex procedure each week. Only 15% of elderly patients living in one of these counties traveled outside that county or contiguous county to reach another hospital performing at least one procedure per week.

For pediatric patients, findings with respect to traveling were similar. With only two hospitals in the state

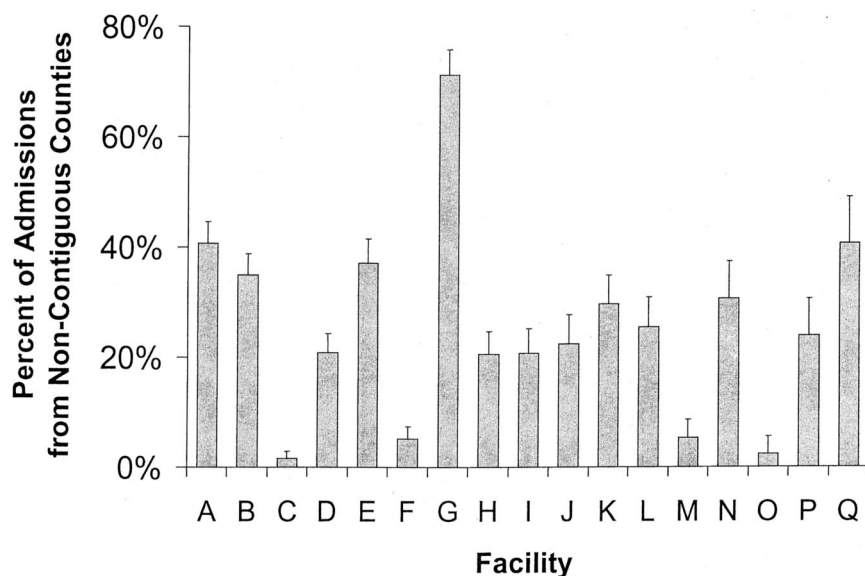


Fig. 3. The percentage of admissions at each facility from patients living outside the county or a county contiguous to the county in which the hospital is located. On average, 25% of patients came from outside the county or contiguous county. The 17 hospitals that performed 50 or more physiologically complex procedures in geriatric patients are labeled A–Q and are listed in decreasing order of the total number of physiologically complex procedures performed. For hospital G, adjusted  $P < 0.05$  when compared with each of the other hospitals. Vertical bars are  $\pm$  SE.

averaging at least one physiologically complex procedure each week, most children did not have the option of visiting a nearby hospital. When a hospital performing physiologically complex surgery was located in the home county or a contiguous one, however, only 13% of pediatric patients went to a hospital located farther away. Like the elderly, most children (or their families) did not travel when there was a hospital nearby that performed an average of at least one physiologically complex procedure each week. The difference in percentages between geriatrics and pediatrics is 2% ( $P = 0.82$ ; 95% confidence interval,  $-11\%$  to  $+11\%$ ).<sup>\*\*</sup>

Although most patients in this study did not travel for physiologically complex surgery, some hospitals are known for attracting patients from a wide geographic area. The proportion of patients who travel from far away to reach the hospital provides another mechanism by which a hospital can differentiate itself from other facilities. For example, 71% of elderly patients having physiologically complex surgery at hospital G came from outside the hospital's county or contiguous counties (fig. 3). This was a significantly larger fraction than for the other hospitals (all adjusted  $P < 0.05$  when compared with each of the other 16 hospitals performing 50 or more physiologically complex procedures).

## Discussion

A hospital may like to make claims about its services to differentiate it from other hospitals that also compete for funds from governmental agencies, philanthropists, charitable organizations, and so forth. A hospital may like to say that its services are more comprehensive, that

it performs a greater diversity of procedures, or that it performs most of the physiologically complex procedures in its region. For pediatric surgery, the larger pediatric hospital could easily substantiate these claims using the methods we developed earlier.<sup>2</sup>

### *Comparison of Geriatric and Pediatric Results Provides Further Validation of the Methodology*

As expected, results involving physiologically complex surgery in elderly patients aged 80 yr and older in the State of Iowa were quite different from the findings involving infants and young children. Multiple hospitals performed a diversity of physiologically complex procedures in elderly patients. In addition, those hospitals could not readily be differentiated from one another based on the numbers and types of procedures performed.

These results are important because they serve as a negative control to strengthen the validity of the methods used previously<sup>2</sup> to analyze the pediatric data. The fact that the geriatric and pediatric results are so different and yet were obtained from the same group of hospitals, time period, and data collection process shows that earlier findings were not chance results. They were not produced as an artifact of coding caused by an individual hospital's preferential use of certain ICD-9 procedure codes over others. Results were not created by differences between hospitals in the classification of operating room or anesthesia charges, or by variations in compliance with reporting regulations and disproportionate omission of some procedures or discharges from the database. Statistical analyses were not overly sensitive to detecting differences among hospitals even when none existed. In addition, the finding that no one or two hospitals performed the majority of rare or physiologically complex procedures in geriatric patients makes the

<sup>\*\*</sup>  $P$  value by Fisher's exact test. Confidence interval is for the difference of the two proportions (StatXact-5).



earlier findings of a dominant role for the larger pediatric hospital seem that much more impressive.

The number of physiologically complex procedures performed in young children was much smaller than that performed in the elderly. Coincidentally, the ratio of 242 procedures to 6 hospitals for pediatrics happens to be close to the ratio of 2,399 procedures to 64 hospitals for geriatric patients. Although it is tempting to conclude that the smaller number of hospitals performing physiologically complex procedures in pediatric patients simply reflects the smaller number of procedures studied, such a ratio is invalid for studying the distributions of procedures among hospitals and comparing the two age groups. Because procedures were not distributed uniformly among hospitals, the probability is incredibly low that 242 physiologically complex procedures in pediatric patients clustered in 6 hospitals purely by chance. In addition, inferential statistics (Kolmogorov-Smirnov and Herfindahl-Hirschman) were used to compare the distributions of procedures among hospitals and differences between age groups. Thus, our findings showing only a small number of hospitals performing physiologically complex procedures in pediatric patients, and dominance of one hospital in particular, reflect the true distributions. Observed differences in the two age groups are real and serve to illustrate the usefulness of this methodology.

Not only did we use this analysis to differentiate among hospitals, we also used it to try to understand the reasons for the differences in results between pediatrics and geriatrics. Analysis of the pediatric data showed a clear difference between hospitals based on the numbers and types of physiologically complex procedures, whereas the geriatric data were not able to differentiate among the hospitals studied based on these criteria. Pediatric patients had a choice of only a few hospitals throughout the state, whereas many more hospitals performed physiologically complex surgery in geriatric patients and most (85%) of the geriatric patients chose nearby hospitals.

Although these particular results are unique to Iowa, they nonetheless serve to illustrate the usefulness of the methodologies for examining differences between hospitals based on surgical procedures. Our methods are clearly able to differentiate among hospitals when one hospital unmistakably surpasses its competitors within the region, as for pediatric surgery. The methodology is also able to demonstrate that two or more hospitals are comparable in scope and depth even though the specific types of procedures performed at each hospital might differ. This type of analysis may thus provide concrete confirmation of physicians' and administrators' general impressions of where surgical care is delivered within a region of interest.

A similar type of analysis is in all likelihood applicable to any state or region that collects discharge data. Nu-

merous states require hospitals to report discharge data, and in the year 2003, 30 states participated in data collection for the State Inpatient Databases as part of the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality. For some states that are large or contain natural barriers that restrict travel, analysis of data and comparisons between hospitals on a statewide basis may not be appropriate. Instead, the region of interest may be a certain portion of the state, a county, or even just a single city in a dense metropolitan area. From the perspective of the larger pediatric hospital, which is hospital G in this study, the entire state is indeed the appropriate region, because it is a tertiary referral center that cares for patients from a wide geographical area. Ideally, the region would be defined, in part, by the expectations of the governmental agencies, charitable organizations, philanthropists, and/or insurers for which the analysis is intended and by the reasons for performing the analysis and the goals of the study. The region could also be defined partly based on initial findings regarding the home counties of patients served by the hospital.

#### *Patient Access to Care for Physiologically Complex Surgery*

For the State of Iowa, we concentrated our analysis on the 17 highest volume facilities in each group because that value corresponds to the number of hospitals that performed 50 or more physiologically complex procedures in geriatric patients, accounting for 85% of all such procedures statewide. We could have also chosen to study the top 64 hospitals in each age group, where 64 is the number of hospitals that performed at least one physiologically complex procedure in geriatric patients. When comparing geriatrics and pediatrics in terms of the distribution of procedures performed at different hospitals, it was important to consider the same number of facilities in each group, rather than 17 (or 64) facilities for geriatrics and 6 facilities for pediatrics.

Consider an extreme example in which there are 100 facilities throughout a province performing an equal number of physiologically complex procedures in geriatric patients but only 2 facilities that both perform the same number of physiologically complex procedures in pediatric patients. If the area of the province is not inconsequential, the distribution of hospitals performing such procedures is not equivalent in the two age groups. From a geographic perspective, an equal distribution of procedures between 2 hospitals is not the same as an equal distribution of procedures among 100 hospitals. Patient access to care is very different in the two situations.

Accessibility matters for disaster planning. It is crucial to recognize that only two hospitals throughout the entire province can accommodate pediatric patients needing physiologically complex surgery, although nu-



merous hospitals routinely perform physiologically complex surgery in geriatric patients.

Accessibility also matters for patient travel. If one's elderly parent needs physiologically complex surgery, one can choose from many hospitals throughout the province. If one's child needs physiologically complex surgery, however, one will likely have to travel far away from the local area because physiologically complex surgery in children is performed at only 2 of 100 facilities in the province.

When examining differences between pediatric and geriatric surgery in terms of the distributions of where procedures are performed, analysis should not be restricted to those two hospitals performing pediatric surgery. Comparing equal numbers of hospitals in each group acknowledges rather than ignores the fact that physiologically complex procedures in young children are *not* performed at 98 of 100 hospitals in the province. For this reason, our comparisons between geriatrics and pediatrics in the State of Iowa always included 17 hospitals in each group, even though some of those hospitals performed zero procedures.

#### *Differentiating among Hospitals Based on Rare Procedures*

We have extended the methods used previously by considering the incidence of rare procedures as another means for differentiating between hospitals. Compared with other hospitals, a larger fraction of physiologically complex procedures performed at hospital G were rare. The hospital can use this information in its annual report or other marketing publication to display its expertise to both the public and governmental agencies and philanthropic organizations. The hospital may want to emphasize that it is prepared to accommodate one-of-a-kind procedures and diagnoses because it possesses specialized equipment and supplies not available at other institutions, a willingness to work outside established protocols, or an especially flexible and knowledgeable perioperative team that together serve as unique assets to the hospital.

#### *Differentiating among Hospitals Based on Traveling*

Many hospitals use maps as part of their marketing materials to show where their patients come from and illustrate the size of the region they serve. In this article, we show how discharge abstract data can be used to provide information about the geographic region served by the hospital based on patients' home counties. The data can also be used to determine the approximate distances patients have traveled to reach the hospital. Results are simple to explain to customers and stakeholders and can be used successfully to differentiate among hospitals. Hospitals can also use information on patient counties together with data on county demo-

graphics to estimate the health care needs of current and future patients. Knowledge of patient traveling distances can aid in scheduling and discharge planning and in assessing the need for ancillary services such as waiting areas, cafeterias, and sleeping accommodations.

#### *Potential Limitations*

The validity of these analysis methods depends on the accuracy and completeness of the discharge database. The contrasting results obtained for geriatric and pediatric surgery in Iowa suggests that differences in reporting among the various hospitals did not bias the analyses. However, a hospital's failure to comply fully with reporting requirements would compromise the integrity of the database for these types of analysis.

For some procedures, the lack of a precise correspondence between ICD-9 procedure codes and CPT procedure codes, together with the broad meaning of individual ICD-9 diagnosis codes, created ambiguity in determining the exact procedure that was performed. Consequently, physiologic complexity could not be determined for 25 procedures. However, that number represents only a small fraction (1%) of all physiologically complex procedures. Results were not changed by inclusion or exclusion of these procedures from the analysis.

When the region of interest contains the border with another state, comparisons between hospitals may be difficult. We have not yet examined the compatibility of data extracted from databases of two adjacent states. In addition, information on patients who travel from one state to another for surgery is incomplete. Although the Iowa database contains data on out-of-state patients who come to Iowa hospitals, we have no way of knowing how many Iowans had surgery elsewhere.

Surgeons, anesthesiologists, and hospitals may not know precisely the relative volumes of procedures at nearby facilities and may not be sure which facilities are their real competitors. They may wish to define the region of interest and decide which hospitals should be used for comparison based on preliminary findings from this type of analysis. Although using initial results to define the region of interest may be desirable, we have not yet evaluated the appropriate statistical measurements needed to do so. The Bonferroni-Holm adjustment procedure<sup>16</sup> to Barnard's test<sup>17</sup> is designed to compare one control group (in this circumstance, the hospital performing the study) to several experimental groups (in this circumstance, other hospitals). The hospital of interest and the other hospitals should be chosen *a priori*, not based on observed data. This was how we used the statistical method in this study.

The number of procedures performed at each hospital must be sufficient to achieve statistical significance for differences between facilities. The number depends mainly on the population in the region, the time period

chosen, the types of procedures studied, and the number of hospitals. The Iowa database provided 6 months of data and contained 2,399 physiologically complex procedures performed in geriatric patients at 62 hospitals, but this sample size was insufficient to apply a similarity index,<sup>2,18</sup> as we did in the pediatric study, to compare the relative proportions of different types of procedures performed at different hospitals. For the pediatric study, a total of 5,671 operative procedures were considered. The minimum number of procedures required is not clear because statistical methods for evaluating the power of a similarity analysis<sup>2,18</sup> have not been established.

This and our previous study have focused on providing information that a hospital can use to help others in appreciating the hospital's importance in the healthcare system of its region. Additional work is needed to learn how the data and statistical analyses can best be used to benefit healthcare organizations and their supporters and how they should best communicate their findings to target audiences.

## Summary

We previously showed how a statewide discharge abstract database could be used to quantify differences between hospitals based on the numbers and types of surgical procedures in pediatric patients.<sup>2</sup> In this study, we performed additional validation of our methodology by studying geriatric patients. Differences in results between geriatric and pediatric patients illustrate the robustness of the analysis techniques. In addition, we expanded our set of techniques to differentiate among hospitals by adding the study of rare procedures and traveling beyond one's home county. Discharge abstract data can be used to obtain

information to assist stakeholders in appreciating individual hospitals' unique contributions to surgical care in a region.

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