Journal of Medical Systems (2019) 43: 187
https://doi.org/10.1007/s10916-019-1326-1

SYSTEMS-LEVEL QUALITY IMPROVEMENT

Limited Intragenerational Mobility of Surgical Caseload of Iowa Hospitals

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Received: 22 February 2019 / Accepted: 5 May 2019 / Published online: 18 May 2019

Abstract
We previously calculated the Gini index for 121 Iowa hospitals over the ten-year period 2007-2016. The Gini index is a statistic used in economics to assess difference in the distribution of wealth among groups. We reported a high degree of "inequality" among hospitals. In this paper, we extend this work by calculating the intragenerational mobility for the hospitals present in 2007-2008 and 2015-2016. Whereas in economics intragenerational mobility often is measured as changes in income over time within a group, we study changes in hospitals' surgical caseloads. Intragenerational mobility was quantified using the Spearman rank correlation, the slope of the ordinary least squares (OLS) regression line in the log scale, and the Shorrocks trace index. The results were consistent across the three measures. There was a low degree of mobility for the surgical caseloads of the hospitals during the 10-year period under study. For example, based on the slope of the OLS regression, intragenerational mobility was not significantly different from zero ($P > 0.05$). None (0%) of the 113 hospitals with at least 10 cases both periods increased from the 1st to 5th quintile, 1st to 4th quintile, 2nd to 5th quintile, 2nd to 4th quintile, or even from 3rd to 5th quintile. The results show the importance of hospitals not investing irrationally based on false hope of surgical growth.

Keywords Intergenerational mobility · Intragenerational mobility · Gini index · Shorrocks trace · Surgical caseload · Surgical services · Operating room management

Background

Measures of economic mobility seek to quantify the change in economic well-being over time for an individual, family, or another group [1, 2]. With respect to hospitals, we define "economic mobility" as the extent to which a given hospital can increase its surgical caseload over time, and thereby improve its relative position among its peer hospitals. The strategic question is whether hospitals or health systems can achieve above-average growth rates in their surgical caseload enough for marked increases in market share.

Recently, we calculated the Gini index for Iowa hospitals over the ten-year period 2007 through 2016. The Gini index is a statistical measure of dispersion or inequality [3]. We found a high degree of "inequality" among the state's 121 hospitals [4]. The Gini index was found to be stable over the 10-year period studied (0.729 versus 0.735) [4]. What remains unknown is the economic mobility of these hospitals, that is, the extent to which changes in the relative rankings of hospitals were possible. Even in a state with a slight overall decrease in the numbers of surgical cases, some hospitals captured market share from other hospitals and grew [5].

The tools to measure intergenerational mobility are well-developed and have been widely applied in economics [1]. These tools measure the relative change in income from one generation to the next. Intergenerational mobility refers to the extent to which the incomes of children can be predicted by the

This article is part of the Topical Collection on *Systems-Level Quality Improvement*

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incomes of their parents. Regarding parents and children, the meaning of a "generation" is discrete and unambiguous. In this paper, we study intragenerational mobility, over the 10-year interval, 2007-2008 to 2015-2016. In contrast to intergenerational mobility, intragenerational mobility relates to change in income over the lifetime of an individual [1]. Whereas these tools were developed to measure the economic mobility of individuals, we will demonstrate how these same tools can be applied to quantify the extent to which the non-federal hospitals in Iowa increased their surgical caseloads over time sufficiently to change relative positions compared with each other. Although there is considerable understanding of how to model monthly and yearly fluctuations in hospitals' surgical caseloads [6], our novel application is to use intragenerational mobility to identify those changes in the competitive positions of hospitals that are both long-lasting and sustainable.

From previous studies, growth or shrinkage in surgical caseload over a decade has not been predicted accurately by changes in county population or in the number of staffed beds. County population is, at most, a weak predictor of surgical caseload at hospitals [7–9].[1] Some surgical facilities in large metropolitan areas perform relatively few surgical cases (e.g., 340 cases per year) [10].[2] Furthermore, changes in county population over a decade can be *inversely* correlated to surgical caseload [11]. The number of staffed hospital beds is also a weak predictor of surgical caseload statewide, because most (≅66%) hospital-based surgery is ambulatory [12], and median hospital occupancy (≅64%) [13] is far too low to limit elective surgery (i.e., the number of beds follows the number of cases, not vice-versa).

Over the past 2 decades, there has been substantial progress made in understanding how a given hospital can predict changes its caseload of each specialty [11, 14]. Data envelopment analysis methods make predictions using the number of cases of different specialties at all hospitals to model each hospital [7–9, 15, 16]. The premise, for example, is that a reliable criterion to evaluate the potential for growth in orthopedic surgery is to compare the current number of hip replacement cases to the hospital's number of colorectal resections, nephrectomies, and other common procedures.[3] Thus, a hospital may "catch up" in certain specialties whose surgeons are performing fewer cases than expected. Nevertheless, generally, an effort to grow a single specialty is an ineffective strategy for overall growth in surgery; growth is poorly correlated among specialties [11].

We hypothesized that the analysis of intragenerational mobility would yield important insights regarding the maximum achievable growth of a given hospital's surgical caseload. By considering intragenerational mobility, hospitals may avoid costly mistakes such as investing in expensive capital equipment for surgery (e.g., million-dollar robotic surgery devices) even when there is insufficient demand [17, 18].

Methods

This retrospective, observational cohort study was performed using de-identified data. The University of Iowa Institutional Review Board determined on June 5, 2018, that this project (#201805852) did not meet the regulatory definition of human subjects research.

The cases studied were those performed at all non-federal hospital-owned surgical facilities in Iowa [19]. We henceforth refer to all such facilities as "hospitals." Both inpatient and outpatient cases were studied that included at least one major therapeutic procedure. Inpatient procedures were counted as major therapeutic if their International Classification of Diseases, Ninth Revision, Clinical Modification or Tenth Revision, Procedure Coding System codes had corresponding categories of "procedures that are considered valid operating room procedures by the Medicare Severity Diagnosis Related Group grouper and that are performed for therapeutic reasons" [20, 21]. Outpatient surgery procedures were counted as major therapeutic if the Healthcare Common Procedure Coding System code had a corresponding surgery flag code = 2, representing "invasive therapeutic surgical procedure" [22]. We did not study the so-called minor therapeutic procedures because many such procedures are often performed without an anesthesia provider (e.g., simple incision and removal of subcutaneous foreign body) [22]. No distinction was made between whether a case was listed in the inpatient or outpatient database because the study was based on the surgical procedures performed, not the patients' hospital length of stay.

The years in the current study were chosen to match those of the previous study of Gini index [4], a prerequisite. The last year of that study was 2016 because that was the most recent year for which all data were available. We studied 10 years of surgical cases, starting with the first quarter of 2007. Although we did not have prior data for power analysis for either the preceding [4] or the current study, we used the entirety of the available data, not a sample of those data. We have relied on statistics of intragenerational mobility with confidence intervals (Table 1) [23].

[1] Among the $N = 120$ hospitals in Iowa in 2010 the year of the last US census, the Pearson correlation between county population and number of surgical cases at hospitals in the county equaled 0.45. The Kendall's τ_b was 0.48. These are relatively large correlations compared with other states.

[2] These examples are from the Iowa Hospital Association data used in this article. The 2 counties compared have relative 2010 census populations of 3.3, where 3.3 is the ratio of the population of one of the metropolitan areas (250,000 to 1 million; code 2) to that of the other (<250,000; rural-urban continuum code 3) [7].

[3] A hospital's ratio of lung resection cases to hysterectomy cases is compared with the ratios of many other hospitals. The data envelopment analysis considers input variables to scale the ratios into numbers of cases. The data envelopment analysis also considers that some hospitals have no general thoracic surgery procedures, which reflects hospital specialization, not that the hospital is small.

Table 1 Intragenerational mobility analysis of hospitals' change in numbers of surgical cases, reported as the point estimate (95% confidence interval) [a]

Statistic quantifying intragenerational mobility	2015-2016 versus 2007-2008, among the N = 113 hospitals performing at least [b] 10 cases during both periods	2015-2016 versus 2007-2008, among the $N = 116$ hospitals performing at least 1 case during both periods	2013-2014 versus 2009-2010,[c] among the N = 116 hospitals performing at least 10 cases during both periods
1 – Spearman rank correlation	0.072 (0.034 to 0.131)	0.074 (0.036 to 0.132)	0.040 (0.017 to 0.084)
1 – ordinary least squares slope between $\log_{10}$(later period) and $\log_{10}$(earlier period)	0.037 (−0.026 to 0.109)	0.000 (−0.077 to 0.071)	−0.007 (−0.052 to 0.051)
Shorrocks' and Prais' trace index [d]	0.364 (0.250 to 0.509)	0.412 (0.345 to 0.610)	0.302 (0.205 to 0.462)

[a] The 95% confidence intervals were calculated using the bias-corrected bootstrap with 10,000 samples

[b] When limited to the 106 hospitals performing at least 100 cases during both periods, estimates were 0.082, 0.073, and 0.365, respectively (i.e., no significant changes from 0.072, 0.037, and 0.364, respectively)

[c] Among the 113 hospitals in all columns, each hospital's cases in 2013-2014 differed on average (mean ± standard deviation) by 13% ± 14% from 2015 to 2016. Each hospital's cases in 2019-2010 differed on average by 13% ± 18% from 2007 to 2008

[d] The Shorrocks and Prais index was calculated using the transition matrix with quintiles, as shown in Table 2. However, the estimates reported in Table 1 are for the bias adjusted mean and its confidence interval, not the single estimate as given in Table 2

The date of each procedure was known at every hospital for each patient. If the same patient underwent more than one major therapeutic type of procedure on the same date and at the same hospital, then those procedures were considered to have been performed during the same case. To assess the change in economic status, we compared the first 2-year period to the last 2-year period. As one of our sensitivity analyses, in Table 1 we repeated the calculations while comparing the second 2-year period (2009-2010) to the fourth 2-year period (2013-2014).

Statistical analyses

We analyzed intragenerational mobility of hospitals using the STATA *igmobil* command [23]. Corresponding 95% confidence intervals were calculated using the bias-corrected bootstrap with 10,000 replications (Table 1). For example, consider the base analysis with $N = 113$ hospitals. The same hospital performed the most cases in 2007-2008 and in 2015-2016. That hospital would be absent from 36.6% of the bootstrap samples, where $0.366 = (1 - 1/113)^{113}$.

Three statistics were used to measure intragenerational mobility. Each has the feature that 0 means no mobility.

First, we calculated the Spearman rank correlation coefficient between the numbers of cases in 2007-2008 versus 2015-2016 (Fig. 1) as a measure of the persistence of the relative rank of surgical cases over this span. As is commonly reported, mobility is measured as 1 minus the Spearman correlation (Table 1). If the relative ranks are unchanged over that span, then persistence = 1 and mobility = 0. By contrast, the maximum mobility of 1 corresponds to the case where persistence, as measured by the Spearman rank correlation, equals 0.

Second, we calculated the ordinary least squares slope between the $\log_{10}$ cases in 2015-2016 versus 2007-2008. This statistic is shown in the 2nd row of Table 1 and in the 2 panes of Fig. 1. If there were no change in cases between periods, then the slope would equal 1 and the mobility index would equal 0. Figure 2 shows that the probability distribution of cases per year was reasonably close to the lognormal distribution.

Third, we calculated the Shorrocks Trace index and its corresponding transition matrix [1, 23, 24]. Shorrocks Trace is explained with an example in Table 2. The five columns of the transition matrix correspond to the five quintiles of the distribution of the count of cases during 2007 - 2008. The Shorrocks measure has proven to be useful in revealing where in the distribution the mobility is occurring. If there were no mobility, then a hospital in the 1st quintile in 2007-2008 would also be in the 1st quintile in 2015-2016, as shown in Table 2.

We performed an additional sensitivity analysis (Table 3). We repeated our base analysis while dividing hospitals between those that are critical access hospitals and those that are not. Critical access hospitals are designated rural hospitals with no more than 25 inpatient beds and, for the geography of Iowa, located more than 35 miles from any other hospital [25]. Critical access hospitals represent 61% of hospitals in the rural US [26, 27]. They represent 78 (68%) of the 114 hospitals in Iowa performing interventional pain procedures [28]. They represent 79 (70%) of the 113 hospitals in the base analysis. Critical access hospitals "are paid for most inpatient and outpatient services to Medicare patients at 101 percent of [the hospital's] reasonable costs" (i.e., different than other facilities) [25].

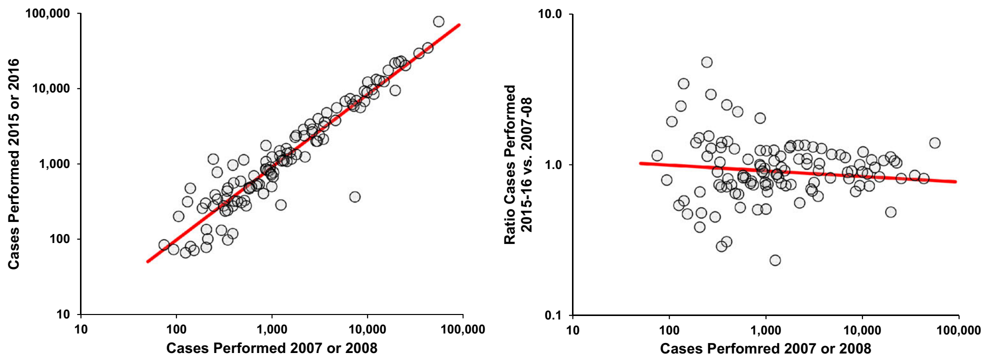

Fig. 1 Plot of cases performed in Iowa from 2015 to 2016 versus 2007-2008. There are N = 113 hospitals shown, each with at least 10 cases performed during both periods. The figure in the right panel is identical to that in the left, except that the ratio of the counts is plotted along the vertical axis. The red line shows the ordinary least squares fit between the log count of cases performed in 2015-2016 versus log count of cases performed in 2007-2008. The slope in the log scale equals 0.963. The Table 1 middle row shows that this slope does not differ significantly from 1.00 (i.e., 95% confidence interval equals 0.891 to 1.026). Also, from Table 1, when repeated using the $N = 116$ hospitals with at least 1 case during both periods (not shown), the slope equals 1.00, with 95% confidence interval 0.929 to 1.077

Results

During the period under study, the total number of surgical cases statewide decreased by 0.83%.[4] The total number of cases performed 2015-2016 was 4.1% less than in 2007-2008, among the 113 hospitals with at least 10 cases both periods.[d] There were 66 hospitals performing fewer cases and 47 hospitals performing more cases. There were 16 hospitals moving to a greater quintile and 15 moving to a lesser quintile (Table 2).

The results for three different quantitative measures of mobility are shown in Table 1. The statistics gave consistent results. The degree of persistence between periods was high, with resulting low mobility (i.e., 1 – persistence). Specifically, one minus the Spearman rank correlation ranged from 0.040 to 0.072. One minus the ordinary least squares regression slope in the log scale did not differ significantly from zero (Fig. 2). The Shorrocks trace index ranged from 0.302 to 0.412.

An intuitive measure of intragenerational mobility is the proportion of people in the bottom quintile of the income distribution who rise to the top quintile of income [29]. Using the quintiles of Table 2, none (0%) of the 113 hospitals increased from the 1st to 5th quintile, 1st to 4th quintile, 2nd to 5th quintile, 2nd to 4th quintile, or even from 3rd to 5th quintile. Of the 22 hospitals that started in the 1st quintile, 5 moved from the 1st to the 2nd quintile, and 2 moved from the 1st to the 3rd quintile.

There may have been greater mobility among the critical access hospitals than among the larger hospitals (Table 3). However, the mobility of these very small hospitals was effectively an average of just 1 extra (or 1 less) case per day. One minus the ordinary least squares regression slope in the log scale did not differ significantly from zero.

[4] Our analyses did not include 4 hospitals totaling 1929 cases in 2007-2008 and not performing surgery in 2015-2016. Our analyses did not include 3 hospitals newly performing surgery in 2015-2016, a total of 18,565 cases.

Discussion

Intragenerational mobility was found to be low for the 113 Iowa hospitals in this study. Surgical caseload increased for some hospitals and decreased for others, but with small changes overall and for most hospitals (Table 2). These results explain our previous finding that there was no measurable change in the Gini index from 2007 to 2016 [4].

We previously examined the mechanism of growth among the hospitals with the largest growth in caseload (in cases per year) [5]. The hospitals were both large (e.g., with many surgeons) and with above average (but not unusually large) percentage rates of growth [5]. We also previously examined the

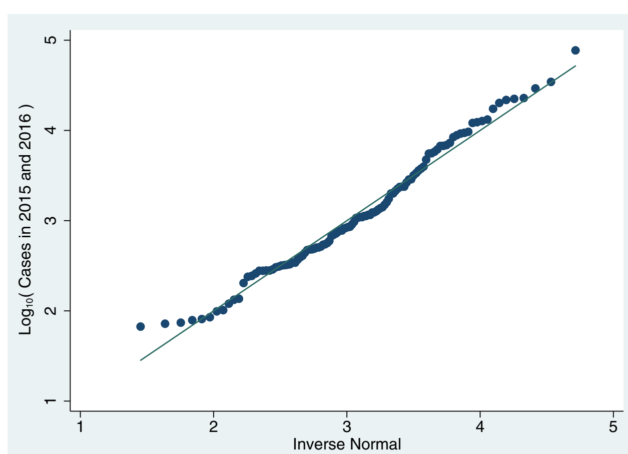

Fig. 2 Probability distribution of cases performed in Iowa from 2015 to 2016. The graph is for the N = 113 hospitals studied, those that each had at least 10 cases performed during both periods

Table 2 Transition matrix among the $N = 113$ hospitals with at least 10 cases both 2015-2016 and 2007-2008, and explanation of the Shorrocks trace index

Mean count of cases during period	37 to 165 cases; 2007-2008	169 to 409 cases; 2007-2008	427 to 771 cases; 2007-2008	794 to 3456 cases; 2007-2008	3577 to 27,653 cases; 2007-2008
34 to 155 cases; 2015-2016	15 66.4%	6 26.5%	1 4.4%	0 0.0%	0 0.0%
159 to 350 cases; 2015-2016	5 22.1%	15 66.4%	2 8.8%	0 0.0%	1 4.4%
360 to 688 cases; 2015-2016	2 8.8%	2 8.8%	16 70.8%	3 13.3%	0 0.0%
706 to 2908 cases; 2015-2016	0 0.0%	0 0.0%	4 17.7%	17 75.2%	2 8.8%
3085 to 38,576 cases; 2015-2016	0 0.0%	0 0.0%	0 0.0%	3 13.3%	19 84.1%

The Shorrocks' and Prais' trace index equals (5 quintiles – trace) / (5 quintiles – 1). The observed trace equals the sum of the proportions of hospitals along the main diagonal, 3.63 = 0.664 + 0.664 + 0.708 + 0.752 + 0.841. The observed index thus equals 0.343, where 0.343 = (5 – 3.63)/ (5 – 1). The unbiased estimate of the mean of the 10,000 bootstrap indices equals 0.364, as shown in Table 1. If all observations were along the main diagonal (i.e., no change in quintile), then the trace would equal 5. Thus, the index would equal 0, indicating no mobility. Analogously, if there were no social mobility for children, then 100% of children born into the quintile of income would remain in the bottom quintile. The trace = 5, with the index = (5 – 5)/ (5 – 1) = 0. Alternatively, if the original (2007-2008) condition were irrelevant to next period (2015-2016), then approximately 1/5th of each column would lie along the main diagonal. Thus, the trace would equal approximately 1, and the index would equal 1. Analogously, if all adults' incomes were statistically independent of their parents' income, then all adults would have an equal chance of being in the top quintile of income. The trace would equal 1, and therefore the index = (5 – 1) / (5 – 1) = 1

characteristics of the surgeons contributing to the largest shares of growth in surgical caseloads at these hospitals and all other hospitals statewide [30]. Most hospitals had less than half of their 1-year growth in cases attributable to surgeons who performed >2 cases per week in the baseline year (23.0% SE 2.5%) [30]. The average hospital had approximately half of its 1-year growth in counts of inpatient and outpatient surgical cases among surgeons who performed 2 or fewer cases per week at each hospital statewide during the baseline year (52.6% SE 2.6%) [30]. The hospital with the largest growth in cases had 61% of its growth among these low caseload surgeons [30]. Hence, it is important for hospitals to focus on low caseload surgeons to maintain or grow the surgical caseload. That is done by appropriate management of operating room time [31, 32]. Overall growth in surgical caseload as measured in the current study is not constrained by a lack of bed capacity, because the vast majority of surgery is outpatient or overnight stay [12]. What the current study shows is that the best that most hospitals can reasonably expect from growth strategies is to maintain stability of the caseload.

Limitations

First, our data were from a single state. Nevertheless, this managerial epidemiology from all non-federal hospitals in the state with surgery is an advance compared to what we believe has not previously been studied. The smaller hospitals we studied may have had greater intra-generational mobility than the larger hospitals. Because the smaller hospitals are principally critical access hospitals and thus must be geographically isolated from other hospitals [25], we cannot separate size from geography. We speculate that being far from another hospital facilitates the critical access hospital's knowledge of local needs because patients are leaving the county for

Table 3 Sensitivity analysis: Intragenerational mobility analysis of hospitals' change in numbers of surgical cases classified based on hospital being critical access or not, reported as the point estimate (95% confidence interval)

Statistic quantifying intragenerational mobility	Table 1 column 1 $N = 113$	Critical access $N = 79$	Not critical access $N = 34$
1 – Spearman rank correlation	0.072 (0.034 to 0.131)	0.182 (0.095 to 0.302)	0.035 0.010 to 0.068)
1 – ordinary least squares slope between $\log_{10}$ (later period) and $\log_{10}$(earlier period)	0.037 (−0.026 to 0.109)	0.165 (−0.021 to 0.403)	−0.017 (−0.135 to 0.108)
Shorrocks' and Prais' trace index	0.364 (0.250 to 0.509)	0.534 (0.329 to 0.687)	0.363 (0.146 to 0.739)

The critical access hospitals had median 304 cases per year in 2007-2008 [interquartile range 156, 600] and 271 cases per year in 2015-2016 [144, 564]. The larger hospitals had median 4613 cases per year in 2007-2008 [2297, 8173] and 3927 cases per year in 2015-2016 [2379, 6592] surgery ("leakage") [33]. The largest hospitals statewide attract patients coming from counties that are not even contiguous to the hospital's county [4]. We urge readers from other large states with rural areas to use the methodology in our paper as a guide for analysis.

Second, Iowa is one of 35 states with Certificate-of-Need (CON) laws that regulate hospital expansion [34]. However, given that growth is due to surgeons who will have flexibility in case scheduling [30], the number of ORs was very unlikely influencing results.

Third, the data were for numbers of cases, not hours of cases. We do not think that this influenced our conclusions because, over years, there is a 0.99 linear correlation between the number of cases and the total hours of cases [35]. Nevertheless, relevance to anesthesiologists would have been enhanced by having statewide data on hours of operating room time in addition to the number of cases.

Fourth, our study was limited to hospitals, their outpatient surgical departments, and the free-standing ambulatory surgery centers they own [19]. Caseload data are not available, as they not reported by Iowa's independent freestanding facilities [36].

Implications

The measurement of economic mobility has important implications for hospital and anesthesia group management. Numerous studies have suggested strategies for increasing surgical caseload and growing market share. For example, some hospitals have established minimally invasive surgery centers to boost market performance and attract patients seeking smaller scars, reduced blood loss, and faster recovery [37]. Our results of limited mobility show that strategic initiatives focused on surgical growth are likely, at best, to be mechanisms for hospitals to retain their relative position compared with other hospitals. The findings show the importance of hospitals not investing irrationally based on false hope of surgical growth.

Acknowledgements Availability of data and materials: The data that support the findings of this study are available from the Iowa Hospital Association, https://www.ihaonline.org/Information/Inpatient-Outpatient-Database/Data-Request. Restrictions apply to the availability and distribution of these data, which were used under agreement with the University of Iowa Hospitals and Clinics.

Author's contributions LO helped analyze the data and write the manuscript.

FD helped design the study, obtain the data, analyze the data, and write the manuscript.

RHE helped design the study and write the manuscript.

Funding Funding for this project was provided solely from departmental sources.

Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

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