

# The Association Between Hospital Outcomes and Diagnostic Imaging: Early Findings

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**Purpose:** Resource use variation across the United States prompts the important question of whether “more is better” when it comes to health care services. The aim of this study was to examine correlations between the use of 4 common imaging modalities (CT, MR, ultrasound, and radiography) and in-hospital mortality and costs.

**Methods:** Using clinical and utilization data for 1.1 million inpatient admissions at 102 US hospitals during 2007, two hospital-specific, risk-adjusted imaging utilization measures for each modality were constructed that controlled for patients’ demographic and clinical characteristics and for hospital characteristics were constructed for each modality. First, logistic regression was used to estimate the odds that each type of imaging service would be provided during an admission. Second, the mean number of services per admission was estimated using output from a two-part ordinary least squares model. Hospital-specific, risk-adjusted inpatient mortality and total hospital costs were also computed, and correlations between the imaging utilization measures and the mortality and cost outcome measures were then assessed using Pearson’s correlation coefficients ( $P < .05$ ). The correlation analyses were weighted by hospital admission volume.

**Results:** Hospitals in which patients were more likely to receive imaging services during admissions had lower mortality, even after controlling for potential confounders. Correlation coefficients were  $-0.2$  for all modalities ( $P = .02-.05$ ). Weaker correlations existed between mean services per admission and mortality, while costs trended insignificantly higher with greater utilization.

**Conclusions:** This study lays the foundation for further exploration of the relationship between resource use and the clinical and economic outcomes associated with imaging utilization.

**Key Words:** Outcomes assessment, diagnostic imaging, inpatients

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## BACKGROUND AND PURPOSE

If the conventional economic tenet of “more is better” held true in health care, we would expect greater resource use to automatically lead to better clinical and patient-reported outcomes, albeit with diminishing returns at the margins. The recent US experience—spiraling health care expenditures that now far exceed those of any other industrialized country and wide variations in resource use across geographic areas and between clinical institutions and health systems [1]—underscores the importance of putting this tenet to the test.

Policymakers and researchers have both begun questioning this tenet [1,2], and a number of empirical studies have demonstrated that geographic areas with high health care utilization have health outcomes and quality of care that are no better, and are sometimes even worse, than areas with less intensive service utilization [3-7]. For example, Cutler [8] and Cutler and McClellan [9] showed definitive net benefits of technological advances in care for heart attack victims, but a Dartmouth case study of myocardial infarction suggested that incremental spending in recent years has not been matched by gains in health outcomes [10].

The dramatic increases in the utilization of advanced imaging technologies (CT, MR imaging, PET, and single-photon emission CT) have caused payers and policymakers to similarly question whether more diagnostic imaging is associated with better health outcomes [11]. Between 2000 and 2006, imaging services grew at more

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than twice the rate of physician services overall per Medicare beneficiary (67% vs 35%) [12], and Congress recently enacted the significant reductions in diagnostic imaging service payments recommended by the Medicare Payment Advisory Commission in 2005 [13]. A recent US Government Accountability Office report shows that these changes reduced Medicare Part B spending on imaging services by \$1.6 billion [14].

In this paper, we explore the hypothesis that more is better for diagnostic imaging by providing preliminary data on the association between the utilization of diagnostic imaging services and two key hospital outcome measures: mortality and costs.

## MATERIALS AND METHODS

### Data Source

We used a sample of data from the Thomson Reuters Hospital Drug Database (HDD) for this analysis. The HDD houses information, primarily hospital billing system data, from >580 US hospitals and allows researchers to evaluate patient-level and admission-level utilization across >31 million hospital discharges [15-18]. Hospitals contribute data to the HDD on a voluntary basis, and those that do participate contribute data on all admissions that occur in their facilities. We examined data from inpatient admissions that occurred during 2007 in the 102 hospitals in the HDD that provided sufficiently detailed data to support assessment of the utilization of inpatient diagnostic imaging services. Data for the admissions included in this study are generally complete, as the information was originally collected as part of the billing process.

### Overview of Study Methods

We constructed two hospital-specific, risk-adjusted imaging utilization measures for CT, MR, ultrasound, and radiography. Risk adjustment is needed to control for the characteristics of an admitted patient or a hospital that may affect the utilization of imaging services. In particular, risk adjustment allows one to “rule out” the possibility that any association between imaging utilization and outcomes is caused by systematic differences in patient or hospital characteristics between hospitals.

The first utilization measure was a binary indicator of whether a patient received a service during an admission, and the second was an estimate of the mean number of services received. We used two imaging utilization measures because a simple yes-or-no measure of imaging could be an insufficiently accurate proxy for the intensity of imaging services provided. In the claims data, imaging services were identified by the presence of procedure codes (ie, separate line items reported originally for billing purposes). Each procedure was considered a single

imaging service, and any imaging procedures performed in the emergency department as precursors to admissions were included as part of the admissions. In addition to constructing metrics for imaging utilization, we constructed two hospital-specific, risk-adjusted outcome measures: inpatient mortality and the costs incurred by the hospitals in providing these inpatient services. We then assessed correlations between the two imaging utilization measures and the two hospital outcome measures.

### Imaging Utilization Measures

**Probability of Receiving an Imaging Service.** We estimated separate logistic regression models for the odds that each imaging service of interest (CT, MR, ultrasound, or radiography) would be used during an inpatient stay. Patient demographic characteristics, patient case mix (defined through application of Thomson Reuters proprietary Clinical Risk Grouping (CRG) software), patient discharge status, and hospital characteristics were included as independent variables in the models (Table 1). The CRG software is based on diagnosis-related groups and is used to identify and group admissions that are clinically similar and which would be expected to have similar resource demands. Next, we used the resulting parameter estimates to predict the probability that each imaging modality would be provided during an inpatient stay, and averaged these predicted probabilities across admissions at the hospital level. Finally, we constructed hospital-level, modality-specific imaging probability indexes by dividing the actual percentage of admissions with an imaging service at the hospital by the mean predicted percentage. Hence, hospitals with index values >1 were “high” utilizers of imaging services because the actual percentage of admissions that included imaging services was greater than one would expect on the basis of

**Table 1.** Covariates for regression models

| Covariate                | Definition   |
|--------------------------|--|
| Patient demographics     | Age at admission<br>Sex  |
| Patient case mix         | 245 binary clinical risk group indicators, as defined by Thomson Reuters proprietary grouping software |
| Patient discharge status | Alive vs deceased  |
| Hospital characteristics | Bed size categories (1–199, 200–299, 300–499, 500 or more)<br>Teaching status<br>Census region         |

the characteristics of the hospital and the patients treated there.

**Imaging Service Volume.** Because a large share of admissions did not involve imaging services, we used a “two-part” model to estimate the mean number of imaging services delivered to avoid biased estimates. Briefly, the two-part model involved multiplying the admission-level predicted probabilities of receiving an imaging service described above by the predicted mean number of imaging services received for the admissions for which at least one imaging service was used. For this second step, we estimated separate ordinary least squares regression models for the number of services received among admissions with nonzero utilization using the regressors in Table 1 and after log transforming the utilization data to account for nonnormality in their distribution. A smearing technique was used to retransform the geometric means back to the original units [19]. Finally, we predicted the number of imaging services received during each admission in the sample using the two-part model and then created an imaging volume index by dividing the actual mean per admission volume of imaging services at each hospital by the average of the predicted number of imaging services at that hospital. This approach allowed us to assess whether there was any type of “dose-response” relationship between the number of images obtained and the outcomes we examined.

### Outcome Measures

**Inpatient Mortality.** We constructed a hospital-level, risk-adjusted inpatient mortality index using methods developed by Thomson Reuters for its 100 Top Hospitals analysis. Briefly, the index used patient-level data to predict diagnosis-specific inpatient mortality rates by age group (<65 and ≥65 years) and type of service (medical and surgical). These estimated mortality rates are based on patients’ demographic characteristics and key clinical details from hospitalizations (age, gender, medical conditions, procedures received, condition and procedure interactions, admission source), as well as key characteristics of the hospitals (bed size, teaching status, census region, urban or rural setting). This mortality index has been used widely and has been compared with patient chart data in terms of its accuracy [20-24]. Predicted mortalities from the model are then used to create a hospital-specific mortality index by constructing a *z* score from the difference between observed and predicted mortality rates.

**Total Admission-Related Costs.** For this study, we used costs reported through each hospital’s accounting system and therefore representing “real-world” experience; no attempt was made to adjust for the likely use of different accounting rules across institutions. We esti-

mated an ordinary least squares regression model for log-transformed costs using the covariates from Table 1. We used these model results to predict admission-level inpatient costs and averaged these predicted probabilities across admissions at the hospital level. Finally, we constructed cost indexes by dividing the actual values for each hospital by the mean predicted values from our model.

### Examining Associations Between Use of Imaging and Outcomes

We used Pearson’s correlation coefficients to test for statistically significant ( $P < .05$ ) associations between each imaging utilization measure (the likelihood of having any imaging service and the volume of imaging services per admission) and the two outcome measures (inpatient mortality and costs). The correlation analyses were weighted by hospital admission volume. This weighting, however, did not fundamentally change the findings.

## RESULTS

The study selection criteria yielded a final sample of 1.1 million admissions at 102 hospitals. Table 2 provides descriptive statistics for the patients and hospitals in the study population (patients were included multiple times if they had multiple admissions). The majority of patients were female; 32.8% were aged 45 to 64 years, with another 29.9% aged 70 to 84 years. The hospitals in this sample ranged from <200 beds (26.5%) to >500 beds (12.8%), and 10.8% of these hospitals were teaching institutions; the majority (70.6%) were in the southern United States.

The logistic and ordinary least squares models fit the data well. The *c*-statistics for the logistic regressions estimating the likelihood of receiving any imaging service ranged from 0.74 for ultrasound to 0.83 for MR imaging. The  $R^2$  values for the ordinary least squares regressions ranged from 0.23 for MR to 0.28 for radiography. Detailed model results are available on request.

Table 3 reports the results of assessing correlations between the two imaging utilization metrics and the primary outcomes. There was an inverse and statistically significant correlation between the risk-adjusted probability of that an imaging service would be used and risk-adjusted mortality for all 4 imaging modalities studied. The correlations were  $-0.22$  ( $P = .02$ ) for CT,  $-0.20$  ( $P = .05$ ) for MR,  $-0.24$  ( $P = .02$ ) for ultrasound, and  $-0.21$  ( $P = .03$ ) for radiography. In other words, hospitals at which patients were more likely to receive imaging services had lower mortality, and vice versa, after controlling for patient and hospital characteristics. There was also an inverse correlation between the risk-adjusted mean number of imaging services per admission at a given hospital

**Table 2.** Sample characteristics

| Variable             | Value       |
|----------------------|-------------|
| Patients             |             |
| n                    | 1.1 million |
| Female               | 53.7%       |
| Age (y)              |             |
| 15–24                | 2.8%        |
| 25–34                | 5.3%        |
| 35–44                | 9.6%        |
| 45–54                | 15.1%       |
| 55–64                | 17.7%       |
| 65–69                | 9.8%        |
| 70–74                | 10.1%       |
| 75–84                | 19.8%       |
| ≥85                  | 9.8%        |
| Hospitals            |             |
| n                    | 102         |
| Hospital size (beds) |             |
| <200                 | 26.5%       |
| 200–299              | 27.5%       |
| 300–499              | 33.3%       |
| ≥500                 | 12.8%       |
| Teaching             | 10.8%       |
| Patients by region   |             |
| Northeast            | 2.0%        |
| Midwest              | 21.6%       |
| South                | 70.6%       |
| West                 | 5.9%        |

and that hospital's risk-adjusted mortality score; however, statistical significance was achieved only for ultrasound (correlation,  $-0.20$ ;  $P = .05$ ). The utilization of imaging services, regardless of how it was measured, showed a positive but statistically insignificant association with costs.

## DISCUSSION

This study, based on >1 million admissions to 102 US hospitals, indicates that inpatient diagnostic imaging may be associated with decreased in-hospital mortality, with a statistically insignificant impact on admission-related costs. It extends landmark investigations conducted by Fisher et al [3,4], Baicker and Chandra [5], and Fowler et al [6] by including all clinical conditions treated in hospitals; examining the experiences of patients with private, commercial, and government-sponsored insurance; and reporting the hospitals' incurred costs.

Interestingly, the use of any imaging service seems to be more tightly correlated with lower mortality than the number of imaging services received. This may be a statistical artifact of the increased variance of the number of services. Alternatively, this finding seems to suggest that there is no dose-response relationship between the number of imaging procedures performed and outcomes beyond the first procedure, and that this may even be a situation in which there are diminishing returns for additional services. Some imaging may be better than none, but additional utilization beyond the first service may create only limited value that is not detectable using our statistical methods.

In short, our results suggest that performing imaging on more patients may improve outcomes. There are also several possible noncausal explanations for the observed correlations, including the existence of unmeasured intervening variables. For instance, hospitals that are more likely to image patients could be more likely to attract better quality physicians and staff members, use better quality control systems, or have better facilities, any of which could improve patient outcomes or make care more efficient and less costly.

**Table 3.** Risk-adjusted imaging and outcome measure correlations\*

| Risk-Adjusted Imaging Measures | Risk-Adjusted Outcome Measures |       |             |       |
|--------------------------------|--------------------------------|-------|-------------|-------|
|                                | Mortality                      |       | Cost        |       |
|                                | Correlation                    | P     | Correlation | P     |
| Receipt of ≥1 imaging service  |                                |       |             |       |
| CT                             | −0.2245                        | .0233 | 0.0176      | .8605 |
| MR                             | −0.1964                        | .0490 | 0.1275      | .2040 |
| Ultrasound                     | −0.2397                        | .0152 | 0.0200      | .8419 |
| Radiography                    | −0.2096                        | .0345 | −0.0224     | .8234 |
| Volume of imaging services     |                                |       |             |       |
| CT                             | −0.1642                        | .0990 | 0.0397      | .6923 |
| MR                             | −0.0744                        | .4598 | 0.1207      | .2291 |
| Ultrasound                     | −0.1957                        | .0487 | 0.0808      | .4195 |
| Radiography                    | −0.0750                        | .4538 | 0.1554      | .1189 |

\*Adjusted for patient age, gender, severity, and hospital characteristics.

It is also reasonable to consider that the increased use of imaging services may in fact be causally associated with lower mortality, with little or no incremental cost. Because providers are only compensated for the professional components of inpatient diagnostic services, the use of these services likely reflects their perceived clinical or cost-saving benefit. This is not surprising, considering that primary care physicians identified diagnostic imaging as one of the most valuable medical innovations in the past 30 years [25], and some researchers have suggested that inpatient imaging lowers costs for selected conditions [26].

Our study illustrates an important yet largely unexplored area of inquiry given policy shifts toward “value-based” payment. One of the greatest obstacles to true value-based payment for imaging is the relative lack of critical evaluations of the relationship between imaging and outcomes. Furthermore, the literature that does exist is often limited to specific applications [27]. Economists’ theory of revealed preference suggests that the dramatic growth in imaging is in itself evidence of inherent value. Alternatively, the growth in diagnostic imaging utilization may reflect the existence of financial incentives within the health care system, a desire to limit professional liability [28], and an inherent preference for the “latest and greatest” [29]. Population-based, empirical evaluations of the value of imaging have mixed results and provide only a limited context for policy recommendations for use of imaging services. The Dartmouth Atlas of Health Care showed no association between high utilization of imaging services and outcomes for hip fracture, colorectal cancer, and acute myocardial infarction in a general population sample [4]. By contrast, Beinfeld and Gazelle [26] reported that shorter hospital stays coexisted with higher spending on imaging services for stroke, appendectomy, lung cancer, upper gastrointestinal procedures, colorectal cancer, and back problems. This limited and contradictory literature highlights our incomplete understanding of the relationship between utilization and outcomes.

There are, of course, limitations to this study. Our risk adjustment methods may have been incomplete, possibly confounding our findings if omitted severity measures correlate with the use of imaging services or costs. We included potential confounders (hospital location, size, teaching status) in the models and used a sophisticated, validated case-mix adjuster (clinical risk groups), but obviously, a number of factors (eg, the use of electronic order systems, the availability of rapid response teams, the availability of imaging equipment, the quality of images, the training of medical staff members reading the images) were unavailable in our data and therefore were not included in our models. In addition, one might argue that a terminal patient would be less likely to receive an

imaging service, and so mortality would be lower in imaged patients not because of the contribution of imaging to their care but simply because the patients most likely to die were selected out of the imaged population. Alternatively, we know that health care resource use is extensive in the last year of life, so it is equally reasonable to expect that very sick patients would be just as likely, or perhaps even more likely, to receive imaging services compared with patients who are less sick.

It is important also to consider how characteristics of the sample may have influenced the results. With a large sample such as this, results may be more likely to achieve statistical significance. The statistically significant findings in this study, however, may or may not translate into clinical significance, and additional research needs to be done to more fully understand the relationship between imaging and outcomes. Furthermore, although our sample included a large number of admissions, these results are unlikely to fully represent national inpatient experience. According to the American Hospital Association, there are currently nearly 6,000 hospitals registered in the United States that provided care for >37 million admissions last year [30]. Obviously, only a small percentage of American hospitals are represented in the study database, and hospitals in the southern United States are overrepresented. Finally, this study is subject to the limitations inherent to administrative claims data, including diagnosis and procedure coding conventions that provide more limited clinical detail than medical records.

Correlational analyses are widely used to examine health care variation, as illustrated by the Dartmouth Atlas of Health Care [31]. Our exploratory correlational analyses, based on a small (although relatively diverse) sample of US hospitals and using two simple measures of imaging utilization and intensity, does not definitively support causal inferences about the underlying relationship between the utilization of imaging services and hospital discharge status or costs. However, we do hope that these findings inspire researchers to use other data sources, more detailed imaging intensity measures, and alternative statistical methods to test the robustness of our results and to examine related hypotheses. Better utilization measures could reduce variance and provide a more accurate assessment of the true correlations. Different data sources might offer data from a more representative sample of hospitals and a broader set of covariates (eg, patient income, education, family status, physician supply) that could be controlled for in the analyses. Alternative statistical methods (eg, tobit models) may also provide more sophisticated ways to reduce variation and increase the accuracy of the statistical estimation in the analyses.

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