

Variability in imaging utilization in U.S. pediatric hospitals

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Abstract

Background Use of medical imaging is under scrutiny because of rising costs and radiation exposure. We compare imaging utilization and costs across pediatric hospitals to determine their variability and potential determinants.

Materials and methods Data were extracted from the Pediatric Health Information System (PHIS) database for all inpatient encounters from 40 U.S. children's hospitals. Imaging utilization and costs were compared by insurance type, geographical region, hospital size, severity of illness, length of stay and type of imaging, all among specific diagnoses.

Results The hospital with the highest utilization performed more than twice as many imaging studies per patient as the hospital with the lowest utilization. Similarly, imaging costs ranged from \$154 to \$671/patient. Median imaging-utilization rate was 1.7 exams/patient on the ward and increased significantly in the PICU (11.8 exams/patient) and in the NICU (17.7 exams per patient, $P<0.001$). Considerable variability in imaging utilization persisted despite adjustment for case mix index (CMI, range in

variation 16.6–25%). We found a significant correlation between imaging utilization and both CMI and length of stay, $P<0.0001$). However, only 36% of the variation in imaging utilization could be explained by CMI.

Conclusion Diagnostic imaging utilization and costs vary widely in pediatric hospitals.

Keywords Children · Diagnostic imaging · Imaging utilization · Medical costs

Introduction

In an era of increasing interest in medical cost containment, imaging is under scrutiny [1, 2]. Utilization of imaging resources has been increasing in the United States in both children [3, 4] and adults [5].

The use of imaging has been associated with decreased length of hospital stay [3, 4], decreased mortality [6], reduced need for specialist referrals [7] and other positive outcomes. However, the optimal use of imaging, in terms of number of studies per patient as well as the use of complex imaging modalities, remains unknown. Some authors have proposed that up to one-third of all imaging studies are unnecessary or inappropriate [8].

Variability in medical spending, imaging utilization and other markers of resource allocation has been studied among Medicare patients in adult hospitals [9]. To our knowledge, no national study has been undertaken to characterize the degree of variability in imaging use among pediatric hospitals in the United States. Our study's purpose is to describe the degree of variability in utilization of pediatric imaging and to investigate possible drivers of variability.

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Materials and methods

We used the Pediatric Health Information System (PHIS) database, an administrative database developed by the Child Health Corp. of America that collects demographic, hospital stay, utilization and diagnostic data from 40 not-for-profit tertiary care pediatric hospitals in the United States. The PHIS dataset has been widely used for cross-hospital comparisons on a number of pediatric quality and clinical outcome studies [10–12].

The current study evaluated data collected on children between the ages of 0 and 18 years who were cared for as inpatients between July 2006 and December 2008. The PHIS database does not currently track outpatient visits, and data on emergency department visits were limited at the time of this study. Therefore, the study was limited to inpatients. The outcome measures evaluated were hospital imaging-utilization rate (expressed as the average number of studies per patient for each hospital) and average imaging costs per patient at each hospital. Variation in these outcomes across hospitals was described by minimum, mean and maximum values and the coefficient of variation. No clinical outcomes were evaluated.

Imaging studies were classified by their relative complexity into three categories: low (radiography), medium (fluoroscopy and US), and high (CT, MRI, interventional and nuclear medicine), based on average cost. We calculated hospital utilization rate and average cost per patient within each complexity category and compared outcomes across categories using analysis of variance. Generalized estimating equations were used to adjust for the correlation among multiple measurements (one for each complexity category) within a hospital. The effect of the location of inpatient admission (ward, neonatal intensive care or pediatric intensive care) and severity of illness, expressed as case mix index (all-patient refined diagnosis-related groups, APR-DRG, version 20 [3M-Corp., Minneapolis, MN, USA]), were analyzed similarly. In addition, we evaluated imaging utilization and cost among the five diagnoses with the highest average case mix index (CMI), among the five diagnoses with the highest imaging-utilization rate per patient, and among the five most common admitting diagnoses to each hospital.

Adjusted charges are generated by PHIS using billed charges adjusted by the CMS wage/price index for each hospital's location. These adjusted charges are then multiplied by each hospital's cost-to-charge ratio to generate the adjusted costs presented in the paper.

The relationship between the outcome variables and potential predictors, such as average CMI and average length of stay, was evaluated using linear regression. Predictors exhibiting a significant correlation using univariate analysis were included in a multivariate regression model to determine the relative contribution of each variable. Analyses were performed with SAS version 9.2 (SAS Software, Cary, NC, USA). Statistical significance was accepted at an alpha level of 0.05.

This study is HIPPA-compliant and was reviewed by our institution's Internal Review Board, which determined that it did not require review board approval. The requirement for informed consent was waived.

Results

Description of hospitals

Forty free-standing pediatric hospitals were included in the study. Their characteristics are described in Table 1. They ranged in size from 104 to 462 staffed beds (mean = 260 beds). The total number of admissions per hospital during the study period ranged from a low of 13,880 patients to a high of nearly 70,000 patients. Average patient acuity also varied considerably from the lowest mean case mix index (CMI) of 1.2 to the highest CMI of 3.0. Similarly, average patient length of stay ranged from a low of 3.9 days to a high of 9.1 days.

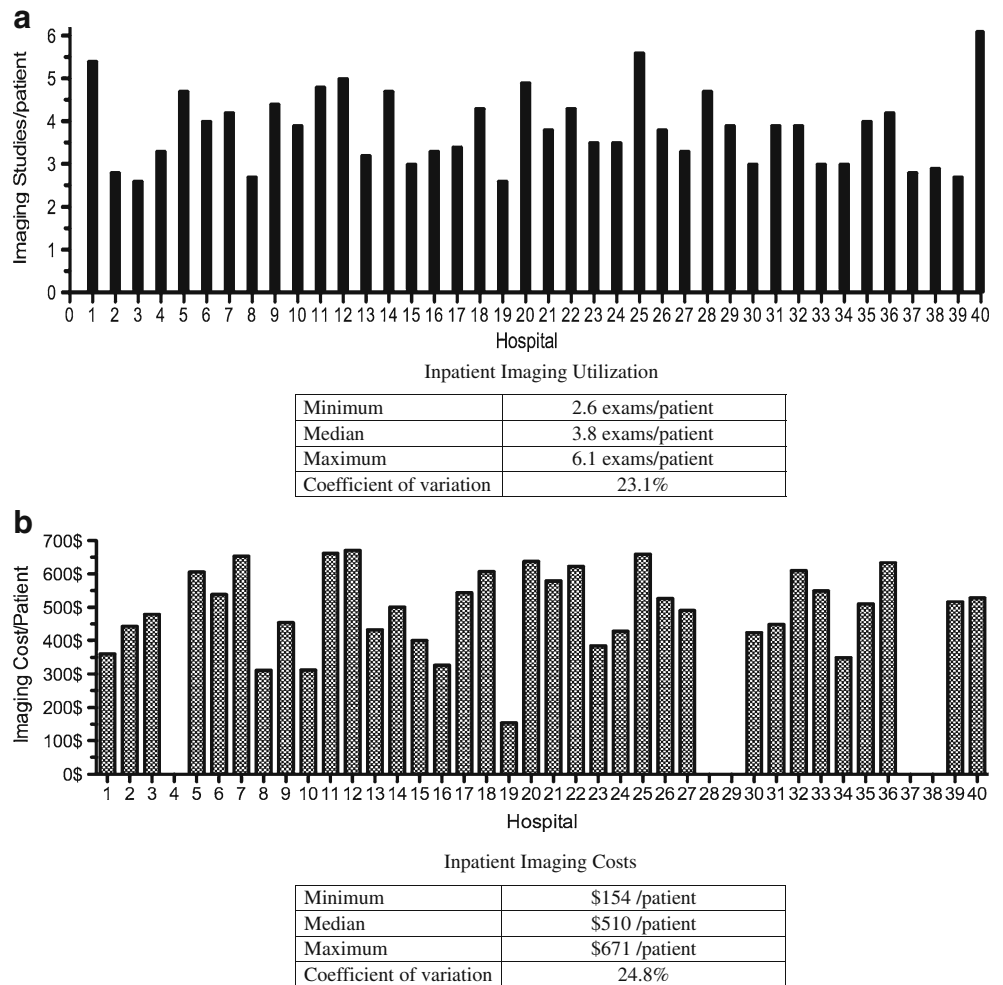
Variability in imaging utilization and cost

A total of 3,617,869 diagnostic imaging studies were performed on 1,461,082 inpatients across all hospitals during the study period. Overall imaging utilization (studies per patient) varied widely among the hospitals studied (Fig. 1). The hospital with the highest utilization performed more than twice as many imaging studies per patient as the

Table 1 Characteristics of the 40 hospitals studied

Characteristic	Minimum	Median	Mean	Maximum	Coefficient of variation
Staffed beds	104	250	260	462	23.1%
Total admissions during study period	13,880	34,336	36,527	69,956	33.8%
Mean length of stay (days)	3.92	5.15	5.46	9.12	21.9%
Mean case mix index	1.17	1.83	1.82	3.02	20.7%

Fig. 1 Graphs and tables show hospital imaging-utilization rate (studies/patient) (a) and hospital average imaging costs (dollars per patient) (b) for each of 40 tertiary pediatric hospitals. Five hospitals did not contribute cost data to the PHIS database



hospital with the lowest utilization. Imaging costs also varied considerably, ranging from a low of \$154 per patient to a high of \$671 at the highest-spending hospital (Fig. 1).

We divided imaging studies into low-, medium- and high-complexity imaging modalities and looked at the degree of variability in utilization and cost in each category (Table 2).

The degree of variability in utilization decreased in a stepwise fashion from 24.5% in low-complexity studies to 10.5% in high-complexity examinations. While imaging costs increased with higher-complexity imaging studies, the variability was more limited, ranging from 31% for medium-complexity examinations to a high of 56.1% for low-complexity studies.

Table 2 Variability in hospital imaging utilization and average imaging costs by imaging complexity

Level of imaging complexity	Hospital imaging-utilization rate (exams/patient) ^a		Hospital average imaging costs (dollars per patient) ^a	
	Mean ± SD (min, max)	CV	Mean ± SD (min, max)	CV
Low	4.8±1.2 (3.0, 7.6)	24.5%	267±150 (130, 832)	56.1%
Medium	3.6±0.7 (2.0, 4.7)	18.5%	524±162 (156, 939)	31.0%
High	2.3±0.2 (1.8, 3.0)	10.5%	1102±445 (180, 220)	40.4%

^a ANOVA comparing mean outcome across imaging complexity category *P*<0.001

Low complexity = radiography (*n*=679,745)

Medium complexity = fluoroscopy, US (*n*=404,562)

High complexity = CT, MRI, interventional, nuclear medicine (*n*=287,930)

Cost data were not available for five hospitals during the time period

CV coefficient of variation

Factors affecting imaging utilization and cost

Effect of inpatient setting

Imaging utilization was evaluated in three patient groups stratified by increasing level of intensity of care: inpatient ward, pediatric intensive care (PICU), and neonatal intensive care (NICU, Table 3). As expected, the median imaging-utilization rate was lowest in patients treated on the ward (1.7 exams/patient), and increased significantly in patients in the PICU (11.8 exams/patient) and in the NICU (17.7 exams per patient, $P<0.001$). Despite normalization by level of intensity of care, the degree of variability in imaging utilization increased in PICU (29.3%) and NICU patients (44%), compared to ward patients (23.2%).

Similarly, imaging costs by patient setting reflected the intensity of care received, increasing from a median of \$291 per ward patient to \$1,506 and \$1,455 per PICU and NICU patient, respectively (Table 3, $P<0.001$). The degree of variation in median costs was highest in the NICU (46.2%), followed by PICU (38.3%), with less variability in median costs in the ward (25.7%).

Effect of disease acuity

We then evaluated the effect of disease acuity on imaging utilization and costs by stratifying patients into four categories of increasing case mix index (CMI). Imaging utilization increased in a stepwise fashion for each category of CMI (Table 4, $P<0.001$). Considerable variability in imaging utilization persisted despite adjustment for CMI (range in coefficient of variation = 16.6–25%).

We found a significant correlation between hospital imaging-utilization rate and hospital average CMI (Fig. 2, $P<0.0001$). However, only 36% of the variation in imaging utilization could be explained by CMI ($r^2=0.36$).

Imaging cost by CMI ranged from a mean of \$150 for the lowest acuity patients (CMI category ≤ 0.5) to a high of

\$2,887 among the patients with a CMI >5.0 ($P<0.001$, Table 4). Variability in costs remained relatively stable across CMI categories (CV ranging from 24% to 32%). There was a weak but significant correlation between increasing average hospital patient acuity and average imaging cost per patient (Fig. 2, $r^2=0.16$, $P=0.03$).

Effect of specific diagnosis category

Case mix index is a useful tool to define the average acuity of patients admitted to a particular hospital. However, hospitals might have similar average patient acuity but entirely different patient populations (e.g., large neonatal ward vs. large transplant service). To normalize the potential effect of heterogeneous patient populations, we evaluated imaging utilization and median costs for three patient populations: the five most common diagnoses discharged from each hospital (Table 5), the five diagnoses with the highest imaging-utilization rate per patient (Table 6) and the five diagnoses with the highest average case mix index (Table 7). As expected, the five diagnoses with the highest case mix index and those with the highest imaging-utilization rates had the highest median utilization rate and costs, while the five most common discharge diagnoses had far lower median imaging-utilization rates and costs. Significant variability in imaging utilization and cost persisted for each of the three categories, with the coefficient of variation ranging between 19.9% and 51.8% ($P<0.001$ by generalized estimation equation model, Tables 5, 6 and 7).

Effect of patient length of stay

Increasing length of stay was significantly correlated with increasing utilization of imaging (Fig. 3, $P<0.0006$ by linear regression, $r^2=0.27$). However, there was no significant correlation between length of stay and average imaging cost per patient ($P=0.07$ by linear regression, $r^2=0.10$).

Table 3 Variability in hospital imaging utilization and average imaging costs by inpatient setting

Inpatient setting	Hospital imaging-utilization rate (exams/patient) ^a		Hospital average imaging costs (dollars per patient) ^a	
	Mean \pm SD (min, max)	CV	Mean \pm SD (min, max)	CV
Ward	1.7 \pm 0.4 (0.7, 2.6)	23.2%	282 \pm 72 (106, 406)	25.7%
PICU	13.1 \pm 3.8 (7.6, 22.7)	29.3%	1,574 \pm 603 (485, 3,920)	38.3%
NICU	20.1 \pm 8.9 (9.2, 47.2)	44.0%	1,719 \pm 793 (723, 4,236)	46.2%

^a ANOVA comparing mean outcome across inpatient setting $P<0.001$

Ward ($n=1,184,803$)

PICU ($n=176,657$)

NICU ($n=77,661$)

Cost data were not available for five hospitals during the time period

Table 4 Variability in hospital imaging utilization and average imaging costs by case mix index category

CMI category	Hospital imaging-utilization rate (exams/patient) ^a		Hospital average imaging costs (dollars per patient) ^a	
	Mean ± SD (min, max)	CV	Mean ± SD (min, max)	CV
0–0.5	1.0±0.2 (0.3, 1.4)	22.8%	150±48 (31, 251)	32.0%
0.51–1.0	1.4±0.3 (0.7, 2.0)	19.9%	249±69 (93, 381)	27.6%
1.01–5.0	3.5±0.6 (2.5, 5.0)	16.8%	545±131 (215, 767)	24.1%
5.01+	29.4±7.6 (18.2, 48.6)	25.7%	2,887±886 (1,078, 5,204)	30.7%

^a ANOVA comparing mean outcome across CMI category $P < 0.001$

CMI 0–0.5 ($n = 360,757$)

CMI 0.51–1.0 ($n = 510,998$)

CMI 1.01–5.0 ($n = 470,328$)

CMI >5.0 ($n = 91,709$)

Cost data were not available for five hospitals during the time period

Predictors exhibiting a significant correlation using univariate analysis were included. A multiple-regression model was created using case mix index and length of stay to determine the relative contribution of each variable. Of

the two variables, only case mix index contributed significantly to the model.

There were no significant correlations between imaging utilization or cost and patient insurance type, hospital geographical region or hospital size.

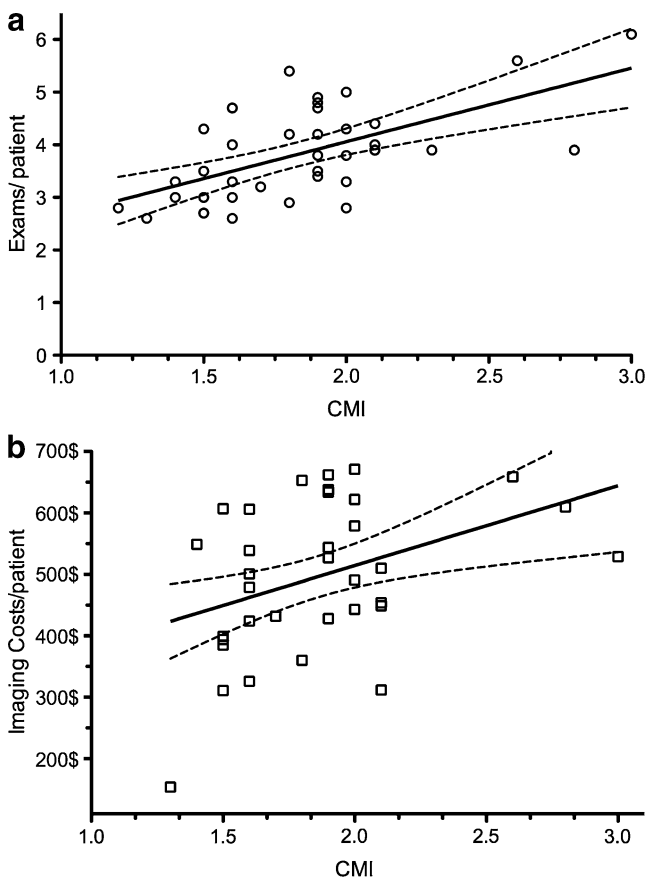


Fig. 2 Scatter plots show (a) comparison of hospital imaging-utilization rate (studies/patient) vs. average case mix index (linear regression $P < 0.0001$, $r^2 = 0.36$) and (b) comparison of hospital average imaging costs (dollars per patient) vs. average case mix index (linear regression $P < 0.03$, $r^2 = 0.16$)

Discussion

Pediatric radiologists value safe and appropriate medical imaging, using the lowest feasible radiation dose, consistent with ALARA (as low as reasonably achievable) principles. Yet, our study shows that there is considerable variation in the use of imaging in hospitalized patients in large pediatric facilities across the United States, even when stratified by inpatient setting, patient acuity and specific disease category. We found that the best predictor of imaging utilization was increasing patient acuity as measured by increasing average case mix index (CMI). Yet CMI only accounted for 36% of the variation in imaging utilization. The remaining 64% of the variability in imaging is not explained by any factors examined in this study.

With respect to cost, the most expensive pediatric hospital in our study spent more than four times as much per patient on imaging as the least expensive hospital. In addition to differences in utilization, at least three additional variables might account for the 400% variation in imaging costs. First, some hospitals use advanced imaging, such as CT or MRI, in greater proportion than other hospitals, resulting in a higher expense per study. Second, operational expenses can vary up to five times among hospitals for identical procedures, depending on regional variations in costs [13]. Third, hospitals and radiology groups generally negotiate payment directly with insurance companies and might be in stronger or weaker negotiating positions that can result in large differences in charges for identical

Table 5 Variability in hospital imaging utilization among the five most common diagnoses at discharge

APR-DRG v 20	Total volume	Hospital imaging-utilization rate (exams/patient) ^a		Hospital average imaging costs (dollars per patient) ^a	
		Mean ± SD (min, max)	CV	Mean ± SD (min, max)	CV
Asthma – 141	70,568	0.9±0.2 (0.4, 1.3)	23.2%	65±22 (31, 110)	33.7%
Seizure – 53	53,738	1.3±0.4 (0.7, 2.7)	29.8%	340±116 (120, 580)	34.1%
Bronchiolitis & RSV pneumonia - 138	49,336	1.2±0.2 (0.6, 1.7)	19.9%	92±29 (44, 169)	31.2%
Other pneumonia – 139	40,095	2.1±0.5 (1.3, 3.5)	22.9%	208±72 (107, 464)	34.8%
Neonate birth wt >2,499 g, normal newborn or neonate with other problem – 640	38,652	0.9±0.5 (0.1, 2.2)	51.8%	105±65 (13,280)	61.6%

^a ANOVA comparing mean outcome across APR DRG category $P<0.001$ asthma

studies [14]. Why is this variability of concern? Overutilization of imaging in children has many possible negative effects, including risks of radiation exposure, sedation and cost. Underutilization of imaging is also undesirable because of the possibility of missing a treatable diagnosis before it becomes more severe or life-threatening. Hendee et al. [15] reported on some of the key forces thought to influence imaging overutilization. These include payment mechanisms and financial incentives in the U.S. health care system, the practice behavior of referring physicians, self-referral (including referral for additional radiological examinations), defensive medicine, missed educational opportunities when inappropriate procedures are requested, patient

expectations and duplicate imaging studies. The factors that most likely apply to the variability of utilization in our study are practice variations, missed educational opportunities and, to a lesser degree, defensive medicine.

Practice variations in pediatric imaging might be in part related to differences in demographic factors such as race, ethnicity and socioeconomic status of the populations served by different hospitals. These factors are likely to mirror variations in practice in pediatric specialties across the U.S. For example, the rate of appendiceal rupture has been associated with race and health insurance status in children [16]. Similarly, the risk of non-sickle-cell-related stroke is significantly higher in black children than in Asian and white

Table 6 Variability of imaging utilization among the five diagnoses that had the highest imaging-utilization rate per patient (APR-DRG v 20)

APR-DRG v 20	Overall imaging utilization rate (studies/patient)	Hospital imaging-utilization rate (exams/patient) ^a		Hospital average imaging costs (dollars per patient) ^a	
		Mean ± SD (min, max)	CV	Mean ± SD (min, max)	CV
Neonate with ECMO – 583	91.6	97.7±39.2 (37.4, 224.2)	40.1%	7534±2800 (2487, 12971)	37.2%
Heart or lung transplant – 2	82.9	93.1±38.4 (32.2, 194)	41.2%	9924±5772 (2719, 25141)	58.2%
Tracheostomy with long-term mechanical vent and extensive procedure – 4	82.1	85.8±29.7 (44.7, 175.6)	34.6%	7865±3374 (2204, 21253)	42.9%
Neonate, birth wt <1,500 g with major procedure – 588	74.5	77.4±34.2 (30.5, 222.7)	44.1%	5610±2881 (1684, 15714)	51.4%
Neonate >2,499 g with major cardiovascular procedure – 630	50.1	53.1±16.8 (18.7, 97.2)	31.7%	4705±1689 (1860, 8762)	35.9%

^a ANOVA comparing mean outcome across APR DRG category $P<0.001$ neonate with ECMO 91.6 exams/patient

APR-DRG v 20 583 ($n=1,310$)

APR-DRG v 20 2 ($n=706$)

APR-DRG v 20 4 ($n=1,013$)

APR-DRG v 20 588 ($n=3,338$)

APR-DRG v 20 630 ($n=4,803$)

Cost data were not available for five hospitals during the time period

Table 7 Variability of imaging utilization among diagnoses with the highest case mix index (APR-DRG v 20)

APR-DRG v 20	Average CMI	Hospital imaging utilization rate (exams/patient) ^a		Hospital average imaging costs (dollars per patient) ^a	
		Mean ± SD (min, max)	CV	Mean ± SD (min, max)	CV
Neonate birth wt <1,500 g with major procedure - 588	34.6	77.4±34.2 (30.5, 222.7)	44.1%	5610±2881 (1684, 15714)	51.4%
Heart or lung transplant - 2	34.2	93.1±38.4 (32.2, 194)	41.2%	9924±5772 (2719, 25141)	58.2%
Neonate with ECMO- 583	30.4	97.7±39.2 (37.4, 224.2)	40.1%	7534±2800 (2487, 12971)	37.2%
Tracheostomy with long-term mechanical vent with extensive procedure - 4	30	85.8±29.7 (44.7, 175.6)	34.6%	7865±3374 (2204, 21253)	42.9%
Neonate birth wt 500-740 g without major procedure - 591	26.6	46.0±23.6 (16.8, 112.6)	51.3%	3153±1709 (1125, 7817)	54.2%

^a ANOVA comparing mean outcome across APR DRG category $P < 0.001$

APR-DRG v 20 583 ($n=1,310$)

APR-DRG v 20 2 ($n=706$)

APR-DRG v 20 4 ($n=1,013$)

APR-DRG v 20 588 ($n=3,338$)

APR-DRG v 20 591 ($n=1,379$)

children [17]. A higher prevalence of one or both of these diseases would be certain to drive up imaging utilization in individual hospitals and contribute to regional variations.

Substantial regional variation in diagnostic imaging utilization has been reported among Medicare recipients, with cardiovascular PET, MRI and CT studies showing the highest degree of variability [9]. Our study did not uncover evidence of a regional effect on imaging utilization in hospitalized children. Marked differences in disease prevalence and practice style between adult and pediatric practice are likely to play an important part in this difference.

Variations in medical care are strongly influenced by subjective factors related to the attitudes of individual physicians [18]. In addition, many referring physicians are unfamiliar with the strengths and weaknesses of different

imaging studies for patients with specific clinical indications. These practice style factors can have profound effects on utilization of medical resources, including imaging. One study of viral lower respiratory illness reported wide variations in resource utilization in these patients, and concluded that “the intensity of therapy bore little relationship to severity of illness but was a primary determinant of resource utilization” [19]. In another study of pediatric trainees, Hirschl et al. [20] compared imaging-ordering practices to appropriateness criteria developed by the American College of Radiology (ACR) for 10 specific clinical scenarios. They found that only half of the five scenarios were handled correctly by the majority of trainees. Educational efforts on the effective use of imaging should begin in medical school and continue throughout medical practice in the form of presentations at meetings and one-on-one consultation with radiologists when complex imaging studies are requested [15].

Finally, the practice of defensive medicine, defined as a deviation from sound medical practice that is induced primarily by a threat of liability [21], might play an important role in the variability of pediatric imaging utilization. This is especially true in high-risk environments. One survey of physicians in six adult specialties at high-risk for litigation (emergency medicine, general surgery, orthopedics, neurosurgery, obstetrics/gynecology and radiology) showed that nearly 43% of physicians practicing defensive medicine used imaging in clinically unnecessary circumstances [21]. The study found a strong correlation between defensive practice and lack of confidence in liability insurance and perceived burden of insurance premiums. A second national survey found that

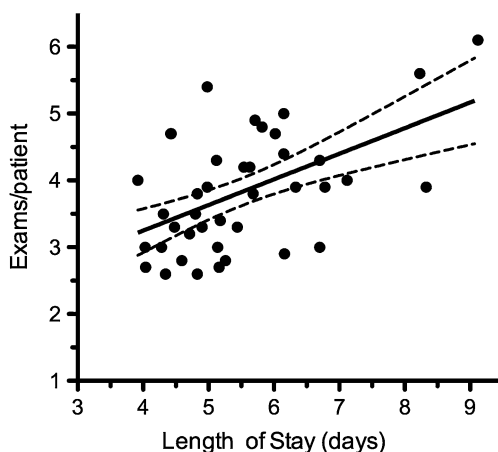


Fig. 3 Scatter plot shows comparison of hospital imaging-utilization rate vs. average length of stay (linear regression $P < 0.0006$, $r^2 = 0.27$)

91% of physicians across all medical specialties practice defensive medicine, and that the perception of risk of legal action had little correlation with actual frequency of litigation [22]. The Massachusetts Medical Society issued a report in 2008 stating that more than 20% of imaging studies in the state were ordered as a defensive hedge against malpractice litigation [23].

Many initiatives designed to guide appropriate imaging utilization are under way. For example, the ACR has developed appropriateness criteria for a wide variety of medical conditions, including many pediatric illnesses. These have often been incorporated into practice guidelines based on available high-quality evidence of effectiveness. The main limitation of this approach at pediatric hospitals is the relative scarcity of appropriateness criteria for pediatric diseases. These criteria are also based on disease processes rather than presenting symptoms and signs and might not be up-to-date in areas with rapidly changing technology.

The current study is a retrospective evaluation of administrative data collected among participating hospitals. As such, it is limited by the lack of specific outcome measures related to use of imaging procedures, lack of information on important demographic variables such as patient race/ethnicity, and the lack of availability of aggregated data. In addition, these data were obtained from free-standing, not-for-profit pediatric hospitals and might not reflect imaging-utilization patterns in other settings of inpatient pediatric care. However, the results of this study point to a large degree of variation in imaging utilization and associated costs in hospitalized children. Although the use of imaging is related to increasing severity of illness, this factor alone only explains a fraction of the variability in utilization and costs.

Conclusion

How do we optimize the decision of when and how to image a sick child? Clearly, there is a need for specific practice guidelines for common pediatric diseases and for appropriateness criteria based on clinical situations and patient-presenting symptoms rather than diagnosis. Ongoing consultation between referring clinicians and radiologists prior to approval of complex imaging procedures in children is an important step, especially in children requiring the use of relatively high doses of ionizing radiation (e.g., CT, PET, cardiac catheterization and interventional procedures) and those requiring sedation or general anesthesia. It is important to reach out to our clinical colleagues and to participate in educational efforts at their teaching conferences and national meetings. Finally, there is a need to deal with both the reality and perception of our fear of frivolous litigation that results in the practice of defensive medicine.

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