Trends and Variation in the Utilization and Diagnostic Yield of Chest Imaging for Medicare Patients With Suspected Pulmonary Embolism in the Emergency Department

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OBJECTIVE. The purpose of this study is to assess trends and variation in chest CT utilization in the emergency department (ED) and its diagnostic yield for suspected pulmonary embolism (PE) among a national sample of Medicare beneficiaries. The relationship between hospital and provider characteristics is also discussed.

MATERIALS AND METHODS. We conducted an observational analysis of Medicare beneficiaries evaluated in the ED for suspected PE from 2000 to 2009. Standard Medicare analytic files representing a 20% sample of fee-for-service beneficiaries were linked to the American Hospital Association Annual Survey of Hospitals, American Medical Association Physician Masterfile, Medicare Physician Identification and Eligibility Registry, and Dartmouth Atlas Project to calculate geographic- and physician-level chest CT utilization (i.e., the proportion of ED visits involving chest CT examination for suspected PE) and diagnostic yield (i.e., the proportion of chest CT examinations with a positive PE diagnosis).

RESULTS. Of 2.5 million ED visits, 2.5% (n = 164,274) included chest CT for suspected PE; 6.2% visits (n = 10,121) resulted in positive findings for PE. Between 2000 and 2009, chest CT utilization increased fivefold. Geographic variation in CT utilization (median, 2.38%; interquartile range [IQR], 1.91–2.92%) and diagnostic yield (median, 6.31%; IQR, 5.11–7.66%) was observed between 306 hospital referral regions. Physician use of imaging was explained by greater experience (lower utilization and higher yield) and emergency medicine board certification (lower utilization and equivalent yield).

CONCLUSION. CT utilization in the ED for suspected PE has steadily risen, whereas diagnostic yields have declined over time. Wide variation in practice is observed at the physician and geographic levels and is explained by several physician and hospital characteristics. Taken together, our findings suggest a substantial inefficiency of chest CT use and substantial opportunities for improvement.

Increased utilization of CT imaging over the past two decades has been cited as a driver of rising health care costs and increasing ionizing medical radiation exposure [1]. These increases are particularly pronounced in emergency departments (EDs) in the United States, where CT utilization increased by 330% between 1996 and 2007 as Americans increasingly sought unscheduled acute care in the ED [2–4]. CT utilization in the ED is often inefficient because, across hospitals and providers, substantial variation exists that is not well explained by differences in patient mix [5–7].

Pulmonary CT angiography has attracted particular attention because evidence suggests that nearly one-third of CT studies ordered to evaluate patients for suspected pulmonary embolism (PE) may be inappropriately ordered, and more than six million patients are evaluated for suspected PE in EDs in the United States annually [8]. In addition, an analysis of a limited sample of Medicare beneficiaries identified geographic variation in the utilization of chest CT across several states. However, the degree to which the observed variation was driven by provider characteristics is unknown [9]. Accordingly, the goal of reducing variation in utilization of chest CT has been integrated into national quality measurement and improvement initiatives, such as Choosing Wisely, that seek to improve the appropriateness of CT and reduce the potential risks of ionizing radiation and IV contrast exposure [9–13]. This information is needed by policymakers and providers seeking to develop and implement targeted interventions to improve imaging performance.

Assessing the appropriateness of CT for PE can be challenging, so prior work has primarily focused on studying utilization [6]. However, utilization is a limited measure of imaging efficiency that is prone to overemphasizing cost reductions over quality and is lacking in necessary clinical nuance for health care policymaking. Therefore, several analyses have sought to assess diagnostic yield (i.e., the proportion of studies yielding a positive result) as a complementary measure to utilization. The conceptual framework of diagnostic yield has been proposed for radiology quality measurement to assess the quality of imaging test selection and as a balance of sensitivity and specificity in imaging practice [14]. Diagnostic yield outcome measures have been frequently applied to cardiac imaging [15], but little work has been done to describe the diagnostic yield of ED imaging for suspected PE in a national dataset [16]. One study utilizing the National Hospital Ambulatory Medical Care Survey described the diagnostic yield of CT for PE among patients with chest symptoms as less than 3% between 2001 and 2009 [11], but sample size or data detail was insufficient to describe annual trends or variation in diagnostic yield between providers or to identify patient and physician predictors of imaging use.

Therefore, we sought to assess trends and variation in the utilization and diagnostic yield of chest CT for Medicare patients with suspected PE in the ED and to identify contributing hospital and provider characteristics.

Materials and Methods

Design and Dataset

This observational analysis of Medicare beneficiaries evaluated in the ED was approved by the institutional review board at the National Bureau of Economic Research. We combined data from Medicare claims files, the American Hospital Association Annual Survey of Hospitals, the American Medical Association Physician Masterfile, and the Medicare Physician Identification and Eligibility Registry. The Medicare claims files include a 20% sample of national Medicare fee-for-service beneficiaries identified from all Medicare Part A and B claims filed from 2000 to 2009.

We included all patients evaluated in the ED on the basis of physician-submitted Medicare Part B claims for evaluation and management services. Consistent with prior research, we defined an ED visit as a claim that included Current Procedural Technology codes 99281, 99282, 99283, 99284, or 99285 and designated the hospital ED as the place of service [17]. To focus our analysis on patients suspected of having PE, we excluded all patients with a history of aortic aneurysm, aortic dissection, or other arterial dissection during an inpatient stay occurring before an ED visit. We also excluded all patients who had any diagnoses indicative of trauma, chest cancer, or pleural effusion at the same time the ED visit occurred. Clinical comorbidities included all 30 comorbidities identified by Elixhauser and colleagues (Elixhauser Comorbidity Software, version 3.6, Agency for Healthcare Research and Quality). A comorbidity was considered to be present if it was mentioned in any inpatient claim in the year before the included ED visit.

We identified all patients who underwent CT for suspected PE by first identifying all radiologist claims for chest CT (Current Procedural Technology codes 71260, 71270, or 71275) performed within 1 day of a patient's ED visit. We classified the outcome of each chest CT examination with the use of inpatient hospital claims. We included claims with either a principal or secondary diagnosis of PE (International Classification of Disease, ninth revision, codes 415.1, 415.11, 415.12, 415.19, or 416.2).

We validated these definitions in previous work in which we compared data abstracted from medical records from two academic medical centers with data from Medicare claims. We found that, among patients with a CT study with positive findings for PE, 87% could be identified on the basis of inpatient administrative claims and that, among patients with a CT study with negative findings for PE, 94% were coded as having negative findings on the basis of our definition [7, 18].

We extracted hospital characteristics from the American Hospital Association Annual Survey of Hospitals, including information on hospital ownership (nonprofit vs for profit), location (rural vs urban), and teaching status. We also identified the hospital referral region of each hospital, using data from the Dartmouth Atlas Project. We obtained physician characteristics from the American Medical Association Physician Masterfile and the Medicare Physician Identification and Eligibility Registry, including the medical school attended, the year of graduation from medical school, and board cer-

TABLE 1: Description of Study Sample, Which Comprised 6,440,281 Medicare Fee-for-Service Beneficiaries in 2000–2009

Characteristic	Value
Patient characteristic	
Age (y), mean (SD)	77.6 (7.8)
Female sex	59
White race[a]	86
No. of comorbidities, mean (SD)	4.6 (2.8)
History of pulmonary embolism	0.3
History of deep vein thrombosis	0.7
Surgery within prior 30 days	2.2
Inpatient hospitalization within prior 30 days	2.5
Hospital characteristic	
Ownership	
For profit	13.2
Nonprofit	86.8
Critical access designation	1.6
Location	
Urban	81.3
Rural	18.7
Teaching status	
Teaching	31.5
Nonteaching	68.5
Physician characteristic	
Experience in years, mean (SD)	17.0 (9.0)
Graduate of top-50 research medical school	28.6
Emergency medicine board certification	51.7

Note—Except where otherwise indicated, data are percentage of patients.
[a]Race variable is from Centers for Medicare and Medicaid Services.

tification. We defined physician experience as the number of years since graduation from medical school. To match physicians to hospitals, we examined all ED evaluation and management visits billed by a physician and assigned physicians to the hospital at which most ED visits occurred.

Outcomes

We used two primary outcome measures. First, we assessed chest CT utilization, which was calculated as the proportion of all ED visits evaluated with chest CT for suspected PE. Second, we assessed the diagnostic yield of imaging, which was calculated as the proportion of chest CT studies with a positive diagnosis of PE. As secondary outcomes, we identified hospital and provider characteristics contributing to variation in utilization and yield.

Analytic Approach

Primary outcome measures were calculated (expressed as median and interquartile range [IQR] values) at the geographic (i.e., hospital referral region) and provider levels across the entire dataset from 2000 to 2009. Trends were reported as the mean annual utilization and yield at the national level.

We evaluated the relationship between hospital and provider characteristics and each primary outcome measure, using linear regression. Regression models were adjusted for patient age, sex, race (from Centers for Medicare and Medicaid Services), and comorbidities. Adjustment for clinical comorbidity included all 30 conditions validated by Elixhauser and colleagues (Elixhauser Comorbidity Software), in addition to several conditions known to confer specific risk for PE, including hospitalization for PE in the previous year, thoracic aortic dissection, abdominal aortic dissection, deep vein thrombosis, any hospitalization within the past 30 days, or any surgery within the past 30 days [19]. Regression models also included fixed effects for each year, to account for time-series trends, and accounted for clustering of observations at the hospital level. For the interpretation of results, $\alpha = 0.05$ was considered statistically significant.

In a sensitivity analysis, we tested our results, including all CT studies, before applying patient exclusions. All analyses were conducted using statistical software (Stata, version 14.2, StataCorp; R, version 3.3.1, R Foundation; and ArcMap, version 10.3, Environmental Systems, Research Institute).

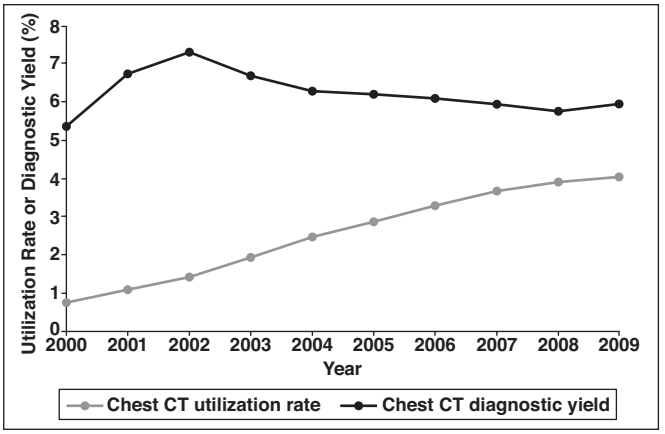

Fig. 1—Graph of national trends in emergency department chest CT utilization and diagnostic yield for 2000–2009.

Results

Study Sample and Characteristics

The total sample for this study included 6.5 million ED visits by patients who were evaluated by 44,062 physicians across all 306 hospital referral regions. A total of 2.5% of patients (n = 164,274) were evaluated with chest CT for suspected PE, and of those patients, 6.2% (n = 10,121) had findings positive for PE. Characteristics of the sample are presented in Table 1. Sensitivity analyses showed no qualitative differences on the basis of the exclusions applied.

National Trends in CT Utilization and Diagnostic Yield

Between 2000 and 2009, utilization of chest CT for suspected PE steadily increased from 0.75% in 2000 to 4.05% in 2009 (Fig. 1). Over the same period, the diagnostic yield of chest CT increased from 5.36% in 2000 to a peak of 7.31% in 2002 and then declined to 5.94% by 2009.

Geographic Variation in CT Utilization and Diagnostic Yield

We found wide variation in ED utilization of chest CT for suspected PE at the geographic level. The median hospital referral region had a CT utilization rate of 2.38% (IQR, 1.91–2.92%) and a median diagnostic yield of 6.31% (IQR, 5.21–7.66%) (Figs. 2A and 2B). As depicted in Fig. S1 (which can be viewed in the *AJR* electronic supplement to this article, available at www.ajronline.org), the correlation between CT utilization at the hospital referral region level and diagnostic yield was −0.04 (p = 0.495).

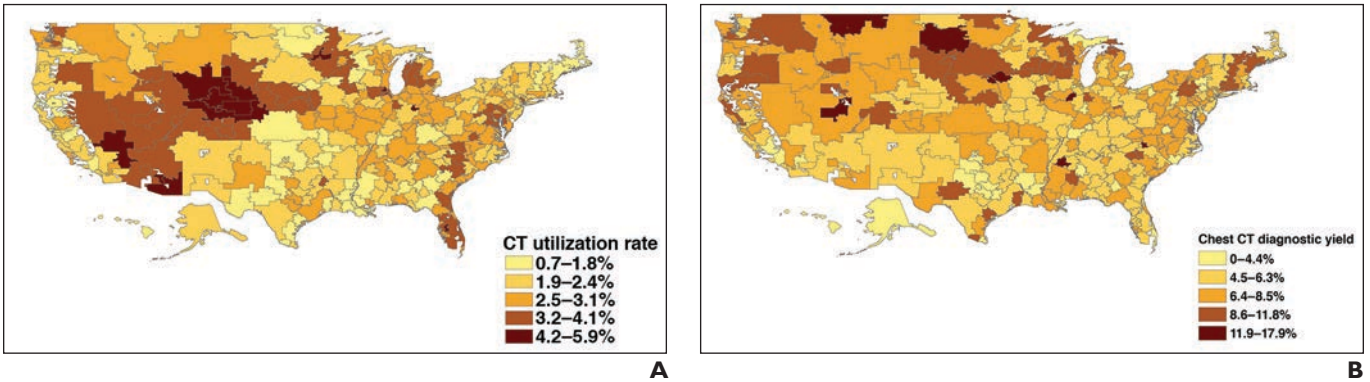

Fig. 2—Geographic variation in chest CT utilization rate and diagnostic yield in emergency department (ED) setting.
A, Map shows geographic variation in utilization rate of chest CT for suspected pulmonary embolism (PE) in ED according to hospital referral region.
B, Map shows geographic variation in diagnostic yield of chest CT for suspected PE in ED according to hospital referral region.

TABLE 2: Relationship Between Hospital and Physician Characteristics and Chest CT Patterns in 2000–2009

Characteristic	Chest CT Utilization		PE Diagnostic Yield	
	Regression Coefficient (95% CI)	*p*	Regression Coefficient (95% CI)	*p*
Hospital characteristic				
For-profit ownership	0.0002 (–0.0013 to 0.0020)	0.788	–0.0053 (–0.0091 to –0.0015)	0.006[a]
Critical access designation	–0.0023 (–0.0038 to –0.0008)	0.003[a]	0.0017 (–0.0128 to 0.0163)	0.817
Teaching status	0.0023 (0.0011–0.0033)	< 0.001[a]	0.0025 (–0.0006 to 0.0056)	0.117
Urban location	0.0075 (0.0065–0.0084)	< 0.001[a]	–0.0095 (–0.0137 to –0.0053)	< 0.001[a]
Physician characteristic				
Experience	–0.0001 (–0.0002 to –0.0001)	< 0.001[a]	0.0004 (0.0002–0.0005)	< 0.001[a]
Emergency medicine board certification	–0.0018 (–0.0024 to –0.0012)	< 0.001[a]	0.008 (–0.0020 to 0.0036)	0.589
Graduate of top-50 research medical school	0.0005 (–0.0003 to 0.0012)	0.246	0.0025 (–0.0015 to 0.0064)	0.220
Graduate of top-50 primary care medical school	0.0010 (0.0002–0.0018)	0.011[a]	0.0025 (–0.0016 to 0.0065)	0.231

Note—Regression results control for patient age, sex, race, Elixhauser comorbidity set, history of pulmonary embolism (PE), history of deep venous thrombosis, and whether the patient had previously been admitted to the hospital or had undergone surgery within the past month. SE values are clustered at the hospital level.
[a]Statistically significant at $p < 0.05$.

Hospital-Level Predictors of CT Utilization and Diagnostic Yield

In regression analysis, we found higher CT utilization rates and lower diagnostic yield at urban hospitals. We also found higher CT utilization among critical access hospitals and teaching hospitals with no difference in diagnostic yield at either hospital type. In addition, we found a lower diagnostic yield among for-profit hospitals, with no difference in CT utilization noted (Table 2).

Physician-Level Predictors of CT Utilization and Diagnostic Yield

In regression analysis, we found an inverse relationship between chest CT utilization and the diagnostic yield of chest CT for PE (Fig. 3). We also found a decrease in CT utilization as physician experience increased, in conjunction with a steady increase in diagnostic yield (Fig. 4). Among physician-level predictors of imaging, we found that physicians with board certification in emergency medicine had lower CT utilization without any differences in diagnostic yield (Table 2).

Discussion

In a national longitudinal sample of Medicare beneficiaries, we found a steady increase in utilization and a decline in the diagnostic yield of chest CT for suspected PE in the ED between 2000 and 2009. We also identified wide variation in CT utilization and diagnostic yield across the United States at both the geographic and physician levels. Taken together, these patterns suggest increasing inefficiencies in the utilization of chest CT for suspected PE and substantial opportunities for improvement.

Our findings are consistent with prior work that showed similar trends in ED utilization of CT for trauma, abdominal pain, and overall CT utilization [3, 20, 21]. In the case of suspected PE, this increasing utilization of CT appears to have initially been associated with improved detection and diagnosis of PE; however, later, increases in CT utilization were observed concurrent with lower diagnostic yields. The initial increase

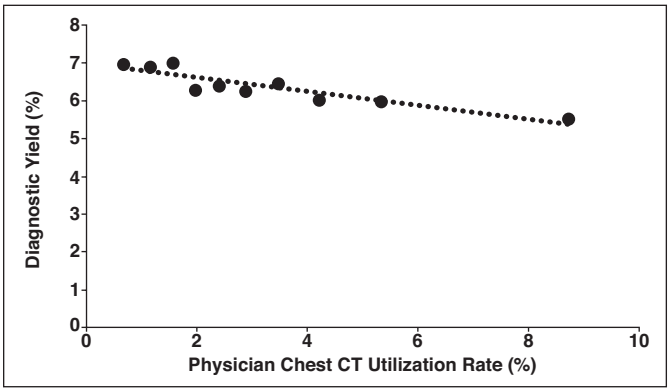

Fig. 3—Graph of relationship between physician chest CT utilization and diagnostic yield.

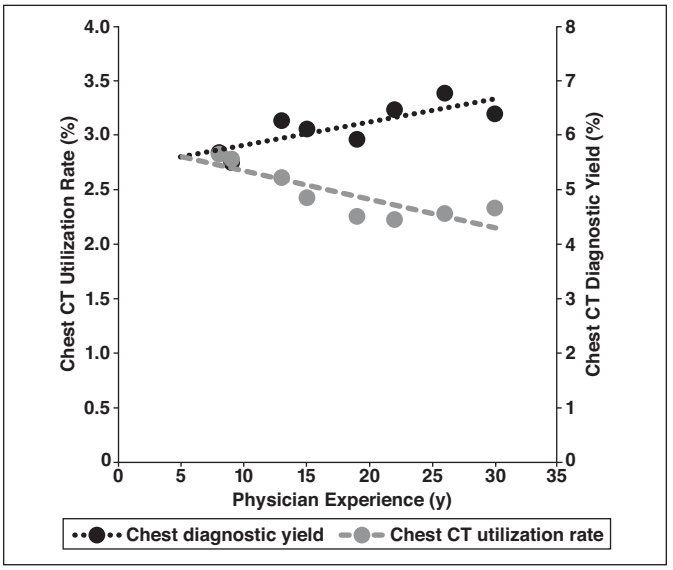

Fig. 4—Graph of relationship between physician experience and chest CT utilization patterns.

in diagnostic yield parallels epidemiologic observations over past decades, which have reported an increased incidence of PE in the ED and substantially lower mortality than was seen in historical cohorts, suggesting that broader utilization of CT allowed earlier diagnosis and treatment of PE or diagnosis of less severe, or subsegmental, PE [22–24]. The trend of declining diagnostic yields may also reflect a national shift in imaging for acute unscheduled conditions from a variety of outpatient settings to the ED as the acute-care diagnostic center, with its readily available diagnostic and treatment modalities [4].

Historically, policymakers and payers have used measures of imaging utilization for public reporting or pay-for-performance purposes without consideration of imaging appropriateness or patient outcomes [6]. Our work presents diagnostic yield as a potential complementary, or balancing, outcome measure to utilization metrics. Diagnostic yield both confers important information about imaging appropriateness and can be measured in existing national data sources. Of interest, although we found an inverse relationship between CT utilization and CT diagnostic yield at the physician level, as well as several physician-level predictors of imaging utilization, we found little to no relationship between regional CT utilization and regional diagnostic yield. This may suggest that imaging decisions and, therefore, measures of quality that intend to reduce variation are better applied closer to the bedside as quality metrics of individual clinicians or hospitals rather than as regional or populations measures of quality. Nonetheless, the measurement of diagnostic yield alone is not a measure of imaging appropriateness, which requires the assessment of clinical judgment and details that is often impossible to perform retrospectively but, rather, is a measure that, when paired with imaging utilization, offers clinicians a balanced target for clinical decision making and provides policymakers with a more comprehensive understanding of resource use.

Our regression analyses highlight several opportunities for future research and practice or policy modification. First, at the hospital level, we found higher utilization and lower diagnostic yield among hospitals located in urban areas. These findings differ from prior work that suggested higher imaging utilization among rural hospitals on publicly reported quality measures [25]. However, existing measures are focused on less acute imaging indications, such as mammography, and often exclude ED imaging. This distinction may suggest that although rural hospital-based imaging departments may appear less efficient by providing access to imaging studies otherwise unavailable in the community, these hospital imaging practices may be more efficient for unscheduled care than those found in urban communities. Given recent hospital-level efforts by EDs to incorporate clinical decision support into electronic health records [13] to meet requirements of the Protecting Access to Medicare Act and advocacy efforts of initiatives and organizations such as Choosing Wisely, the American College of Radiology, and the American College of Emergency Physicians [26–28], these hospital-level patterns should be reexamined for continued clinical practice variation. Also, future research should explore the causes of these hospital-level differences, including the degree to which different types of hospital-based EDs use CT differently in providing access to acute diagnostic imaging services.

At the physician level, our regression analyses reveal several important patterns. First, physician experience was associated with lower utilization and increased diagnostic yield. This parallels previous work suggesting that clinical experience can improve the value of clinical gestalt in physician diagnostic accuracy for suspected PE [29] and shows the importance of clinical decision support and structured risk stratification to reduce variation among less-experienced clinicians. In addition, we found that physicians with board certification in emergency medicine were less likely to use chest CT, which may reflect the effect of formal training on the use of evidence-based diagnostic pathways for suspected PE. However, given prior work suggesting that the current training and certification of emergency physicians is unlikely to meet staffing demands for several decades [30], efforts to improve physician and other clinician education to standardize clinical practice regardless of specialty board certification will be essential to reducing variation and improving the efficiency of physician imaging practices in the ED.

These findings need to be interpreted within the context of several limitations of our study design. First, our analysis was conducted during a period of substantial changes in diagnostic testing availability and guidelines for suspected PE in the ED, including clinical decision rules, the widespread introduction of D-dimer assays, and the wide availability of CT scanners within EDs [30]. However, given that changes in practice since the end of our study are likely limited, we anticipate that current practice is likely similar to the trends and relationships described. Second, our analyses were conducted using administrative claims data developed for billing purposes and not clinical research. Although our ascertainment of specific clinical details may be limited, our methods are supported by chart-validated definitions and the use of Medicare standard analytic files that are the current basis for numerous national quality measures.

Conclusion

We identified increasing inefficiency in chest CT utilization for suspected PE in the ED, both in terms of trends in CT utilization and in terms of geographic- and physician-level variation in imaging utilization and yield. Future policy efforts should consider incorporating diagnostic yield alongside measures of utilization to ensure that clinically meaningful variation is reduced.

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