ORIGINAL ARTICLE

Imaging Trends in Acute Venous Thromboembolic Disease: 2000 to 2015

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Abstract

Purpose: To measure diffusion of new knowledge and correlate imaging utilization for suspected acute venous thromboembolism (VTE) with D-dimer utilization, landmark publications, and institutional guidelines.

Materials: Between 2000 and 2015, the number of CT pulmonary angiograms (CTPAs), CTPA combined with indirect CT venography (CTV), ventilation-perfusion (VQ) scans, and lower extremity venous Doppler ultrasound (US) examinations were obtained for inpatients and emergency department (ED) patients and correlated with D-dimer utilization, landmark publications regarding radiation and VTE imaging, and an institutional inpatient best-practice alert requiring VTE prophylaxis assessment (2008). Volume data were normalized per 1,000 patients.

Results: CTPA and D-dimer utilization were correlated (ED: $r = 0.94$, inpatient: $r = 0.87$; $P < .001$). VQ volume peaked in 2004 to 2005 (20 of 1,000 ED patients; 14 of 1,000 inpatients) and decreased since to a low of 1 of 1,000 and 3 of 1,000, respectively. US volume increased since 2002 and was higher than CT volume for inpatients (annual mean 149 of 1,000 patients [US], 46 of 1,000 patients [CT]), but not ED patients (annual mean 18 of 1,000 patients [US], 35 of 1,000 patients [CT]). For ED patients, CTPA volume peaked in 2008 at 57 of 1,000 patients, declined through 2012 to 30 of 1,000 patients, and rose annually since to 37 of 1,000 patients (2015). For inpatients, CTPA volume also peaked in 2008 at 70 of 1,000, but continued to decline through 2015 to 27 of 1,000 patients.

Conclusion: After the Prospective Investigation of Pulmonary Embolism II and Brenner and Hall publications, there was a transient 4-year decline in ED CTPA utilization. The decline was sustained in inpatients, where a best-practice VTE prophylaxis alert was implemented. Best-practice alerts may sustain the impact of new knowledge.

Key Words: Pulmonary embolism, imaging utilization, D-dimer, VQ scan, CTPA

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INTRODUCTION

The clinical evaluation for suspected acute pulmonary embolism (PE) is common in the emergency department (ED) and inpatient settings in hopes of avoiding the significant morbidity and mortality of undiagnosed and untreated PE [1]. Diagnosis and treatment decisions are made through a combination of clinical signs and symptoms (eg, dyspnea, lower extremity edema), laboratory values (eg, D-dimer, arterial-alveolar gradient), scoring systems (eg, Wells score, Pulmonary Embolism Rule-Out Criteria score [2,3]), and diagnostic imaging [4,5]. The imaging diagnostic reference standard is most commonly CT pulmonary angiography (CTPA), and less often Tc99m ventilation-perfusion (VQ) scanning [6]. Lower extremity Doppler ultrasound (US) may be used for risk stratification and for the evaluation of suspected lower extremity venous thrombosis in the absence of signs and symptoms of PE, but it is not reliable in evaluating the pelvic veins or inferior vena cava [7]. A negative D-dimer test can exclude acute venous thromboembolism (VTE) in certain subgroups, but false-positives are common, and its role is limited to patients with a low pretest probability for PE [8-12].

CTPA evaluates the pulmonary arterial vasculature and may or may not include indirect CT venography of

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the pelvis and lower extremities to evaluate for central and lower extremity venous thrombosis [6]. As a CT of the entire thorax, it also evaluates all of the thoracic structures for other etiologies of a patient's signs and symptoms, because the presenting symptoms of chest pain and shortness of breath are not specific to PE. In the multicenter Prospective Investigation of Pulmonary Embolism (PIOPED) II study, inclusion of indirect CT venography was shown to improve the diagnostic accuracy of CT for the diagnosis of PE. Specifically, CTPA of the thorax alone had a sensitivity of 83% and a specificity of 95% for the diagnosis of PE, and CTPA with indirect venography had a sensitivity of 90% and specificity of 95% [6]. However, the diagnostic advantages of indirect CT venography require additional cost (ie, scanning of additional body parts), additional radiation (eg, gonads), and a larger contrast volume than if only scanning the thorax [4,13].

As health care professionals and the public have become increasingly aware of medical radiation and overuse of diagnostic imaging over the last 15 years [14], utilization of various diagnostic strategies for the evaluation of VTE has evolved to include considerations unrelated to diagnostic accuracy. In this study, we measure diffusion of new knowledge and correlate imaging utilization for suspected acute VTE in inpatients and ED patients with D-dimer utilization, landmark publications, and institutional care guidelines.

METHODS

Institutional review board approval was waived for this HIPAA-compliant retrospective cross-sectional study. No protected health information was collected or analyzed.

Data Collection

From January 1, 2000, to December 31, 2015, the number of CTPAs alone, CTPA combined with indirect CT venography (CTV) of the pelvis and lower extremities, VQ scans, and lower extremity venous Doppler examinations (US) were obtained from the hospital and radiology information systems for each calendar year for adult inpatient and ED patients at our quaternary care hospital. Examinations were identified by billing codes, and samples were checked manually for accuracy.

All CTPA examinations were labeled in the radiology information system with a "PE" modifier before our study period. CTPA examinations before 2006 were assigned the Current Procedural Terminology (CPT) code 71260 (CT THORAX W IV CONTRAST), which transitioned after 2006 to the CPT code 71275 (CT ANGIO CHEST WO AND W CONTRAST). Data for CTPA alone without indirect CTV was obtained searching for CPT codes 71260 and 71275 with the PE modifier but excluding any examinations that were associated with CPT code 73701 (CT EXTRM LOW W IV CONTRAST). Data for CTPA combined with indirect CTV was obtained searching for CPT code 73701 associated with a CTPA examination (CPT 71260 or 71275) carrying the PE modifier.

VQ scan data were obtained by searching for CPT codes 78588 (NM LUNG VENT PERFUSION) and 78582 (NM PULM VENT AND PERF IMG) excluding the International Classification of Diseases, ninth rev (ICD-9) codes I27.0, I27.2, I27.82 (Primary pulmonary hypertension, other secondary pulmonary hypertension, and chronic PE). Exclusion of these ICD-9 codes was done to limit data capture to examinations performed to assess for acute PE.

The diagnostic vascular lab provided lower extremity Doppler examination census data separated by emergency or inpatient setting.

D-dimer laboratory utilization data were provided by query of the electronic medical record (EMR) order entry system. Data were available for the adult ED population from 2002 to 2015 and for the adult inpatient population from 2006 to 2015. Due to changes in information technology infrastructure during the study period, not all D-dimer tests could be localized to patient setting (ie, ED versus inpatient). D-dimer results that could not be localized to patient setting were not considered in the setting-specific analyses. At our institution, a level above 0.5 mg/L fibrinogen equivalent units is considered abnormal.

Annual data were normalized per 1,000 patients using ED and inpatient census totals. ED census data were available from 2002 to 2015, and inpatient census data were available from 2003 to 2015. Normalization was done to eliminate bias that might be introduced by changes in the ED or inpatient census volume and to allow comparison of imaging volumes across modalities. The fraction of CTPA examinations that included indirect CTV was calculated on a yearly basis by dividing the number of indirect CTV examinations by the number of CTPA examinations, and it is expressed on a scale from 0 to 1.

Lower extremity Doppler US imaging volume data were not available for retrospective review before 2002. Overall ED census data were not available for