The Journal of Arthroplasty xxx (2016) 1–5

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Original Article

End Tidal Carbon Dioxide as a Screening Tool for Computed Tomography Angiogram in Postoperative Orthopaedic Patients Suspected of Pulmonary Embolism

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ARTICLE INFO

Article history:
Received 4 January 2016
Received in revised form
11 March 2016
Accepted 15 March 2016
Available online xxx

Level of Evidence:
diagnostic study
level II evidence

Keywords:
pulmonary embolism
prospective study
orthopedic surgery
diagnostic tool
capnography
peri-operative

ABSTRACT

Background: Computed tomography pulmonary angiography (CTA) is the gold standard for diagnosing pulmonary embolism (PE) but involves radiation and iodinated contrast exposure. Of orthopedic patients evaluated for PE, a minority have a positive CTA study. Herein, we evaluate end tidal carbon dioxide ($ETCO_2$) as a method to identify patients at low risk for PE and may not require a CTA. We hypothesize that $ETCO_2$ will be useful for predicting the absence of PE in postoperative orthopedic patients.
Methods: In this prospective study, all patients older than 18 years who were admitted for orthopedic surgery and who had a CTA performed for PE were eligible. These patients underwent an $ETCO_2$ measurement. Patients were determined to have PE if they had a positive PE-protocol CT.
Results: Between May 2014 and April 2015, 121 patients met the inclusion criteria for the study. Of these patients, 84 had a negative CTA examination, 25 had a positive examination, and 12 had a nondiagnostic examination. We found a statistically significant difference ($P = .03$) when comparing the average $ETCO_2$ values for the positive and negative CTA groups. An $ETCO_2$ cutoff value of 43 mm Hg was 100% sensitive with a negative predictive value of 100% for absence of PE on CTA.
Conclusion: This study demonstrates a significant difference in $ETCO_2$ measurements between postoperative orthopedic patients with and without CTA-detected PE. A cutoff value of >43 mm Hg may be useful in excluding patients from undergoing CTA.

Orthopedic surgery is an independent risk factor for pulmonary embolism (PE) [1]. The risk of venous thromboembolism (VTE) is elevated in patients who have recently undergone major orthopedic surgery, particularly hip and knee arthroplasty [1,2]. Prior epidemiologic studies in elective hip and knee arthroplasty patients have demonstrated the postoperative rate of symptomatic VTE to be between 1.1% and 10.6% [3-8] and in orthopedic spine surgery patients from 0% to 31%, depending on patient population, method of surveillance and type of prophylaxis [9-21]. PE is a morbid and potentially fatal condition, with long-term sequelae including chronic pulmonary hypertension [22]. Because of its availability, high sensitivity, and high specificity, computed tomography pulmonary angiography (CTA) is now considered the gold standard for evaluating patients with suspected PE [23]. This diagnostic test, however, requires radiation exposure [24] and risks contrast-induced nephropathy [25]. Of postoperative orthopedic patients evaluated for PE by CTA, only 22%-28% have a positive study for PE [26,27].

Diagnostic algorithms, often using a D-dimer test, have been developed to help clinicians determine if a CTA may not be warranted [28,29]. D-dimer, however, is of limited utility in the postoperative setting because invasive procedures activate inflammatory pathways and the coagulation cascade elevating d-dimer levels [30,31]. Recent investigations have shown that end tidal carbon

There was no external funding for this study.

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to doi: http://dx.doi.org/10.1016/j.arth.2016.03.033.

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http://dx.doi.org/10.1016/j.arth.2016.03.033
0883-5403/

dioxide ($ETCO_2$) measurements may be similarly used to determine in which patients a CT scan may not be warranted in the general emergency room setting [32]. $ETCO_2$ testing is an indirect measure of pulmonary vascular obstruction. PE results in increased dead space ventilation, preventing alveolar CO_2 elimination, and resulting in decreased CO_2 concentration at end exhalation. Some conditions such as advanced chronic obstructive pulmonary disease, pulmonary fibrosis, or congestive heart failure may impact $ETCO_2$. Perioperative conditions such as opioid-induced hypoventilation may also impact $ETCO_2$, but recent surgery should not.

Herein, we evaluate $ETCO_2$ measurement as a method to identify postoperative orthopedic patients who are at low risk for PE and may not require CTA. We hypothesize that $ETCO_2$ will be useful for excluding PE in a postoperative orthopedic surgical population.

Materials and Methods

In this single-center, prospective study, all patients aged 18 years or older who were admitted between May 2014 and April 2015 for orthopedic surgery (including all subspecialties) and who had a CT pulmonary angiogram (CTA) performed to evaluate for PE were eligible. Sample size was determined based on effect size and standard deviation (SD) reported by Hemnes et al [32], who reported on using ETCO2 in the emergency department setting. Given an effect size of 5 mm Hg, SD of 6.8 mm Hg, 80% power, and $\alpha = 0.05$, our study required 120 patients including 20 patients with CTA positive for PE.

Patients undergoing CTA had an $ETCO_2$ measurement performed by a certified respiratory therapist using an Omnimax N-85 (Nellcor; Boulder, CO) portable bedside capnograph. The devices have been in use in this institution since 2010. The capnometer is calibrated per manufacturer instructions annually or after 4000 hours using a Scott Medical calibration kit (Plumsteadville, PA) with 5% CO_2 and 21% O_2. The device is calibrated to ± 2 mm Hg up to 38 mm Hg and $\pm 5\%$ of the reading over 40 mm Hg. Patients are monitored for 5 minutes, and 2 $ETCO_2$ readings are recorded.

Neither patients nor testers were blinded. The decision to order a CTA was determined by the treating physician regardless of $ETCO_2$ results. Exclusion criteria were an inability to cooperate with either the $ETCO_2$ test or CT scan. Patients were determined to have PE if they were found to have a positive CTA as interpreted by the "on-call" chest radiology attending. Our institution's electronic medical record was used to identify all patients who met the study's inclusion criteria. Data regarding patient age, gender, ethnicity, past medical history, symptoms, and vital signs leading to the evaluation for PE, type of surgery, laboratory studies, CTA result, and $ETCO_2$ were recorded from the patient's medical record [18,30]. These collected values were used to calculate 3 prognostic scoring tools commonly used in the evaluation of PE: the Pulmonary Embolism Severity Index (PESI) [33], the Shock Index [34], and the Modified Geneva Score (Table 1) [35,36]. The PESI score is used to predict the 30-day risk of mortality and severity of complications from PE. The Shock Index has been used to predict mortality risk in patients with PE. The Modified Geneva Score is used to predict the likelihood of PE in a given patient.

Descriptive statistics were performed on all variables. Wilcoxon rank sum tests for continuous variables and Fisher exact tests for categorical variables were conducted to compare the group with negative CTA and the group with positive CTA. Diagnostic statistics, such as sensitivity, specificity, positive predictive value, and negative predictive value, were calculated at different cutoff points of $ETCO_2$. Multivariate logistic regression was fitted to evaluate the association between the CTA result and the variables listed previously. All analyses were conducted using SAS 9.3 (Cary, NC).

Table 1
Commonly Used Prognostic Scoring Tools for the Evaluation of Patients Suspected of Having a Pulmonary Embolism.

Scoring Tool	Parameter
PESI Score	Age
	Gender
	Cancer history
	Heart failure history
	Chronic lung disease history
	Heart rate
	Systolic pressure
	Respiratory rate
	Temperature
	Altered mental status
	Oxygen saturation
Shock Index	Heart rate
	Systolic pressure
Modified Geneva Score	Age
	DVT or PE history
	Surgery under general anesthesia
	Active malignancy
	Unilateral lower limb pain
	Hemoptysis
	Heart rate
	Unilateral lower extremity edema

DVT, deep vein thrombosis; PESI, Pulmonary Embolism Severity Index; PE, pulmonary embolism.

Results

Between May 2014 and April 2015, 121 patients met the inclusion criteria for the study, and 106 patients underwent CTA without $ETCO_2$ measurement. Table 2 describes the 2 study groups (positive CTA and negative CTA for PE) and demonstrates no significant differences between the patients in the groups. Figure 1 provides a histogram describing the $ETCO_2$ measurements. Of these patients, 84 had a negative CT examination, 25 had a CT examination positive for PE, and 12 had a nondiagnostic CT examination (Fig. 2). The average $ETCO_2$ values with SDs were 35.35 mm Hg (5.75), 32.26 mm Hg (5.89), and 36.33 mm Hg (4.61) for the negative CTA, positive CTA, and nondiagnostic examinations, respectively. There was a statistically significant difference between the average $ETCO_2$ values for the positive CTA and negative CTA groups ($P = .03$). Of the positive CTA examinations, 4 patients had a CT examination positive for subsegmental PE, and 21 patients had a CT examination positive for segmental PE. The average $ETCO_2$ values with SDs were 34.38 mm Hg (7.97) and 31.86 mm Hg (5.57), respectively. There was not a statistically significant difference ($P = .10$) between the $ETCO_2$ values of the different sized PEs.

Figure 3 demonstrates the sensitivity, specificity, negative predictive value, and positive predictive value for different cutoff values used to exclude PE. An $ETCO_2$ value of 36 mm Hg or greater (as was described by Hemnes et al [32]) was a 76% sensitive, 42% specific, with an 85% negative predictive value, and a 28% positive predictive value, whereas a cutoff value of greater than 43 mm Hg was a 100% sensitive (95% confidence interval = 0.86-1.0), 7% specific, with an 100% negative predictive value, and a 24% positive predictive value.

We also investigated 10 established risk factors for PE in our study population using logistic regression analysis. No variables were found to be predictive of PE in the postoperative orthopedic setting in our study sample (P values = .49-.86). With regard to the PE prognostic scoring tools, average values for positive and negative CTA examinations were 98.44 (SD = 29.04) and 98.14 (30.19) for the PESI Score, 0.88 (0.18) and 0.87 (0.22) for the Shock Index, and 7.76 (1.20) and 7.73 (1.31) for the Modified Geneva Score. No significant differences were identified between the patients with positive and negative CTA with regards to the three evaluated prognostic scoring tools ($P = .51$-.91).