



RESEARCH ARTICLE



# Computed tomography pulmonary angiography is overused to diagnose pulmonary embolism in the emergency department of academic community hospital

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## ABSTRACT

**Background:** Pulmonary embolism (PE) is a common disease in the USA responsible for up to 10% of hospital mortality. Modified wells score (MWS) and D-dimer assay are used to categorize patients into high or low probability of PE. Patient with high probability need Computed tomography pulmonary angiography (CTPA), while patients with low probability and low D-dimer can safely forgo the CTPA. **Objectives:** The aim of this study was to investigate the rate of inappropriate CTPA use in the emergency department of a community teaching hospital. **Methods:** A retrospective chart review of adult patients who underwent CTPA for suspected PE in the emergency department for 2015 was done. CTPA use was considered inappropriate if MWS was less than or equal to 4 and D-dimer was either not ordered or its value was less than 500 µg/L. Bivariate analysis with Fisher's exact tests and Student's t-tests as well as multivariate logistic regression analysis were done to examine relationship between study explanatory variables and study outcome.

**Results:** 295 patients were included in the study. The mean age was 51.2(±14.5) years, 68.8% were females. The prevalence of PE was 5.4% and 41% of the CTPAs -were inappropriately ordered. Males were twice (OR 2.1; 95% CI 1.2, 3.6) as likely as females to have an inappropriately ordered CTPA after controlling for a high MWS, age, and tobacco history.

**Conclusion:** CTPA is overused to diagnose PE in the emergency department. Quality improvement projects are needed to encourage physicians to adhere to the current guidelines.

## ARTICLE HISTORY

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## KEYWORDS

Computed tomography pulmonary angiography; pulmonary embolism; modified Wells score; D-dimer assay; Emergency Department

## 1. Introduction

Pulmonary embolism (PE) is a common disease in the USA responsible for 5–10% of all hospital deaths and an estimated 100,000–200,000 annual deaths [1]. Due to the nonspecific symptoms and high mortality, the approach to its clinical evaluation should be efficient so therapy may be started as early as possible to decrease morbidity and mortality.

One of the most commonly used diagnostic algorithms is the application of the modified Wells score (MWS) in conjunction with D-dimer levels [2]. This algorithm incorporates pretest clinical probability (PTCP) and D-dimer levels to classify the patients as having a high or low probability of PE. Patients with MWS of >4 have high PTCP and classified as (PE likely group) and require further testing with computed tomography pulmonary angiography (CTPA) to confirm the diagnosis, while patients with a score of ≤4 have low PTCP and classified as (PE unlikely) and can safely forego the CTPA if the concomitant D-dimer level is low (≤500 µg/L). This score is simpler and more efficient than the full Well's score and have been validated in several trials [3,4].

The combination of low PTCP and a low D-dimer excludes the diagnosis of PE with a negative predictive value of 99% [5]. Adherence to these guidelines helps physicians identify high-risk patients who will benefit from further testing and, more importantly, low-risk patients who can avoid the radiation and contrast exposure hazards of CTPA.

The aim of this study was to investigate the rate of inappropriate CTPA use in the emergency department of a community teaching hospital.

## 2. Methods

### 2.1. Study design

The authors conducted a retrospective chart review of electronic medical records from 1 January 2015, to 31 December 2015. Charts of adult patients (>20 years old) who underwent CTPA ordered by the Emergency Department physicians for suspected PE during the study period were identified. We excluded trauma patients, patients with known coagulation disorders, pregnant patients, and those taking hormonal supplements. No sampling scheme was utilized since all the

patient encounters from the year were included. The study was approved by Hurley Medical Center/ Michigan State University Institutional Review Board.

## 2.2. Data collection

A data collection spreadsheet was prepared and included the various parameters for calculating MWS, value of D-dimer if ordered, CTPA result as well as age, sex, BMI, and smoking status of the patients. Each unique encounter was reviewed by the authors and data was collected as per the data collection sheet. CTPA use was considered appropriate if MWS was greater than 4 or any score with high sensitivity D-dimer greater than 500 µg/L (higher cutoff as per the lab). CTPA use was considered inappropriate if MWS was less than or equal to 4 and D-dimer was either not ordered or its value was less than 500 µg/L.

## 2.3. Statistical analysis

Before proceeding to do any statistical analysis, we assessed the presence of data outliers and out of range values. Thereafter, data cleaning and editing was performed through a series of frequencies, proportions, descriptive statistics (e.g., mean, median, and standard deviation) and figures (e.g., histograms and box and whisker plots). After this process, bivariate analyses such as Fisher's exact tests and Student's t-tests were performed to determine any associations between the study explanatory variables (i.e., age, sex, MWS, BMI, tobacco history, and CTPA) and the presence of PE. Multivariate logistic regression analysis was conducted to examine the relationship between the main study explanatory variable (i.e., CTPA) and the main study outcome (i.e., PE) after controlling for age, sex, MWS, BMI, and tobacco history. All analyses were done using Stata statistical software package (Stata Corporation, College Station, TX, USA). The usual 0.05 Type I error threshold for statistical significance was used for all analyses.

## 3. Results

### 3.1. Study population

The study population was 295 patients for whom CTPA was ordered at the emergency department to

rule out PE. Our population was mostly females (68.8%) and had a mean age of 51.2 ( $\pm$ 14.5) years and an average Well's score of 2.8 ( $\pm$ 1.8) (Table 1). The prevalence of PE in our study population was 5.4% (Figure 2) and 41% of the CTPAs performed were inappropriately ordered.

### 3.2. Patients with appropriately ordered CTPAs based on high Wells scores

A total of 88 (30%) patients out of the 295 had a high pretest probability of PE prior to getting the CTPA based on the Wells score. Out of the 88 patients, 13 (15%) had unnecessary D-dimer testing done, which was found to be high on all of them. Out of the 88 patients, 12 (14%) had a CTPA positive for PE (Figures 1 and 2).

### 3.3. Patients with appropriately ordered CTPAs based on combination of low Wells scores and positive D-dimer assays

About 207 (70%) patients had low pretest probability of PE prior to getting the CTPA (Figure 1). Out of the 207 patients, only 89 (43%) patients had a D-dimer assay done prior to undergoing the CTPA and 87 patients (42%) had a positive D-dimer. In this group, only three cases of PE were diagnosed (Figure 2).

In all patients with appropriate CTPA the average Well's score was 3.4 ( $\pm$ 1.9).

### 3.4. Patients with inappropriately ordered CTPAs

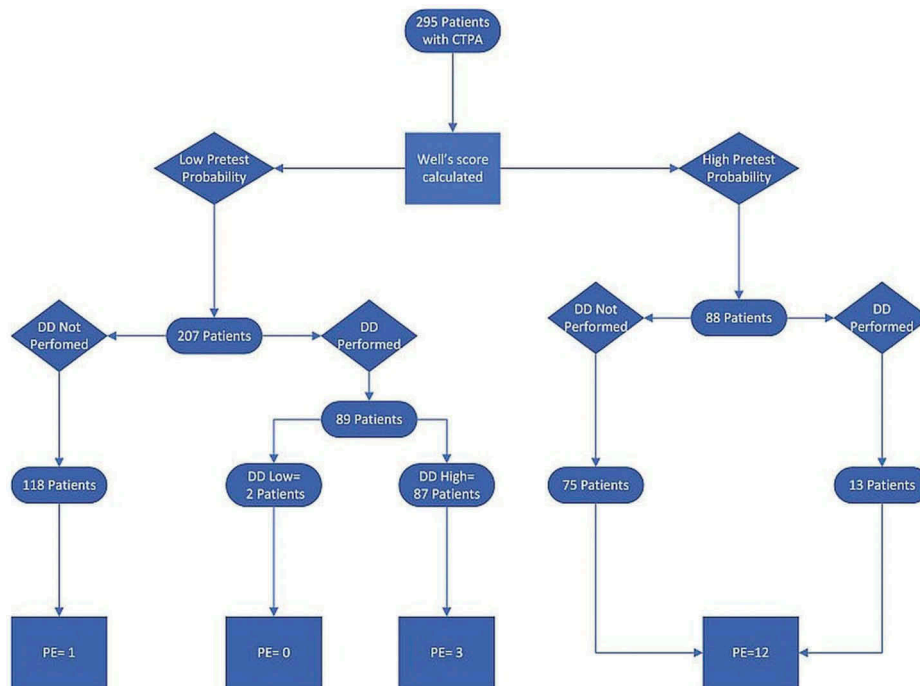
A total of 120 patients received inappropriately ordered CTPAs. Most of them (118 orders) were classified inappropriate because the patients had low pretest probability and the CTPA was ordered before pursuing a D-dimer assay. The other two patients with CTPA orders classified as inappropriate were due to the fact that they had low D-dimer levels. Only one case of PE was diagnosed in this group (Figure 1). The average Well's score in this group was 1.7 ( $\pm$ 1.2) (Table 1).

Multivariate logistic regression analysis found that a high MWS decreased the chances of an inappropriately ordered CTPA by 90% (OR 0.10; 95% CI 0.05, 0.20) ( $p < .001$ ) after adjusting for age, sex, and tobacco history. In contrast, males were twice (OR 2.1; 95% CI 1.2, 3.6) ( $p = 0.022$ ) as likely as females to

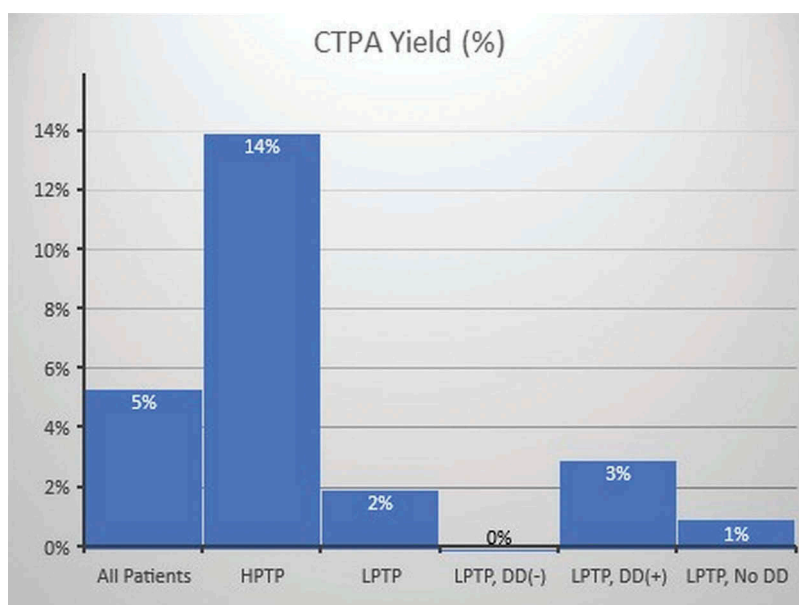
**Table 1.** Comparison of patients with appropriately and inappropriately ordered CTPA.

|                              | Total (n = 295)  | Inappropriate (n = 120) | Appropriate (175) | p-Value |
|------------------------------|------------------|-------------------------|-------------------|---------|
| Age (mean $\pm$ SD)          | 51.2 (14.5)      | 50.7 (14.2)             | 51.5 (14.8)       | 0.646   |
| Sex, Female (%)              | 68.8             | 60.7                    | 74.6              | 0.015   |
| Smoking (%)                  | 32.0             | 33.1                    | 31.2              | 0.800   |
| BMI (mean $\pm$ SD)          | 32.0 (9.3)       | 30.1 (8.6)              | 33.4 (9.6)        | 0.003   |
| Well's score (mean $\pm$ SD) | 2.8 ( $\pm$ 1.8) | 1.7 ( $\pm$ 1.2)        | 3.4 ( $\pm$ 1.9)  | <0.001  |

CTPA: computed tomography pulmonary angiogram; SD: standard deviation; BMI: body mass index.



**Figure 1.** Flow chart showing the study results. CTPA: computed tomography pulmonary angiography; PE: pulmonary embolism; DD: D-dimer assay.



**Figure 2.** Histogram showing the yield of CTPA in different patient groups. CTPA: computed tomography pulmonary angiography; HPTP: high pretest clinical probability; LPTP: low pretest clinical probability; DD: D-dimer assay.

have an inappropriately ordered CTPA after controlling for a high MWS, age, BMI, and tobacco history (Table 2).

Lastly, sensitivity of the combined pretest clinical probability and D-dimer assay, when used appropriately, was found to be 93.8% (95% CI 69.8–99.8%). Specificity was 42.7% (95% CI 36.8–48.7%), positive predictive value was 8.6% (95% CI 7.4–9.9%), and

negative predictive value was 99.2% (95% CI 94.7–99.9%).

#### 4. Discussion

CTPA is considered the gold standard diagnostic modality for PE with a sensitivity of 83% and specificity of 96% [6]. Despite the high diagnostic accuracy

**Table 2.** Adjusted odds ratio (OR) for inappropriately ordered CTPA.

|                           | Adjusted OR (95% CI) | <i>p</i> -Value |
|---------------------------|----------------------|-----------------|
| Age                       | 1.0 (0.97, 1.00)     | 0.121           |
| Male                      | 2.0 (1.1, 3.5)       | 0.022           |
| High modified Wells score | 0.1 (0.1, 0.9)       | <0.001          |
| BMI                       |                      |                 |
| Overweight (BMI > 25)     | 0.4 (0.1, 1.5)       | 0.166           |
| Obesity (BMI > 30)        | 0.3 (0.1, 1.1)       | 0.058           |
| Smoking history           | 0.7 (0.4, 1.2)       | 0.201           |

CTPA: computed tomography pulmonary angiogram; BMI: body mass index.

of CTPA, less than 10% of the scans done to diagnose PE in the USA are positive, compared to a rate of 30% in European countries [3,7–10]. Moreover, CTPA comes with a high risk from exposure to ionizing radiation as well as risk from contrast-induced nephropathy [11,12].

In our study, only 5.4% of CTPAs came back positive for PE, which is in concordance with the national US trend observed in similar studies that reported numbers as low as less than 2% [13,14]. Surprisingly, European physicians seem to have a better yield in diagnosing PE since their positive CTPA rate is 2–3 times higher than that of the US. This can be explained partly by the fact that CTPAs are more accessible to US physicians and may also reflect the fact that European physicians adhere to the guidelines more than their US counterparts [15,16].

In our patient pool, 41% received inappropriately ordered CTPAs to diagnose PE. In other words, these patients were exposed to unnecessary risks of radiation and contrast exposure. Other studies have reported numbers of avoidable imaging ranging from as low as 33% up to 71%; the difference in the reported numbers is mainly due to differences in physicians' practices and adherence to guidelines [14,17,18]. A very plausible explanation for these patients receiving inappropriately ordered CTPAs is that physicians did not pursue further D-dimer testing in 98% of the cases to further classify the patients as low- or high-risk patients. Instead, physicians opted to pursue CTPA directly and in only two cases physicians pursued D-dimer testing. Even when the results of the D-dimer were below the cut-off point, physicians still ordered the CTPA inappropriately according to the current clinical guidelines.

Among our study population, the majority (70%) were considered to have low pre-test probability for PE based on the Wells score. Among them, only 43% received further D-dimer assays as per the guidelines, while the rest underwent CTPAs without D-dimers ordered. This has been reported in previous studies documenting underutilization of the D-dimer assay in the low-risk group in emergency departments across the US [13,18].

We tried to identify some patient-related risk factors that led to inappropriately ordered CTPAs. Among the tested variables were gender, age, tobacco use, and BMI. Only gender was found to be statistically significant with males having twice the likelihood of females to get inappropriately ordered CTPAs after controlling for other variables. The tendency of physicians to inappropriately order CTPAs in men may be explained by the fact that the incidence and mortality of PE are higher in males than females. Prior knowledge of these facts may make physicians more likely to lean toward pursuing the diagnosis of PE in males more than in females [19,20].

## 5. Limitations

This retrospective study was conducted in a single center; hence it may be difficult to generalize the results to other centers. However, our findings were comparable to other studies done in different institutions. Another limitation is that the Wells scores were calculated retrospectively from the electronic medical records, which may have overestimated or underestimated the final Wells scores. Moreover, age adjusted D-dimer was not used in our study.

## 6. Conclusion

CTPA is overused to diagnose PE in the emergency department while D-dimer assays are underutilized in patients with low risk for PE in this patient population. The improper use of CTPA coupled with the underutilization of D-dimer is leading to unnecessary exposure to radiation and contrast as well as adding to the cost of health care. Quality improvement projects are needed to encourage physicians to adhere to the current guidelines. A possible method to encourage physicians to adhere to the current guidelines is the use of evidence-based clinical decision support reminders as part of the electronic medical record to remind physicians about the importance of D-dimer assay in the low PCTP group [21].

## Disclosure statement

No potential conflict of interest was reported by the authors.

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