Computed tomography pulmonary angiogram as a result of medical emergency team calls: a 5-year retrospective audit

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ABSTRACT

Objective: To determine the proportion of computed tomography pulmonary angiograms (CTPAs), performed after medical emergency team (MET) calls, that are positive for pulmonary embolism (PE), and whether there are useful clinical predictors of positive CTPA results.

Design: All patients from a tertiary referral hospital in Melbourne who had an MET response and an associated CTPA within 6 hours, from 2009 to 2013, were included. We reviewed medical records to assess indications for CTPA, including MET clinical triggers, time of day of the MET (implying the seniority of decision making), chest x-ray results and Wells scores as a clinical decision rule for PE.

Results: There were 4578 MET responses (in 3136 patients) over the 5-year study period, from which 70 CTPAs were ordered (2.2% of all patients). A PE was identified in 12 patients (17.1%). The median age of CTPA patients was 70 years (interquartile range, 60–76 years) and most were surgical patients (80%). The major MET triggers for CTPA were hypoxia (42.9%) and hypotension (28.6%). An abnormal chest x-ray was associated with a low likelihood of PE. The Wells scores and MET indications of hypoxia, hypotension and tachycardia were not accurate in predicting the presence or extent of PE.

Conclusion: Clinical decision rules and MET indications were not significantly associated with the presence of PE on CTPA. However, an abnormal chest x-ray has a high negative predictive value and therefore may be helpful in preventing unnecessary CTPAs.

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Pulmonary embolism (PE) is a cardiovascular emergency with high morbidity and mortality.[1] Computed tomography pulmonary angiogram (CTPA) as a diagnostic tool has the advantage of speed, wide availability, visualisation of pulmonary arteries up to subsegmental vessels, definitive diagnosis of PE, and the ability to establish alternative diagnoses. The disadvantages of CTPA include cost, high radiation exposure, the possibility of inducing nephropathy or allergy associated with iodinated contrast material,[2,3] and the risk of detecting clinically insignificant emboli.[4] Radiation dose from CTPA has been identified as an important public health concern, especially in young women.[5,6]

The widespread availability of CTPA has encouraged doctors to lower their threshold for using it to look for PE.[6] Clinical practice guidelines[7-9] suggest that clinicians should reserve CT pulmonary angiography for patients at intermediate to high risk of PE, based on algorithms that combine clinical probability and D-dimer test results.[10] These recommendations are based on studies in which most of the study population were outpatients.[8,10]

In an inpatient setting, clinical prediction rules have not been extensively studied. A recently published study from Buenos Aires suggests that the Wells score was not sufficiently predictive to rule out PE.[11] The D-dimer assay lacks specificity in hospitalised patients[12] and for this reason is not routinely used for inpatients. A retrospective review from the International Cooperative Pulmonary Embolism Registry found that a chest x-ray in PE-confirmed patients is usually abnormal, with the most frequently encountered findings (plate-like atelectasis or pleural effusion) being non-specific.[13]

The aims of our audit were to:

- ascertain the proportion of medical emergency team (MET) events that led to a CTPA
- compare patients who had a CTPA after an MET call with the rest of the population who had an MET call
- determine the proportion of positive CTPA results in the setting of MET calls
- determine if there were features (clinical and/or imaging), present at the time of the MET call, that are associated with a positive CTPA.

Such information might then be used to reduce the number of unnecessary CTPAs being obtained in patients who are unlikely to have a PE, resulting in decreased cost and radiation exposure, and avoiding potential adverse events such as contrast allergy and contrast-induced nephropathy (CIN).

Methods

Hospital setting

Our study was conducted in a public hospital in Melbourne, Australia. The hospital is a 400-bed, university-affiliated tertiary referral hospital. The hospital's MET was established in 2002 as part of the Medical Emergency Response and Intervention Trial,[14] and continued after the study's completion.

Ethics approval and study design

After study approval (QA 008/14) was obtained, a search of a prospectively collected MET database was conducted to

Table 1. Characteristics of patients who had a CTPA as part of an MET call

Characteristic, *n* (%)*	Study population (*n* = 70)	General MET population (*n* = 3066)	*P*
Median age, years (IQR)	70 (60–76)	69 (55–79)	–
Women	38 (54%)	1330 (43.4%)	0.07
Surgical admission type	56 (80%)	1651 (36.6%)	< 0.001
Neurosurgical	19 (27.1%)	266 (16.1%)	–
Orthopaedic	15 (21.4%)	147 (8.9%)	–
Other surgical	22 (31.4%)	1238 (75.0%)	–
Reason for MET call†			
Hypoxia (Spo_2 < 90%)	30 (42.9%)	900 (20.3%)	< 0.001
Hypotension (SBP < 90 mmHg)	20 (28.6%)	956 (21.5%)	0.156
Altered conscious state (GSC change by 2)	16 (22.9%)	1229 (27.7%)	0.369
Tachycardia (HR > 40 beats/min)	14 (20%)	577 (13%)	0.011
Increased respiratory rate (RR > 36 beats/min)	8 (11.4%)	438 (9.9%)	0.665
Arrest	1 (1.4%)	245 (5.5%)	0.139
Staff concern	4 (5.7%)		–
Investigation			
Chest x-ray	53 (75.7%)	1107 (26.7%)	< 0.001
Blood gas	42 (65.6%)	1504 (36.3%)	< 0.001
ECG	50 (78.1%)	2063 (49.6%)	< 0.001
Daytime MET calls	48 (68.6%)	2405 (53.4%)	0.011
Previous NFR order	5 (7.1%)	763 (17.3%)	0.026

CTPA = computed tomography pulmonary angiogram. MET = medical emergency team. IQR = interquartile range. SBP = systolic blood pressure. GCS = Glasgow Coma Scale. HR = heart rate. RR = respiratory rate. ECG = electrocardiogram. NFR = not for resuscitation. * Unless otherwise specified. † A single patient may have multiple MET call criteria.

identify patients who underwent CTPA as a result of an MET call for the 5-year period starting 1 January 2009. Patients who had had a CTPA before the MET or more than 6 hours after the MET call were excluded, as CTPAs performed after 6 hours were likely to be initiated by the home team rather than by the MET.

Data source and collection

The hospital has a robust MET database. Audit forms are completed by intensive care unit registrars for every medical emergency attendance. A log of calls to the hospital paging system is also checked to ensure that all events are identified. ICU research nurses check the forms against the patients' medical records to ensure completeness and calls are audited weekly by senior medical staff. The information collected includes the date, time and location of the event, event calling criteria, vital sign observations, the occurrence of cardiac arrest and the interventions performed.

Table 2. Diagnostic predictive value for ruling out PE

Criterion, *n* (%)	No PE	PE	*P*
Wells score > 4	24 (41.4%)	7 (58.3%)	0.282
MET call indication			
Hypoxia	47 (46.6%)	4 (33.3%)	0.401
Hypotension	16 (27.6%)	6 (50%)	0.128
Tachycardia	11 (19%)	3 (25%)	0.634
Abnormal chest x-ray	28 (62.2%)	1 (12.5%)	0.009

PE = pulmonary embolism. MET = medical emergency team.

Further data on patients identified from the MET database were obtained from the radiology results system (picture archiving and communications system [PACS]) and hospital patient administrative system (PAS). The PACS database provided dates and times of CTPAs, as well as the images and formal radiologist reports for the chest x-rays and CTPAs. The hospital's PAS is maintained by trained personnel to permit accurate reporting to government health authorities for funding purposes. Patient information including sex, age at admission, treating unit and date and time of admission and discharge were extracted from the PAS database.

Data analysis

Data obtained from the MET, PACS and PAS databases were used to assess indications for CTPA, including MET clinical triggers, time of day of MET calls (implying the seniority of decision making), chest x-ray results and Wells scores[15] (see Appendix). The Wells score contains a component based on subjective assessment that a diagnosis of PE is more likely than other diagnoses. To standardise the subjective component of the Wells score, a score of 0 was given if a clear alternative diagnosis was present at the time of the MET call (ie, an abnormal chest x-ray or alternative diagnoses documented by the attending clinician, consistent with the clinical setting and evident on investigation [eg, acute coronary syndrome, pulmonary oedema or anaemia]).

Results for continuous data are expressed as medians with interquartile ranges, and for categorical variables as *n* values and percentages. Univariate analyses using the χ^2 test or Fisher exact test were undertaken to examine the association between MET indications, chest x-ray results, Wells score as a clinical decision rule and positive CTPA results. Data were analysed using Stata version 12 (StataCorp). Statistical significance was set at $P < 0.05$.

Results

There were 4578 MET events for 3136 patients over the 5-year period from 1 January 2009. CTPAs ordered as a result of MET calls occurred in 70 patients (2.2%).

The demographic and clinical characteristics of the MET call cohort who underwent CTPA, and those who did not, over the same period are shown in Table 1. Compared with the general MET call population (3066 patients), the study population had similar age and sex distributions. MET calls with associated CTPAs were more likely to involve surgical patients (80% v 36.6%, $P < 0.001$) and to have MET calling criteria of hypoxia (42.9% v 20.3%, $P < 0.001$) and tachycardia (20% v 13%, $P = 0.011$). Patients who had an MET call and a CTPA were more likely to have a chest x-ray (75.7% v 26.7%, $P < 0.001$), blood gas analysis (65.6% v 36.3%, $P < 0.001$) and electrocardiogram (ECG) (78.1% v 49.6%, $P < 0.001$) performed. Decisions to perform a CTPA were more likely to occur in the daytime (68.6% v 53.4%, $P = 0.011$) and patients were less likely to have a "not for resuscitation" order in place (7.1% v 17.3%, $P = 0.026$).

PE was present in 12 of the 70 patients (17.1%) who underwent CTPA. Of the patients with PE, a Wells score greater than 4 was present in 58.3%, hypoxia in 33.3%, hypotension in 50% and tachycardia in 25% of patients (Table 2). The association between Wells scores, MET indications, chest x-ray results and CTPA results are shown in Table 2. Chest x-rays were abnormal in 29 patients (41.4%), normal in 24 (34.3%) and not done in 17 patients (24.3%) (Table 3). Of the patients who had chest x-rays performed (75.7%), an abnormal chest x-ray was associated with a low likelihood of PE ($P = 0.009$).

Clinical probability assessment using the Wells score is shown in Figure 1. Thirty-one patients (44.3%) had a Wells score suggestive of PE and, of these, only seven (22.6%) had a positive scan for PE. Of 39 patients (55.7%) with a Wells score greater than 4, 34 (87.2%) had a negative scan for PE.

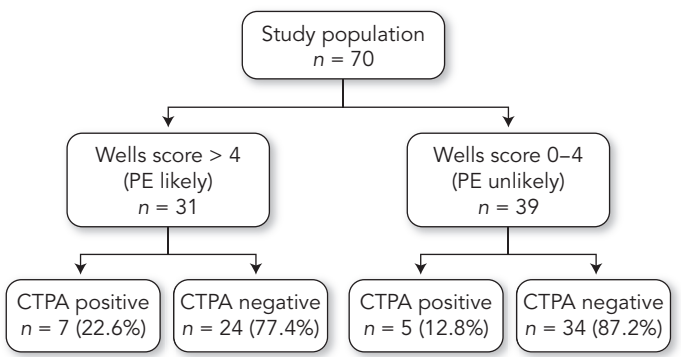
A review of the 12 patients with PE revealed no association between the Wells score, chest x-ray results, MET indications and the degree of PE, as shown in Table 3. All the patients were treated with anticoagulation agents after the diagnosis of PE.

Table 3. Comparison of degree of PE, by patient characteristic

Characteristic*	Degree of PE: Large† ($n = 8$)	Small‡ ($n = 4$)	None ($n = 58$)	*P*
Median age, years (IQR)	62 (60–68)	66 (65–69)	72 (60–77)	–
Female	3 (37.5%)	3 (75%)	32 (55.2%)	0.565
Surgical admission	7 (87.5%)	3 (75%)	46 (79.3%)	0.888
MET indication				
Hypoxia	3 (37.5%)	1 (25%)	27 (46.6%)	0.706
Hypotension	3 (37.5%)	3 (75%)	16 (27.6%)	0.153
Tachycardia	1 (12.5%)	2 (50%)	11 (19%)	0.269
Wells score > 4	5 (62.5%)	2 (50%)	24 (41.4%)	0.562
Chest x-ray result				
Abnormal	1 (12.5%)	0	28 (48.3%)	0.009
Normal	6 (75%)	1 (25%)	17 (29.3%)	–
Not done	1 (12.5%)	3 (75%)	13 (22.4%)	–

PE = pulmonary embolism. IQR = interquartile range. MET = medical emergency team. * *n* (%) unless stated otherwise. † Bilateral PE with or without saddle embolus. ‡ Unilateral lobar PE.

Figure 1. Clinical probability assessment using Wells score and CTPA results



CTPA = computed tomography pulmonary angiogram. PE = pulmonary embolism.

Discussion

CTPA was requested in a low percentage of inpatients needing MET review. Neither high-probability Wells scores nor MET call criteria of hypoxia, hypotension or tachycardia were accurate in estimating a high clinical probability for PE in this patient group. The presence of an abnormal chest x-ray had a high negative predictive value (NPV), and might be used to avoid unnecessary CTPAs. There was no apparent predictor of large PEs that could be ascertained from the study.

Our study population had a similar age and sex profile compared with the general population who had MET calls,

and surgical patients were more likely to undergo CTPA. Patients who had a CTPA more commonly had the MET calling criteria of hypoxia and tachycardia and were more likely to receive investigations such as chest x-ray, blood gas and ECG, suggesting a higher level of concern by the bedside clinician.

The prevalence of PE in the study population was lower (17%; 95% CI, 9%–28%) but was not statistically different when compared with other studies evaluating hospitalised patients with suspected PE (95% CI, 25%–36%).[11,12,16] The Wells score in our study performed poorly compared with the study of Posadas-Martínez and colleagues.[11] This cross-sectional study from a registry, conducted in 613 patients, used the Wells score to ascertain clinical probability for PE and found the Wells score to have a positive predictive value (PPV) of 66% and an NPV of 80%.[11] In our study, the Wells score had a PPV of 23% and an NPV 87%, although our study is not sufficiently powered to assess the accuracy of the Wells score.

Arguments for the use of CTPA in undifferentiated hypoxia and/or cardiovascular instability are as follows.

- *Multidetector CTPA is highly sensitive (83%–100%) and specific (89%–97%)*[1-4] *for the diagnosis of PE*. In our study there were two non-diagnostic CTPAs: one investigation progressed to an ultrasound of the lower limbs which was negative; for the other, there were no further investigations, which suggested a low clinical suspicion. Both patients were discharged with no readmission to the hospital to date. Of the 58 patients with a negative or non-diagnostic CTPA, six (10.3%) had an ultrasound of the limbs to look for deep vein thrombosis, of which none were positive.
- *CTPA has the ability to establish an alternative diagnosis*. In our study cohort, only one patient without PE had a CTPA result which changed their treatment. The patient was found to have a large pericardial effusion and cardiac tamponade that was otherwise unsuspected. In this setting, an ECG may have been a better diagnostic modality, which would have negated the risk associated with transport of an unstable patient. Other abnormal CTPA findings of pulmonary consolidation and pleural effusion were also evident on chest x-ray, and did not affect the patient's treatment.

The following risks associated with CTPA must be considered.

- *There is a real risk associated with patient transfer.* Major adverse events, including cardiac arrest during transfer of the patient to the radiology department, are a real risk, especially if the patient is deteriorating clinically.[17,18] To our knowledge, there were no major adverse events as a result of transfer in the study group, although this was not specifically examined. A single cardiac arrest in the study group was the trigger for an emergency response, but was not a result of patient transfer.
- *CIN and allergy need to be considered*. The incidence of CIN may be up to 30% in high-risk patients, ie, diabetic patients, patients with a history of congestive heart failure or chronic renal impairment, and older patients.[19] Information on the incidence of adverse events relating to contrast and allergic reaction was not collected.
- *The significance of small subsegmental PEs poses a clinical dilemma for clinicians*.[4] All study patients with positive CTPAs were treated with anticoagulation agents, including a patient with one small segmental PE. The relationship between such emboli and clinical deterioration, and their natural history in this setting are uncertain.[4] Perhaps, in a cohort with clinical deterioration, it can be argued that PE should be treated but must be weighed against the risk of anticoagulation therapy, when 84% of the emboli in this study group occurred in surgical patients, with 21% being neurosurgical patients.

Study limitations

Our study has several limitations. First, it was a retrospective analysis, which was not designed or powered to compare clinical probability assessment methods. Because the patients included were specifically those who had had a CTPA within 6 hours of an MET call, and did not include other diagnostic modalities such as a ventilation–perfusion scan or transthoraxic echocardiogram, the exact incidence of PE in the patients who had had an MET call overall remains unknown.

Second, the Wells score as a clinical decision rule was retrospectively calculated. The subjective score of the likelihood of an alternative diagnosis (highly weighted in Wells scoring) may place patients in a high- or low-probability group, therefore altering the study results. To address this potential bias, we combined the written documentation of MET events (outlining clinicians' thoughts of the most likely diagnosis) as well as investigation results (ie, chest x-ray or ECG at the time of the MET with clear alternative diagnosis). It may be possible that a Wells score given, unless there was clear documented evidence not to do, so may falsely increase the number of Wells scores greater than 4 (the "PE likely" group).

Third, our analysis involved data from a single hospital and would benefit from comparison with other centres.

Implications

The search for PE is often driven by the fear of missing a fatal disease, rather than by a high clinical suspicion for PE. When PE is one of the differential diagnoses after an MET call, we recommend a chest x-ray before deciding on a CTPA. An abnormal chest x-ray can help a clinician decide

against a CTPA, especially when the clinical suspicion for PE is low. Avoiding unnecessary CTPAs would reduce harm to patients and costs to health systems.

Conclusion

For patients who had had MET calls, clinical decision rules and MET indications were not significantly associated with PE on CTPAs. However, an abnormal chest x-ray has a high NPV and therefore may be helpful in preventing unnecessary CTPAs.

Competing interests

None declared.

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Appendix. Wells PE scoring*[15]

Variable	Points
Clinical signs and symptoms of DVT (minimum of leg swelling and pain on palpation of deep veins)	3
PE more likely than alternative diagnosis	3
Heart rate > 100 beats/min	1.5
Immobilisation (> 3 days) or surgery in previous 4 weeks	1.5
Previous PE or DVT	1.5
Haemoptysis	1
Malignancy (receiving treatment, treated in past 6 months, or palliative treatment)	1

PE = pulmonary embolism. DVT = deep vein thrombosis. * Score > 4 = high probability (PE likely); score 0–4 = low probability (PE unlikely).