Can a Trained Radiology Technician Do Arterial Obstruction Quantification in Patients With Acute Pulmonary Embolism?

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Objectives: To assess interobserver variability between a trained radiology technician (RT) and an experienced radiologist in arterial obstruction quantification using the Qanadli obstruction index (QOI), in patients diagnosed with acute pulmonary embolism (APE) at CT pulmonary angiography (CTPA).

Materials and Methods: A RT and a radiologist independently reviewed CTPAs of 97 consecutive, prospectively enrolled patients with APE, and calculated the QOI. They classified patients into three risk categories: high for QOI ≥40%, intermediate for QOI 20–37.5%, low for QOI <20%. Interobserver variability was investigated for QOI as a continuous variable and as a categorical variable (high, intermediate, and low-risk groups).

Results: Mean QOI (±SD) was 39.5 ± 24.3% and 38.6 ± 18.9% for the RT and the radiologist, respectively. The mean QOI was not statistically different between the RT and the radiologist (p = 0.502), and the interobserver agreement was excellent (ICC = 0.905). The RT classified 54 patients (55.7%) as high, 17 (17.5%) as intermediate, and 26 (26.8%) as low risk. The radiologist classified 55 patients (56.7%) as high, 22 (22.7%) as intermediate, and 20 (20.6%) as low risk. The interrater agreement for risk stratification was excellent (weighted kappa = 0.844).

Conclusion: Once the diagnosis of APE was established, an adequately trained RT achieved an accuracy comparable to that of an experienced radiologist regarding QOI calculation and risk assessment.

Keywords: CT pulmonary angiography, pulmonary embolism, radiology technician, radiologist, interobserver agreement

INTRODUCTION

Acute pulmonary embolism (APE) is a life-threatening condition associated with in-hospital mortality rates ranging from 5 to 75%, depending on the hemodynamic status (1–5). As a consequence, a specific diagnosis is needed for early risk stratification (RS) and appropriate management (3, 4, 6).
Echocardiography, although not recommended to diagnose suspected APE, is a useful tool to identify APE patients who have a poor prognosis (7, 8). However, echocardiography has several drawbacks, including occasional suboptimal image quality of the right ventricle (RV), and the inability to reliably demonstrate APE as the cause of RV pressure overload (1, 9, 10).

Today, contrast-enhanced multidetector computed tomography (CT), which enables the acquisition of high-resolution images covering the whole thoracic cavity within a single breath-hold, is the modality of choice for clinically suspected APE (1, 11–14). CT pulmonary angiography (CTPA) permits multiplanar reformating, evaluation of pulmonary vessels till sub-segmental branches, and assessment of clot burden in the pulmonary arteries. Associated or alternative diagnoses can also be assessed with CTPA (9, 12, 15).

To evaluate the degree of vascular obstruction in APE, several quantitative scores have been described, including the modified angiographic Miller, and Walsh scores adapted for CTPA, and the CTPA-derived Mastora and Qanadli scores (16). To our knowledge, the Qanadli obstruction index (QOI) is the most used. The QOI is easy to calculate, even in cases with anatomical variations, and can provide an objective and reproducible means to quantify vascular obstruction, with a high degree of correlation to the selective pulmonary angiographic index (9, 11). Moreover, the QOI differentiates between complete and partial obstruction of the most proximal clot, which is supposed to add relevant details about lung perfusion (1).

Because APE is a critical medical condition, CTPA studies for suspected patients are frequently carried out in emergency departments which are commonly overcrowded, and proper management entirely relies on fast and accurate diagnosis (17). Although there may be concern about the role of trained radiology technicians (RT) in interpretative and quantitative radiological tasks, the unremitting workload increase and the shortage of radiologists have encouraged radiology departments to involve selectively trained RT in such tasks. Assigning this task to RT could, therefore, save radiologists’ time to carry out more complex investigations (18, 19).

The primary purpose of our study was to compare the performance of a selectively trained RT with that of a radiologist in QOI score calculation and RS for patients with APE.

**MATERIALS AND METHODS**

**Patients**

This prospective study included 97 consecutive patients aged between 65 and 93 years who presented clinically with signs and symptoms of APE and had positive CTPA findings. All CTPA scans were performed in a tertiary hospital between September 14th, 2009 and November 22nd, 2011. Uninterpretable CTPA due to suboptimal enhancement were excluded from the study ($n = 5$). All subjects were hemodynamically stable and were not in need of special care to maintain systolic blood pressure above 100 mmHg. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the Canton de Vaud.

**Image Acquisition**

All CTPA scans were performed using a GE Healthcare Discovery CT750 HD (GE Healthcare, Milwaukee, WI, USA) following the radiology department’s routine APE CTPA protocol. The acquisition was performed from the diaphragm to lung apices in supine position, during a single breath-hold or shallow breathing, depending on the patient’s level of dyspnea. The images were obtained using 120 kVp, automatic exposure control enabled, 100–300 mA, beam collimation geometry of $64 \times 0.625$ mm, section thickness of $1.25$ mm, reconstruction interval of $1$ mm, and a table speed of $39.37$ mm per $0.6$ s rotation time (0.984 pitch). The field of view was appropriately adjusted to the size of the patient. A $70$-ml bolus of iodine-based non-ionic contrast (Accupaque 300 mg/mL [Iohexol]; GE Healthcare, Oslo, Norway) was administered through an antecubital vein at a rate of $4$ mL/s, followed by a $40$ mL normal saline flush at a rate of $4$ mL/s, and acquisition was triggered using the vendor’s bolus tracking technique. Images were anonymized and de-identified before analysis and transferred to a workstation (Advantage Workstation 4.2, GE Healthcare, Buc, France). All axial images were reviewed using mediastinal window settings [window width (WW), $400$ HU; window level (WL), $40$ HU] and lung window settings (WW, $1,600$ HU; WL, $-600$ HU). Observers were free to obtain sagittal and coronal maximum intensity projection (MIP) and to change window settings for optimal visualization of the vessels.

A RT who received a 3-month training on CTPA interpretation with QOI calculation under the supervision of a radiologist with 25 years of experience in cardiothoracic imaging, as well as a fellowship-trained vascular radiologist with 5 years of experience, interpreted the studies. The RT and radiologist were requested (a) to confirm the presence of partial or complete endovascular filling defects in the pulmonary arteries; (b) to calculate the QOI, and (c) to determine the RS category.

To calculate the QOI, each lung is considered to have 10 segmental arteries (three to the upper lobes, two to the middle lobe or lingula, and five to the lower lobes). When a proximal or lobar clot is present, occlusive disease does not need to be quantified in the vessels arising distally. The percentage of vascular obstruction is calculated as follows:

$$\text{Percentage of obstruction (QOI)} = \left[ \sum_{d=1}^{n} \frac{(n.d)}{40} \right] \times 100$$  \hspace{1cm} (1)

where $n$ is the number of segmental arterial branches arising distally (minimum, 1 indicates obstruction of one segment; maximum, 20 indicates obstruction of both the right and left pulmonary arteries) and $d$ represents the degree of obstruction (minimum, 0 means patent vessel; maximum, two means occluded vessel). The value of $d$ provides semi-quantitative information about the perfusion distal to the thrombus. Therefore, the maximum score is 40; to calculate the percentage of vascular obstruction (QOI), the patient score is divided by the maximal total score, and then the result is multiplied by 100. The RT and the fellowship-trained vascular radiologist were blinded to the patient records and independently interpreted the studies, quantified the QOI score, and then graded the risk (RS) based on...
the QOI score as follows: low risk, 1–17.5%; intermediate risk, 20–37.5%; high risk, ≥40% (20, 21).

**Statistical Analysis**

Statistical analysis was conducted using R 3.1.3 (R Core Team, 2015, Vienna, Austria). Results are presented as absolute and relative number of subjects; quantitative variables are presented as mean ± standard deviation (SD). To investigate the difference between the QOI of the radiologist and the RT, a paired t-test was applied. The interobserver agreement was evaluated with intraclass correlation coefficients (ICC) and interpreted as follows: <0.40, poor; 0.40–0.59, fair; 0.60–0.74, good; ≥0.75, excellent. Differences in QOI quantification agreement were also visualized on a Bland-Altman plot. To investigate interobserver (RT vs. radiologist) agreement of qualitative ratings, weighted kappa coefficients were used and interpreted as follows: <0.01, poor; 0.01–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; ≥0.81, excellent. P-values <0.05 were considered statistically significant.

**RESULTS**

The study population consisted of 97 patients with positive CTPA for APE, 57 (58.8%) males, and 40 (41.2%) females; mean age, 77.2 years; SD, 7.7 years.

The mean overall QOI (±SD) was 39.5 ± 24.3% and 38.6 ± 18.9% for the RT and the radiologist, respectively. There was no statistically significant difference in mean QOI between the RT and the radiologist (p = 0.502), and the interobserver agreement was excellent (ICC = 0.905). Visual interpretation of the Bland-Altman plot confirms a good level of agreement between the RT and radiologist, with a trend towards a variability increase for higher QOI scores, i.e., in high-risk patients (Figure 1). The intra-observer agreement was excellent for the RT and the radiologist (ICC = 0.930 and 0.964, respectively).

Of the 97 CTPA studies included, the RT classified 54 (55.7%) patients as high risk, 17 (17.5%) as intermediate risk and 26 (26.8%) as low risk. On the other hand, the radiologist classified 55 (56.7%) patients as high risk, 22 (22.7%) as intermediate risk and 20 (20.6%) as low risk. The result of risk stratification by the RT and the radiologist is summarized in a three-way contingency table (see Table 1). The interobserver agreement was excellent (weighted kappa = 0.844). The intra-observer agreement was excellent for the RT and the radiologist (weighted kappa = 0.818 and 0.911, respectively).

The discrepancy rate for RS was 11.3% (11 cases), of which 4 cases were related to artifacts (predominantly streak or metallic artifacts), 2 cases were related to motion artifacts, 2 cases were linked to adjacent pulmonary parenchymal consolidation due to infection and infarction/atelectasis (Figure 2), 1 case was referred to chronic pulmonary embolism (Figure 3). Only 2 cases (18.2%) had no apparent cause. We noticed that the QOI of the case with chronic pulmonary embolism was scored 50% by the RT and the RS assessment was categorized as high, while the radiologist scored the QOI 17.5% and RS assessment was categorized as low.

**DISCUSSION**

In this prospective study comparing quantitative CTPA interpretation between a trained RT and an experienced radiologist, we found no significant difference in QOI calculation.
and a high interobserver agreement in patient RS. Our results indicate that a selectively trained RT can detect APE on CTPA scans, quantify the QOI index and stratify patients’ risk with satisfactory accuracy. In most cases of discrepancy, an underlying cause, such as artifacts or concomitant pulmonary pathology was found. It is noteworthy that one patient had findings consistent with chronic pulmonary embolism that let the RT overestimate the QOI, as chronic pulmonary emboli should not be included in the QOI.

In the last few decades, the diagnostic approach to suspected APE has dramatically changed due to substantial improvements in image quality of the pulmonary vasculature (14). CTPA
Currently, APE is life-threatening, requiring fast and accurate diagnosis. CT for PE detection is fast, readily available, and effective. However, understaffing in radiology departments can lead to increased workloads and diagnostic delays. This study assesses the potential of trained radiographers (RTs) to perform quantitative imaging tasks, specifically the QOI calculation.

As APE is a medical emergency, CT is the preferred modality for diagnosis. Rotzinger et al. (2019) compared RTs' accuracy in reporting PE compared to radiologists'. They showed that trained RTs can achieve comparable accuracy to radiologists in interpreting PE findings, particularly when assessing CTPA scans.

The study concluded that RTs have the potential to quantify obstruction in CTPA with APE findings, improving their role in diagnostic radiology. Further research is needed to establish the effect of learning curves on performance and the feasibility of using RTs in routine practice.

**ETHICS STATEMENT**

The study was reviewed and approved by the ethics committee of the canton de Vaud. Written informed consent was obtained from every participant.

**AUTHOR CONTRIBUTIONS**

DR: study design, data analysis, and interpretation, literature review; SB: data acquisition, interpretation, literature review; J-FK: data analysis, statistical analysis; CB-A: data analysis, literature review; A-MJ: data acquisition and analysis; SQ: study design, data analysis, and interpretation, literature review; All authors contributed in drafting the manuscript and revising it critically.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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