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Original Article

Accuracy of computed tomography angiography in the detection of pulmonary embolism in patients with high body weight

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ABSTRACT

Background: The accuracy of CT pulmonary angiography (CTPA) in detecting or excluding pulmonary embolism has not yet been assessed in patients with high body weight (BW).
Methods: This retrospective study involved CTPAs of 114 patients weighing 75–99 kg and those of 123 consecutive patients weighing 100–150 kg. Three independent blinded radiologists analyzed all examinations in randomized order. Readers' data on pulmonary emboli were compared with a composite reference standard, comprising clinical probability, reference CTPA result, additional imaging when performed and 90-day follow-up. Results in both BW groups and in two body mass index (BMI) groups (BMI <30 kg/m^2 and BMI ≥ 30 kg/m^2, i.e., non-obese and obese patients) were compared.
Results: The prevalence of pulmonary embolism was not significantly different in the BW groups ($P = 1.0$). The reference CTPA result was positive in 23 of 114 patients in the 75–99 kg group and in 25 of 123 patients in the ≥ 100 kg group, respectively (odds ratio, 0.991; 95% confidence interval, 0.501 to 1.957; $P = 1.0$). No pulmonary embolism-related death or venous thromboembolism occurred during follow-up. The mean accuracy of three readers was 91.5% in the 75–99 kg group and 89.9% in the ≥ 100 kg group (odds ratio, 1.207; 95% confidence interval, 0.451 to 3.255; $P = 0.495$), and 89.9% in non-obese patients and 91.2% in obese patients (odds ratio, 0.853; 95% confidence interval, 0.317 to 2.319; $P = 0.816$).
Conclusion: The diagnostic accuracy of CTPA in patients weighing 75–99 kg or 100–150 kg proved not to be significantly different.
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1. Introduction

Pulmonary embolism (PE) is the most serious manifestation of venous thromboembolism (VTE) and is the third most common cause of cardiovascular mortality in developed Western countries [1–4]. Several observational studies showed that obesity is an independent risk factor for VTE in both sexes [5–12]. As the prevalence of overweight and obesity in the population is increasing [13–15], the number of obese patients with PE is also expected to rise. The assessment of clinical probability of the disease in obese subjects can be challenging because they often present with dyspnea and tachycardia even without PE and the physical examination of the lower limbs is often difficult in them [16].

In the last decade, multidetector row CT pulmonary angiography (CTPA) became the primary imaging tool for excluding acute PE [1, 17–21]. The data in the literature on the diagnostic performance of CTPA are based on patient populations with mixed body habitus with various body weight (BW) and body mass index (BMI). We are not aware of any analysis of the accuracy of CTPA in obese patients or in those with high BW. However, such an analysis may be interesting because CT image quality is generally reduced in these patient groups as a result of the high absorption rate of X-rays by fat tissue, resulting in increased image noise [22]. Decreased spatial resolution because of larger field of view and beam hardening artifacts due to large body size are further factors leading to decreased image quality, which might negatively affect the detection of emboli. Measures counteracting image quality degradation can result in increased radiation dose (e.g., increasing tube current), lead to lower signal in the contrast enhanced vessels (e.g., increasing tube voltage) or negatively affect the spatial resolution (e.g., increasing image reconstruction size thickness).

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Thus, such measures must be applied cautiously with keeping the risks and benefits in mind. With the steadily increasing proportion of overweight or obese patients with suspected PE, the problem is expected to be encountered more frequently in future.

The aim of the current retrospective analysis was to assess the diagnostic accuracy of CTPA in patients with high BW, defined as 100 kg. We hypothesized that increased BW has a negative impact on the accuracy of CTPA.

2. Patients and methods

2.1. Patient selection

Our database was retrospectively searched for patients weighing ≥100 kg who underwent CTPA to exclude PE on the emergency unit of a tertiary-care center (University Hospital Bern, Switzerland) between September 2007 and April 2011. There were no exclusion criteria. One hundred twenty-three consecutive patients were identified and entered into the analysis, which corresponded less than 5% of all subjects with CTPA in that period. If patients had more than one examination, the first CTPA was enrolled and the others were omitted.

The control group consisted of 114 patients weighing 75 to 99 kg who underwent CTPA between September 2008 and April 2011. These subjects participated in the normal-dose arm of the Reduced Dose in Pulmonary Embolism Diagnosis (REDOPED) trial, which was a single-center, prospective randomized study conducted in the same hospital, comparing normal-dose and low-dose CTPA in patients weighing <100 kg (registered at ClinicalTrials.gov, NCT01258140, sponsored by the Stanley Thomas Johnson Foundation) [23]. These patients served as ideal control subjects because of their well-documented pretest probability for PE. The lower limit of BW was set at 75 kg because, in our experience, the image quality of CTPA with our protocol is usually good to excellent below this threshold, but sometimes deteriorates above this BW because of high image noise. Former studies showed that the image quality of CTPA correlates with BW better than it does with BMI, which justified selecting BW as a discriminative parameter [24,25].

All prospectively acquired patients in the <100 kg group gave written informed consent. In the ≥100 kg group, all patients who could be reached by phone during follow-up gave oral consent to the study. The Ethics Committee of University of Bern waived written informed consent in the ≥100 kg group and approved the study protocol.

2.2. Clinical data and diagnostic tests

The simplified revised Geneva score was used to assess clinical probability of PE [26]. D-dimer tests were done at the discretion of the referring physician by using an enzyme-linked fluorescent immunoassay (VIDAS©, bioMérieux, Marcy l'Etoile, France). The threshold for a normal D-dimer level was 500 ng/mL. Additional imaging modalities such as compression sonography with color Doppler of the lower limb veins and ventilation–perfusion (V/Q) scanning were performed only if indicated.

2.3. CTPA protocol

Patients were examined with the same 16-row CT scanner (Somatom Sensation 16, Siemens Medical, Forchheim, Germany) by using 16 × 0.75 mm collimation, 0.5 s tube rotation time and 1.15 pitch. In all patients in the <100 kg group and in 102 patients in the ≥100 kg group, the tube voltage was set at 100 kVp and the quality reference tube current time product at 100 mAs. In 21 of 123 patients in the ≥100 kg group, a tube energy of 120 kVp was used at the same tube current to keep image quality at a diagnostic level. This decision was made by the emergency radiologist at her/his own discretion. Automatic real-time modulation of the tube current was used in all patients (CareDose4D).

One hundred milliliters of standard contrast medium (CM) with 300 mg/mL iodine concentration (iobitridol, Xenetix 300, Guerbet, Aulnay-sous-Bois, France) was injected intravenously using an injector (CT Expres, Swiss Medical Care, Lausanne, Switzerland). Bolus tracking (Care Bolus, Siemens) was used to reach optimal enhancement in the vessels, and image acquisition was triggered by the CM bolus in the pulmonary trunk. The threshold to start scanning was 100 HU.

Contiguous transverse images (5 mm and 1 mm thick) were reconstructed. From the thin transverse slices, overlapping coronal maximum intensity projections (MIPs) were calculated at 10 mm using increments of 2 mm. All images were stored in a picture archiving and communication system (PACS).

2.4. Analysis of CTPA

Three board-certified general radiologists (JLC, EH, JS) with CT experience of 4 years, 9 years and 15 years, independently evaluated all CTPAs in randomized order on standard LCD monitors. Readers were asked to report the presence and location of PE down to the second subsegmental level. Observers were allowed to analyze all series, including the coronal MIP images. The diagnosis of PE was established in the case of a complete or partial filling defect in the pulmonary arteries on at least three contiguous transverse images of 1 mm thickness with no major movement artifacts. The readers were blinded to all clinical data. Adjustment of window level and width, as well as magnification of images, was allowed during the analysis.

2.5. Follow-up

A trained study nurse with several years' experience searched electronic patient records for new admissions to our hospital in the 90 days after CTPA. Patients were interviewed by telephone 3 to 12 months after CTPA and asked for any admission to other medical institutions or primary-care doctors. They were also asked for any clinical signs and symptoms suggesting PE or deep venous thrombosis during the 90 days after initial CTPA: new or increasing dyspnea, chest pain, or swelling or pain in the lower extremities.

2.6. Reference standard CTPA diagnosis

The radiological reference standard for CTPA was established by a chest radiologist with CT experience of 13 years (*ZS*), who did not act as a reader. He knew the original written reports and readers' data but not the results of additional imaging and follow-up. In cases of doubt, equivocal CTPAs were shown to a second chest radiologist with CT experience of 10 years (*AC*) and decisions were made by consensus. This reference CTPA diagnosis was used to establish a composite reference standard diagnosis and to compare with initial radiological reports.

2.7. Composite clinical reference standard

In a second step, a composite standard of reference was established in accordance with the guidelines of the European Society of Cardiology [1], which included pretest probability (low, intermediate and high based on the simplified revised Geneva score), presence and localization (segmental or more central) of PE in the reference CTPA diagnosis, results on additional imaging and 90-day follow-up. The final decision about whether PE was present in a patient or not was made from the composite reference standard. Although missing data on follow-up did not necessarily lead to an indeterminate diagnosis, the reference standard diagnosis was equivocal for some special combinations of results (Table 1). The composite reference standard diagnosis served as basis for calculation of the prevalence and for comparison with findings made by the three independent readers.

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