Detectability of subsegmental pulmonary vessels in 64 MDCT-pulmonary angiography.

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Abstract

Objective: Identification of subsegmental pulmonary vessels is the basis for identifying subsegmental embolism. In the past studies have been performed to evaluate the depiction rate of spiral CT scanners. In this study the detection rate of subsegmental vessels using 64 MDCT (Sensation 64, Siemens, Germany) has been analyzed.Materials and Methods: Study population consisted of 55 consecutive patients with suspected pulmonary embolism. Standard acquisition parameters were applied using 1.2 mm collimation. An overall of 3127 segmental and subsegmental vessels was counted.Results: An overall depiction rate of 98% for the subsegmental vessels could be demonstrated.Conclusion: In times of increasing slice numbers and faster acquisition techniques, recent technical equipment allows better depiction of subsegmental pulmonary vessels. Anatomic regions of the subsegmental pulmonary vasculary that proved to be difficult to depict in the past can now be visualized more exactly.

INTRODUCTION

During the past decade, the contribution of computed tomographic angiography (CTA) in the diagnosis of pulmonary embolism (PE) has dramatically increased as a consequence of major advances in CT technology. Consequently, CTA has been recognized as the golden standard in a large multi centric study on PE (PIOPED) [1].

Thus, the critical question now no longer concerns demonstrating the clinical value but optimizing the use of CT. Since the introduction of multidetector CT (MDCT) with high spatial and temporal resolution, CTA has become the routine method for imaging the pulmonary vessels when PE is suspected in routine clinical practice. This change in the imaging algorithm has resulted in numerous practical consequences. Because CT images contain additional diagnostic information in patients with suspect of having acute PE it may lead to alternative diagnosis. The increased use of CT has improved patient care by minimizing diagnostic delays that may be incurred when alternative imaging tests are used. The recent possibility of performing electrocardiographically gated examinations of the entire thorax has further reinforced the role of CTA in this clinical setting, adding coronary artery disease to the list of alternative diagnoses detectable and enabling the use of CTA to provide prognostic information from the same data set as that used to help diagnose acute PE. However, the increasing use of CT has raised concerns about the overall radiation exposure to the population scanned and has imposed on the radiology community the need to optimize scanning protocols. Because of changes in the diagnostic strategy over the past few years and the numerous issues still being debated, the Fleischner Society has deemed it useful to propose a consensus update on the role of CTA in the diagnostic approach to PE in 2007 [2].

Thromboembolic disease remains an important diagnostic challenge for both clinicians and radiologists. The diagnostic accuracy of CT to diagnose emboli located in the main, lobar, and segmental pulmonary arteries is approximately 90% [3-7]. When all vessels, including subsegmental pulmonary arteries, are included into the analysis, its diagnostic accuracy was reported to drop dramatically in the past with a sensitivity of approximately 63% [3]. To date, its clinical importance is not well known, but the prevalence of isolated subsegmental clots has been reported to vary between 5 and 30% in patients with acute PE [3-7]. Until recently, subsegmental pulmonary arteries were difficult to identify on CTA because of their respective small diameter and their complex branching patterns with the pulmonary arterial tree. Using multislice spiral CTA, thoracic imaging could be investigated rapidly, with thin collimation which

provides highly detailed images of fine anatomical structures. The detection rate of subsegmental PE could be significantly increased with the introduction of this new generation of CT [8]. To determine whether this is an important clinical problem, the incidence of subsegmental PE is a crucial point. In an analysis of the 383 pulmonary angiograms from the PIOPED study [9;10] that were positive for PE, the proportion of PE limited to subsegmental pulmonary arteries (SSP) was 6% (95% confidence interval [CI]: 4–9). A prerequisite to identify subsegmental clots is the clear and doubtless identification of the subsegmental vessels themselves. To date there exists no scientific data about the detection rate of recent 64 row MDCT scanners in the depiction of subsegmental vessels.

METHOD

Altogether, 55 consecutive patients were included into this retrospective study, all of them being examined routinely in MDCT for suspected pulmonary embolism and without detected pulmonary clots.

Of the 55 patients two had to be excluded, one male patient due to resection of the lower left lobe and one female patient due to massive pleural effusions with reactive compression atelectases with potentially also compressed subsegmental vessels. The resulting study population counted 53 patients, consisting of 30 female and 23 male patients. The mean age of the study population was 61 years (SD 15.5 years). In the subgroups of the male patients a mean age of 63.2 years (SD 15.3 years) and of the female patients of 67.9 years (SD 16.7 years) was observed.

SCANNING

Scanning was performed from the lowest part of the lower pleural recessus to the apex of the lungs with a 64-section CT scanner (Sensation 64, Siemens Medical Solutions). To calculate the bolus arrival time for the contrast-enhanced scan, 20 ml of contrast medium (Ultravist 370, Schering) was injected at a rate of 3.5 ml/sec with a power injector (Ulrich, Ulm, Germany), followed by a chaser bolus of 50 ml saline in the antecubital vein. CT attenuation values were measured continuously in the pulmonary trunc to identify the first slice with sufficient enhancement for calculation of the scanning delay time. Subsequently, the contrast medium bolus (60 ml) was injected (rate 3.5 ml/sec) followed by a 50-ml saline chaser (rate 3.5 ml/sec). The collimation was 24 × 1.2 mm; rotation time 0.5 s; pitch 1.4; and effective tube current 140 mAs at 120 kV. Images were reconstructed with an increment of 0.7 mm to obtain overlapping slices with 0.5 mm slice thickness.

COUNTING VESSELS

For the visual identification of bronchovascular structures the following definitions as outlined by Remy-Jardin et al [11] were applied:

Bronchi and vessels are tubular structures, the presentation of which depends on the orientation of the structure to the scan plane. They appear longitudinal when parallel, oval when oblique, and rounded when perpendicular to the imaging plane.

To identify pulmonary arterial sections with confidence, lung and mediastinal images reconstructed at same increments were analyzed simultaneously.

We did not attempt to account for anatomical variants of the segmental arteries, which, if present, were considered but not classified in this study. For the purpose of this study, an artery was defined as subsegmental artery if it fulfilled at least one of the following criteria:

1) The artery was derived directly from a segmental artery division.

2) Its location has been described in the current anatomical literature concerning subsegmental pulmonary arteries.

3) The diameter was compatible with a subsegmental artery's diameter.

To identify subsegmental arteries, we used Boyden's nomenclature [12] as used by Remy-Jardin et al [5] modified by Schoepf et al [13], as outlined in table 1. All data were analyzed in transversal plane images (figure 1).

Figure 1

Table 1: Nomenclature of bronchovasular anatomy used. Corresponding Jackson and Huber classification included in table.

Jackson and Huber nomenclature [14]	Boyden nomenclature [12]		
	Segments	segmental arteries	subsegmental arteries
right upper lobe			
apical	S1	RA1	RA1a
			RA1b
anterior	S2	RA2	RA2a
			RA2b
posterior	S3	RA3	RA3a
			RA3b
Right middle lobe			
lateral	S4	RA4	RA4a
			RA4b
medial	S5	RA5	RA5a
			RA5b
right lower lobe			
apical	S6	RA6	RA6a+b
			RA6c
medial basal	S7	RA7	RA7a
			RA7b
anterior basal	S8	RA8	RA8a
			RA8b
lateral basal	S9	RA9	RA9a
			RA9b
posterior basal	S10	RA10	RA10a
			RA10b
left upper lobe			
apicoposterior	S1+3	LA1	LA1a
			LA1b
		LA3	LA3a
			LA3b
anterior	S2	LA2	LA2a
			LA2b
lower division			
superior lingula	S4	LA4	LA4a
			LA4b
inferior lingula	S5	LA5	LA5a
			LA5b
left lower lobe			
apical	S6	LA6	LA6a+b
			LA6c
anteromedial basal	S7+8	LA7+8	LA7a
			LA7b
			LA8a
			LA8b
lateral basal	S9	LA9	LA9a
			LA9b
posterior	S10	LA10	LA10a
			LA10b

Figure 2

Figure 1: transversal CT scans for pulmonary vessel identification

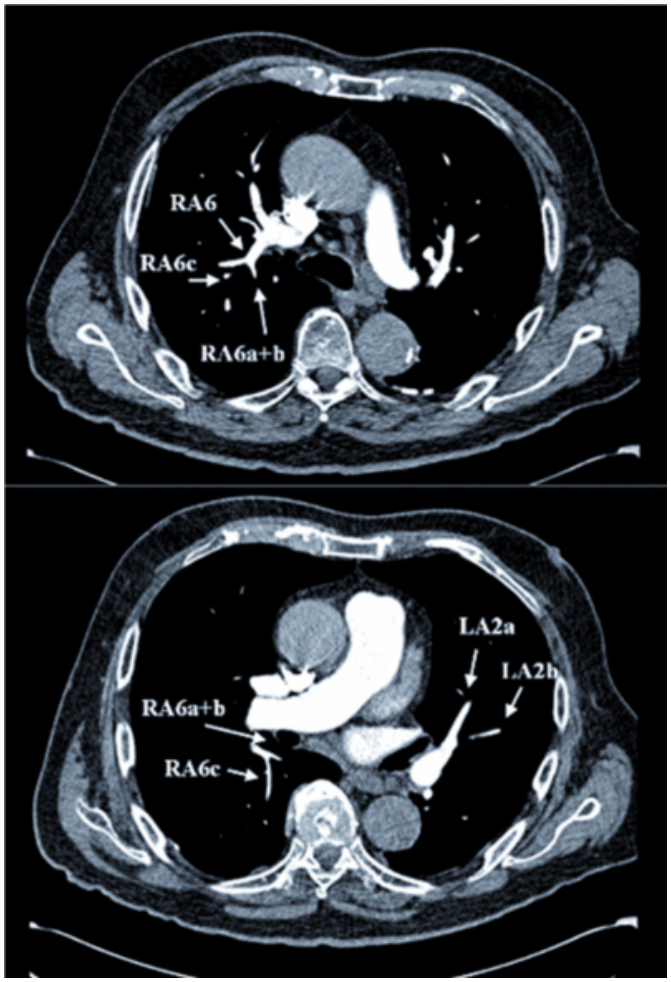

Figure 3

Table 2: Total numbers for identification of classical subsegmental pulmonary arteries according to anatomic location (percentage in brackets)

Upper lobe (group n=53)											
right						**left**					
RA1		RA2		RA3		LA1		LA2		LA3	
a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*A*	*b*	*a*	*b*
53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	48 (90)
Middle lobe (group n=53)											
Right				**Left (lingula)**							
RA4		RA5		LA4		LA5					
a	*b*	*a*	*b*	*a*	*b*	*a*	*B*				
53 (100)	53 (100)	51 (96)	50 (94)	53 (100)	53 (100)	42 (79)	53 (100)				
Right lower lobe (group n=53)											
RA6		RA7		RA8		RA9		RA10			
a+b	*c*	*a*	*b*	*a*	*b*	*a*	*B*	*A*	*b*		
53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53 (100)	53(100)	53 (100)	53 (100)	53 (100)		
Left lower lobe (group n=53)											
LA6		LA7		LA8		LA9		LA10			
a+b	*c*	*a*	*b*	*a*	*b*	*a*	*B*	*a*	*b*		
53 (100)	53 (100)	53 (100)	43 (81)	53 (100)	50 (94)	53 (100)	53 (100)	53 (100)	53 (100)		

RESULTS

All main arteries and all 1007 segmental pulmonary arteries were correctly identified. The total number of subsegmental pulmonary vessels to be counted was 2120. Of these a total number of 34 subsegmental vessels (1.6%) could not be identified. These non-counted vessels consisted of 5 LA3b, 2 RA5a, 3 RA5b branches in the right lung and 11 LA5a, 10 LA7b and 3 LA8b branches in the left lung. An overall resulting number of 98% of the subsegmental vessels could be identified. See table 2 for an detailed overview. On the whole a total number of 3127 vessels was analyzed in all patients.

DISCUSSION

The counting of the pulmonary vessels revealed a high detection rate for identification of subsegmental vessels of 98%.

This study revealed how pulmonary arterial classification remains complex. Some previous anatomical studies, specifically that of Boyden [12], defined a nomenclature of pulmonary segmental and subsegmental arteries.

In previous studies, Remy-Jardin et al [6] analyzed 93% of segmental arteries on spiral CT with a 2 mm collimation and 2 mm interval. The authors used a spiral scanner (Somatom Plus 4A, Siemens, Germany). A mean of 61% of subsegmental arteries was visualized in a group of 20 patients. Insufficient visualization (<35% of cases) was located in the following anatomic regions: RA2a, RA4a, RA4b, and LA7a.

Schoepf et al [7] documented a non-optimal depiction of subsegmental arteries in the following segments: RA3 and LA1 on spiral CTA due to a short arterial axis and anatomical variants. The authors used 5 mm collimation and an effective section thickness of 3 mm interval in reconstructed images. They used a spiral scanner (Somatom Plus 4A, Siemens, Germany). LA7 was poor visualized because of kinetic artifacts (heart motions). In this study, 73% of subsegmental arteries were depicted in the right lung and 70% in the left lung. Lateral rami of RA2, RA3, LA2, and LA3 were not adequately depicted due to defective arterial opacification. Arteries of the middle lobe and of the lingula were poorly visualized due to their short size, obliquity in transverse scans, and kinetic artifacts related to subsegmental arteries in lingula (heart motion).

In contrast to the previously quoted studies, Ghaye et al [15] demonstrated in their review that multidetector CT with 1 mm collimation allows much better results such as analysis of 94% of subsegmental arteries.

A study performed by Coche et al [16] revealed identification of 96% of subsegmental arteries. They applied 1 mm thin collimation with 1.3mm effective slice thickness using spiral CT (Mx 8000, Philips, Netherlands).

The study presented here relies on a 64 row CT scanner with 1.2mm collimation and 0.5 mm ultrathin reconstructed effective slice thickness. Due to the improvement in image resolution and acquisition time, our results achieved a correct identification of 98% of subsegmental pulmonary arterial vessels. The ultrathin reconstructed effective slice thickness further simplified identification of the small subsegmental vessels.

Anatomical regions that were not adequately depicted in our study corresponded to subsegmental arteries alike in previous studies albeit with a higher detection rate, i.e., in the middle lobe (RA5a, 96%; RA5b, 94%), in the lingula (LA5a, 79%), subsegments in left paracardiac region (LA7b,81%), and subsegmental rami of anterior segment in the left lower lobe (LA8b, 94%). These paracardiac anatomic locations are exposed to the motion of the beating heart muscle and therefore artifacts resulting in lower depiction rate can be expected.

A “cardiac gating” system added to multi-slice CT may probably decrease the kinetic artifacts due to heart motion in these subsegments and yield confident analysis of these arteries. This might be a problem in terms of radiation safety, since the heart rate directly influences the radiation exposure [17]. Recent developments in even faster image acquisition in terms of increasing slices numbers or dual source technique will probably further increase depictability of subsegmental arteries especially by further reducing acquisition time.

Taking into account the uncertainty regarding the necessity to treat patients with isolated subsegmental PE, the clinical impact of the depiction of subsegmental clots still remains unclear [18]. Although patients with isolated subsegmental defects appear to have a more benign clinical presentation than patients with segmental or more proximal PE, the role of isolated subsegmental pulmonary embolism (ISSPE) for long term and short term outcome is still under investigation. Interestingly, ISSPE patients less frequently show associated DVT and clinical symptoms like dyspnea [19]. Some authors consider that one of the functions of the pulmonary circulation is to prevent small emboli from entering the systemic circulation and believe that such distal emboli may occur even in healthy subjects [20;21]. On the other hand, small peripheral PE may prove clinically relevant in the case of diminished cardio-respiratory reserve which underlines the clinical importance of a correct diagnosis or exclusion of subsegmental PE. In order to achieve this demand, the technical feasibility to clearly depict the normal anatomy is mandatory. Our study defines a much better delineation of the subsegmental pulmonary arteries in patients and thus a prerequisite to correctly diagnose subsegmental arterial occlusion or embolisation.

To date, no data are available on the long-term consequences of subsegmental PE, especially on the occurrence of chronic pulmonary hypertension. Further research in randomized trials might be necessary to clarify these questions.

CONCLUSION

CTA remains the golden standard in the diagnostic work-up of patients with suspected pulmonary embolism. With technical parameters according to published and broadly accepted guidelines, a vast majority of pulmonary vessels, including the subsegmental arteries can readily be identified using 64 row CT thin collimation and ultrathin image reconstruction [22;23]. Recent developments in CT technique will probably further increase possibilities in decreasing resolution, minimizing artefacts and correctly depicting subsegmental pulmonary vessels. Still, the clinical impact of the possible identification of isolated subsegmental pulmonary embolism remains unclear. If isolated depiction of subsegmental pulmonary embolism proves to lack significant clinical impact this insight may allow for changing the concept of optimized resolution and aim for reduced radiation dose by applying increased collimation and/or increased noise. The modification of CT parameters like e.g. reduced tube current to restrict clear visualisation to the segmental pulmonary artery level. In a differentiated approach, lower dose CT may rule out central and segmental PEs in the majority of patients while only in a dedicated preselected patient group a high dose, high resolution CT must be applied to also detect/exclude subsegmental PE.

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