Thrombosis Research 161 (2018) 52–59

Contents lists available at ScienceDirect

Thrombosis Research

journal homepage: www.elsevier.com/locate/thromres

Full Length Article

Clinical study of optical coherence tomography in the diagnosis of peripheral pulmonary artery thrombus☆

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ARTICLE INFO

Keywords:
Optical coherence tomography
Peripheral pulmonary artery thrombus
Selective pulmonary angiography
Diagnosis
Anticoagulant therapy

ABSTRACT

Background: Peripheral pulmonary artery thrombus (PPT) is common in the clinic. However, due to the lack of an ideal diagnostic tool, PPT cannot be quickly diagnosed and effectively treated at present. Optical coherence tomography (OCT) is a new intravascular imaging technique that is characterized by high image resolution. This technique is suitable for small vessel imaging and has the ability to distinguish red and white thrombi.

Objective: This study aimed to evaluate the value of OCT in the diagnosis of PPT and in identifying the nature of thrombi by comparing the difference in sensitivity between OCT and selective pulmonary angiography (SPA).

Methods: Highly suspected PPT patients were enrolled in this study. Pulmonary ventilation/perfusion (V/Q) mismatch pulmonary segments or peripheral pulmonary arteries were chosen. SPA was performed first, followed by OCT imaging. The diagnostic standard of thrombus with SPA was an intraluminal filling defect. The procedure and criteria for OCT diagnosis of thrombus were previously introduced in intracoronary OCT thrombus images. The diameter of the imaging vessels was measured, and they were grouped according to diameter. The diameter was < 2 mm in the distal segment group, 2–3 mm in the middle segment group, and > 3 mm in the proximal segment group. The recognition abilities of intravascular thrombus with the different diameters of these two techniques were compared. Patients with obvious clinical symptoms and more red thromboses revealed by OCT were given standardized anticoagulant therapy for half a year. The clinical symptoms, 6-minute walking test and changes in the thrombus in the OCT images of these patients before and after treatment were observed.

Results: A total of 22 patients with highly suspected PPT were suggested to undergo V/Q inspection. Finally, 12 patients were eligible for the study. SPA and OCT were performed in 61 peripheral pulmonary arteries in all 12 patients. The ideal SPA and OCT images obtained from a total of 76 blood vessel segments were suitable for comparative analysis. A total of 62 thrombi were found by SPA. Among these, eight thrombi were in the distal segment, 29 thrombi were in the middle segment, and 25 thrombi were in the proximal segment. A total of 81 thrombi were found by OCT, among which 22 thrombi were in the distal segment, 31 were in the middle segment, and 28 were in the proximal segment. There was a significant difference between two groups in the distal segment group ($P = 0.013$), while there was no significant difference between two groups in the middle segment group or the proximal segment group ($P > 0.05$). In addition to all the thrombi found by SPA, OCT found other thrombi that were missed by SPA. According to previous OCT images for determining the nature of thrombi, OCT revealed 81 thrombi, of which 48 (59%) were red thrombi and 33 (41%) were white thrombi. Then, seven patients who had obvious clinical symptoms and more red thrombi in the peripheral pulmonary artery were given anticoagulant therapy for six months. After treatment, these symptoms were improved, oxygenation indexes increased, and the six-minute walking test was extended in all these patients. After anticoagulation therapy, five patients underwent OCT review. These OCT images were matched and compared before and after anticoagulation therapy. The results revealed that most of the thrombi had disappeared, and a small amount of red thrombi turned white as the volume reduced. The mean lumen area before and after treatment was $2.05 \pm 1.03\ mm^2$ and $2.86 \pm 1.24\ mm^2$, respectively, and the difference was statistically significant ($P = 0.035$).

Conclusion: OCT can clearly show the structure of the lumen and the wall of the peripheral pulmonary artery tube. The sensitivity of the diagnosis of PPT with a diameter of < 2 mm was higher than that of SPA. Moreover,

☆ Funding by the Natural science fund project of Guangdong province. Fund No. 2014A030310219.

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https://doi.org/10.1016/j.thromres.2017.10.021
Received 19 June 2017; Received in revised form 26 September 2017; Accepted 26 October 2017
Available online 28 October 2017
0049-3848/

OCT has the ability to distinguish between red and white thrombi, which is of guiding significance in anticoagulant therapy.

The incidence of pulmonary thromboembolism (PTE) is high with a low diagnosis rate and a high mortality rate. The incidence of PTE in hospitalized patients is 0.4% in America [1,2]. However, the study of PTE is mainly confined to proximal central-type PTE, and peripheral pulmonary artery thrombus (PPT) remains poorly understood at present. Extensive PPT leads to increased pulmonary vascular resistance, reduced pulmonary blood flow, and a proportional imbalance in pulmonary ventilation/perfusion (V/Q), causing breathing difficulties in patients. Thus, timely and effective treatment is required [3,4]. Previous autopsy studies have shown that PPT is not uncommon. However, due to the lack of an effective method, the diagnosis rate of PPT is much lower than that of PTE [5,6]. It is very important to find an effective imaging tool to improve the diagnosis rate and understand more about PPT.

Selective pulmonary angiography (SPA) has been considered an effective method for the diagnosis of PPT. However, satisfactory results are often difficult to obtain due to the low resolution of the image [5]. Optical coherence tomography (OCT) is a newly developed optical imaging technology characterized by real-time, dynamic intraluminal imaging and high resolution [7]. The OCT imaging guide wire is composed of single fiber imaging with a guide wire diameter of only 0.014 in. (approximately 0.36 mm) and a guide wire length of up to 191 cm. The guide wire can be sent into a small vessel in a distal part of the body for imaging, and the OCT images have the ability to distinguish different types of thrombi [7]. Therefore, in this study, we aimed to compare the diagnostic value of SPA and OCT in PPT, to determine the identification ability of OCT between fresh and old thrombi, and to study the clinical value of OCT in PPT diagnosis as well as its guidance value in anticoagulation therapy.

1. Subjects and methods

1.1. Study subjects

Patients who were admitted to the hospital between January 2013 and December 2016 and who were suspected of PPT according to clinical manifestations, laboratory tests and imaging examinations were included in this study.

1.1.1. Inclusion criteria

High risk factors (age > 65 years, puerperium, treated with estrogen, oral contraceptives (> 1 month), anticardiolipin antibody syndrome, lower activity of protein C and lower activity of protein S) for thrombus were present in patients. No thrombi were found above the segmental pulmonary arteries by CT pulmonary angiogram (CTPA).

1.1.2. Exclusion criteria

Patients who were < 14 years old, patients who had chronic renal insufficiency (serum creatinine level > 133 mol/L or > 1.8 mg/dL), patients who were allergic to contrast agents, patients who were pregnant or lactating, and patients or the families of patients who did not agree to undergo the procedure were excluded from the study.

This study was approved by the hospital ethics committee (Approval number: GZGYHR-2009-04-20-02). Before the examination, the patient was fully informed of necessities and possible risks and complications. All participants signed an informed consent prior to participating in the study and a consent for optical coherence tomography.

1.2. Materials and methods

1.2.1. Equipment and materials

1.2.1.1. Imaging equipment. The digital X-ray angiography instrument INNO-VA2000 (GE, USA) was used. Imaging devices included the arterial sheath (5 Fr or 6 Fr) (Terumo, Tokyo, Japan), multifunction contrast tube (MP, Cordis, Miami, Lakes, Florida, USA) and the hydrophilic coating long guide wire (outer diameter 0.035 in., length 260 cm; Amplatz, USA). The commonly used soft-top steel guide wires were PILOT series/CROSS series/BMW/ATW, in which the outer diameter of the guide wire was 0.014 in. and the length was 191 cm.

1.2.1.2. Main devices of OCT. OCT instruments (M2 series intravascular imaging system; LightLab Imaging, Inc., Westford, MA, USA) and the OCT system for the automatic withdrawal of the device, in which the imaging guide wire was automatically withdrawn according to the set data, were used. An OCT imaging guide wire (outer diameter: 0.014 in. ≈ 0.36 mm; length: 191 cm) and a Helios™ occlusion balloon catheter (OBC) (outer diameter: 3 Fr) with a low-pressure balloon forcing pump (GoodTec INDEFLATOR LID-1) were also used.

1.2.1.3. Materials. The contrast agent was Visipaque (270 mg/mL iodixanol injection; GE, USA), 100 mL/bottle; the specific amount to be used was determined according to practical considerations, and the total amount was no > 200 mL.

1.2.2. Methods

1.2.2.1. Recording related indexes of patients. The name, gender, chief complaints, clinical diagnosis and factors of thrombus were record for all patients. Experimental tests included plasma D-dimer level, thrombophilia-relevant examinations (anticardiolipin antibody and activities of protein C and protein S), and six-minute walking distance.

1.2.2.2. Determination of vessels for imaging and selective pulmonary angiography and OCT imaging. According to the V/Q scan results, mismatch pulmonary segments or peripheral pulmonary arteries were selected for imaging. In each patient, 5–10 peripheral pulmonary arteries were selected for imaging. SPA inspection was first performed, followed by OTC imaging. SPA process: the guide wire was sent into the vessel and was filled with the contrast agent. A multifunctional catheter was sent along with the guide wire into the angiography vessel. The position of the catheter was adjusted to position the catheter and vessel to be in the same axis. After determining the contrast position, the contrast agent was pushed by hand for imaging. Then, the imaging position was transformed for re-imaging. Four angiograph projection positions were selected in each vessel: left anterior oblique 45° plus cranial and caudal 20° and right anterior oblique 30° plus cranial and caudal 20°. OCT imaging process: the morphology and proximal vascular diameter were determined according to the imaging results. The OBC and imaging guide wire were transported to the distal blood vessels along the catheter. Then, the OBC was withdrawn. OCT imaging began simultaneously with the hand push of the contrast agent to replace the blood in the blood vessels. The specific imaging process was observed [8–10].

1.2.2.3. Groups according to lumen diameter. The imaging vessels were divided into three groups according to the vessel inner diameter. The diameter was > 3 mm in the proximal segment group, 2–3 mm in the middle segment group, and < 2 mm in the distal segment group.

SPA image grouping method: Taking the transverse diameter of the