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Review

Optical coherence tomography of the pulmonary arteries: A systematic review

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ABSTRACT

Optical coherence tomography (OCT) is an imaging technique extensively used for visualizing the coronary circulation, where it assists clinical decision-making. Along with the new interventional procedures being introduced for pulmonary vascular disease, there is an increasing need for intravascular imaging of the pulmonary arteries. Additionally, measurements of the wall thickness of the pulmonary arteries of patients with various types of pulmonary hypertension (PH) may provide relevant diagnostic and prognostic information. The aim of this review is to summarize all the available evidence on the use of OCT for imaging the pulmonary bed and to describe a simple protocol for OCT image acquisition. We conducted a systematic review of the literature using electronic reference databases through February 2015 (MEDLINE, Cochrane Library, Web of Knowledge, and references cited in other studies) and the search terms "optical coherence tomography," "pulmonary hypertension," and "pulmonary arteries." Studies in which OCT was used to image the pulmonary vessels were considered for inclusion. We identified 14 studies reporting OCT imaging data from the pulmonary arteries. OCT was able to identify intravascular thrombi in patients with chronic thromboembolic PH (CTEPH), and an increase in vessel wall thickness was found in most patients with PH, compared with the controls. OCT has also been reported to be useful for the selection of balloon size in the setting of balloon pulmonary angioplasty for CTEPH. The main limitations include lack of standardization, little data on outcomes, cost, and the technical limitations involved in visualizing small-diameter (<1 mm) pulmonary vessels. OCT has become a potential tool for the *in vivo* study of vascular changes in the pulmonary arteries, and may provide additional information in the assessment of patients with PH. Prospective high-quality studies assessing the safety, validity, and clinical impact of OCT imaging for pulmonary vessels are warranted.

Contents

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Introduction

Pulmonary hypertension (PH) is not a disease *per se*, but a hemodynamic and pathophysiological state that can be found in multiple clinical conditions. It is defined as an increased mean pulmonary artery pressure (mPAP) of higher than 25 mmHg at rest, as assessed by right heart catheterization (RHC) [1]. The revised 2013 PH clinical classification includes five major categories with different etiological, pathophysiological, prognostic, and therapeutic features [2]. While the exact causes of PH remain under investigation, and are likely to vary with the underlying pathogenic or genetic causes, it is widely recognized that the hallmark of all forms of PH is structural alterations of the vascular wall [3].

Until recently, direct morphological assessment of the pulmonary arteries was limited to pulmonary angiography and lung biopsy [4]. Digital subtraction pulmonary angiography only images the lumen, and does not provide information on wall abnormalities; on the other hand, direct histological evaluation yields valuable information on changes in pulmonary vessel walls, but requires a thoracotomy, a potentially dangerous procedure for patients with PH [4]. Additionally, because of the difficulties in visualizing and measuring changes in the vascular walls of patients during the course of the disease, most evidence for remodeling is derived from postmortem or postoperative specimens [5].

The rapidly developing intravascular imaging modalities, intravascular ultrasound (IVUS) and optical coherence tomography (OCT), show promise for providing *in vivo* and real-time quantitative and qualitative descriptions of pulmonary vascular structures. IVUS has been validated to be a reliable method for assessing the morphology of pulmonary vessel walls, and can explore pulmonary arteries ranging from 2 to 5 mm in diameter [4,6,7]. However, the image resolution of IVUS is often insufficient for ensuring accurate assessment of changes in the walls of pulmonary arteries [8,9]. OCT is a near-infrared light source-based imaging technique with a resolution of 10–20 μm, 10-fold greater than that achieved by IVUS [10,11]. The results of several recent OCT-based studies on imaging the pulmonary arteries suggest that it is a useful tool for the *in vivo* study of the vascular remodeling process, and may have clinical impact on the diagnosis and management of PH patients. Additionally, with the development of new interventional modalities such as balloon pulmonary angioplasty (BPA) for inoperable chronic thromboembolic PH (CTEPH) [12–15] and pulmonary artery denervation for pulmonary arterial hypertension (PAH) [16], the need for intravascular imaging is increasing, and OCT may emerge as an important tool for guiding these procedures.

This review summarizes all the available data on the use of OCT for imaging the pulmonary arteries.

Methods

A systematic literature search was conducted between January 2013 and February 2015. It focused on peer-reviewed original research that investigated OCT imaging of the pulmonary arteries. The search resources included MEDLINE *via* PubMed, the Cochrane Library, Web of Knowledge, and references cited in other studies. The search employed the following terms: "optical coherence tomography," "pulmonary hypertension," and "pulmonary arteries." The search was limited to English-language articles published from January 2000 to February 2015. Studies in which OCT was used to image the pulmonary vessels and with original data were considered for inclusion. Publications that did not report original data were excluded. Conference abstracts and results posted in trial registries were excluded. No search of the gray literature was performed.

Study selection was performed by the investigators E.J. (interventional cardiologist) and R.B. (clinical cardiologist). References were managed using Mendeley Desktop software (V.1.12.3). Retrieved papers were individually searched for additional references. The citation list is available upon request. Eligible studies included participants who underwent OCT imaging of the pulmonary arteries (controls and patients with PH). The following variables were extracted, when available: year of publication, sample size, PH subgroup, diameter of imaged vessel, wall thickness, and a summary of main findings of the study.

Grading the quality of evidence of included studies

The Effective Public Health Practice Project (EPHPP) was used to rate the quality of evidence in the reviewed studies [17]. Each study was assigned a grade of strong, moderate, or weak. Studies were graded by independent reviews conducted by two of the authors (E.J., R.B.). Studies for which the two original ratings disagreed underwent a resolution review by a third author (P.M.). The results are shown in Supplementary Table 1.

Results

Study selection

Of the 29 identified publications, 15 papers were excluded because they lacked original data. Fourteen studies met the inclusion criteria and underwent quality assessment (Fig. 1). Two articles included OCT follow-up data [18,19]. The independent quality assessments were in agreement in all 14 cases (3 moderate and 11 weak). All studies were observational. The sample sizes ranged from 1 to 124 individuals. The inner diameter of the imaged pulmonary arterial vessels ranged from 0.98 mm [12] to 3.76 mm [20].

OCT technical procedures for image acquisition in the pulmonary arteries

Seven studies reported the anatomic locations of the OCT images; OCT was performed in the inferior pulmonary lobes in all