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Invited article

Optical coherence tomography of re-pressurised porcine coronary arteries: A systematic study ☆

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ABSTRACT

Cardiovascular death is the most frequently reported cause of adult natural death in autopsy reports in the UK. However, the approach used for diagnosing coronary artery disease at autopsy is largely based on visual assessment of coronary artery cross sections to determine the severity of stenosis. This is subject to criticism and heterogeneity.

Objective: We investigated the potential role of a novel intravascular imaging technique, optical coherence tomography (OCT), in post-mortem diagnosis of coronary artery disease and what effect re-pressurisation has on vessel dimensions, as measured by OCT. Our long term aim is to investigate the role of OCT as a minimally invasive autopsy tool.

Materials and methods: We used several ex-vivo porcine hearts to develop the techniques. Subsequently, 6 coronary arteries were used for detailed experiments. Vessels were gradually re-pressurised using normal saline and clinical coronary pressure wire and OCT systems were used for recording the pressure and intracoronary imaging.

Results: Our data showed re-pressurisation significantly alters the vessel dimensions. The mean cross sectional area increased from 3.3 to 8.4 mm^2 proximally and from 2.5 to 7.4 mm^2 distally.

Conclusion: We conclude that OCT in the ex-vivo setting is feasible and re-pressurisation significantly alters vascular dimensions. This implies, there might be significant discrepancies between the true severities of stenosis in life and that which is determined by visual estimation during autopsy in the collapsed vessels. OCT of re-pressurised vessel can overcome this issue and has the potential to improve the accuracy of post-mortem assessment of coronary artery disease.

1. Introduction

Despite a worldwide decreasing trend, England and Wales continue to have a high autopsy rate, reported as 22% of all registered deaths [1]. This is much higher than Scotland and Northern Ireland (10% and 9%) and most other European countries [1–3]. Most (nearly 95%) of these 110,000 autopsies performed every year are coronial autopsies [4] and vast majority of these autopsies have a natural cause of death of which ischaemic heart disease is the most frequent diagnosis [5].

The post-mortem diagnosis of coronary artery disease is based on a probabilistic approach by determining severity of stenosis in the major epicardial arteries by direct observation of cross sections [6,7]. These vessels may be collapsed, being devoid of blood flow and pressure after the cessation of circulation. This approach is therefore subject to significant variability [8] due both to the limitations of a visual assessment of a coronary luminal stenosis exacerbated by the differential effects of depressurisation on both normal and abnormal coronary anatomy. New approaches, capable of demonstrating the severity of coronary disease in a re-pressurised vessel therefore have the potential to improve the accuracy of a post mortem diagnosis of coronary artery disease.

Optical coherence tomography (OCT) is an imaging modality that uses near infrared light interferometry and is capable of showing tissue microstructure. In 1991, Huang et al. first

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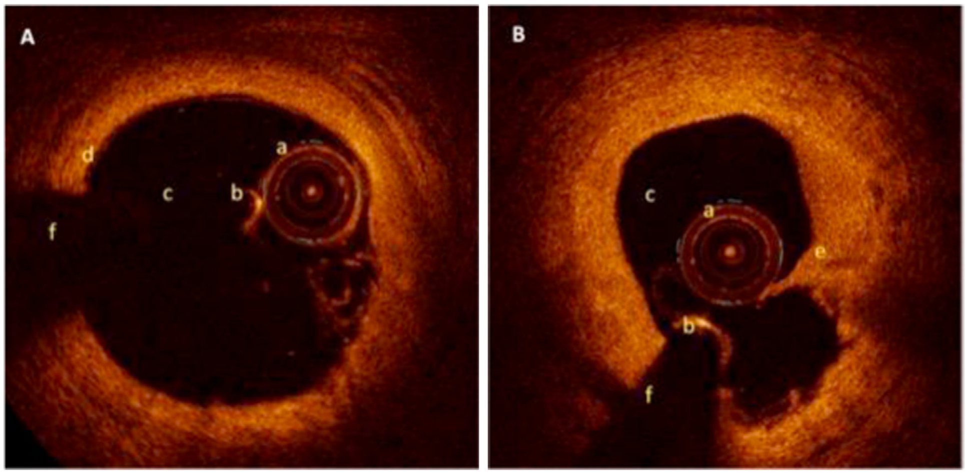

Fig. 1. OCT cross-section of (A) normal and (B) diseased coronary artery segments in the right coronary artery of a patient. (a) OCT catheter, (b) guide wire, (c) coronary artery lumen, (d) normal coronary arterial wall, (e) atherosclerotic plaque with disruption, and (f) optical shadow of the guide wire.

demonstrated its potential in medical imaging using ex-vivo examples of retina and human coronary artery [9]. The strength of OCT is the high spatial resolution in the range of 10–15 µm, which is 10 times higher than Intra Vascular Ultrasound (IVUS). Current systems are able to image a length of 54–70 mm of coronary artery within seconds. OCT findings of atherosclerotic plaques have been well validated against histological studies [10–13]. The principal roles of OCT in clinical cardiology are for detailed assessment of severity of coronary stenosis, identifying vulnerable or ruptured plaque (Fig. 1), stent deployment and diagnosis of complications such as coronary artery dissections and in-stent thrombosis [13–19].

Although OCT has been used in animal and cadaveric studies for its validation as a virtual histology tool [14,20–23], these were largely performed in ex-vivo and dissected coronary arteries. Only recently, Adlam et al. published a proof of concept paper [24] demonstrating OCT of the right coronary artery in an intact cadaver. This work showed the feasibility of performing in-situ OCT of the coronary artery in the context of minimally invasive autopsy. The vessel was not repressurised during that study.

We describe a preliminary study on ex-vivo and re-pressurised porcine coronary arteries using intracoronary OCT. Our aim was to demonstrate the feasibility of performing OCT in ex-vivo re-pressurised coronary arteries and to demonstrate the effect of different pressures.

2. Materials and methods

The local research and ethics committee approved the study as part of the on-going minimally invasive autopsy project. The animal hearts were collected from a local abattoir where they were killed in accordance with UK national practice for food consumption.

The set-up and techniques discussed below were initially developed using nearly 20 ex-vivo specimens of porcine hearts.

Once the technical aspects were developed, experiments were conducted on 6 coronary arteries from 4 porcine hearts and data were collected. The hearts were collected in the morning soon after the animals were killed and stored in in room temperature. Experiments were completed within 3–8 h from the time of death.

The left main stem and the right coronary artery ostia were identified and cannulated using a modified tip, 6 Fr. size, coronary guide catheter, secured with a suture. The proximal end of the catheter was connected through a 'Y' connector to a fluid filled bag (0.9% sodium chloride) and a pressure transducer. A coronary pressure wire system (RadiAnalyzer™ St. Jude Medical Inc., Minnesota, USA) was connected to record pressure readings from the transducer, which was fully calibrated. In a fluid filled system, this transducer was recording pressure from the tip of the guide catheter reflecting the proximal intra-coronary pressure.

The coronary artery was infused with 0.9% sodium chloride through the catheter. A coronary guide wire was passed into the distal vessel using tactile feedback and direct visualisation through the translucent wall. This was subsequently exchanged for a pre-calibrated coronary pressure wire (PressureWire™ Certus™, St. Jude Medical Inc., Minnesota, USA) using a micro-catheter (Finecross® MG, Terumo IS, NJ, USA) for recording distal coronary pressure. An OCT catheter (DragonFly™ Duo, St. Jude Medical Inc., Minnesota, USA) was passed over the pressure wire and placed at approximately 5 cm distal from the tip of the guide catheter. The OCT catheter was then connected to the OCT machine (Ilumien™ PCI Optimization System, St. Jude Medical Inc., Minnesota, USA) and the pressure wire was connected to the RadiAnalyzer™. (St. Jude Medical Inc., Minnesota, USA) system. Pressure in the fluid bag was then increased step wise using a sphygmomanometer cuff, from 0 to 120 or 150 mmHg at 10 mmHg interval, and OCT pullback was performed twice at each point. Both the proximal and distal intravascular pressures were recorded simultaneously. Further details of the re-pressurisation have been described in a paper, by Robinson et al. in the same edition of this journal.

Experiments were conducted on the left anterior descending (LAD) artery and right coronary artery (RCA). The circumflex arteries were not used in these experiments as guide-wire passage without fluoroscopic guidance into this coronary territory was found to be challenging leading to an increased risk of damage to the guide-wire and vessel wall. Occasionally air bubbles were seen within the coronary artery during OCT, which were removed using a retrograde irrigation technique through the central lumen of the OCT catheter (Fig. 2).

OCT recordings were obtained from the proximal 5 cm of the vessels excluding the very first 1–1.5 cm where the catheter was attached. The images were subsequently analysed offline and the vessel diameter and cross sectional area were measured at a proximal, mid and distal point of each vessel, at each point of re-pressurisation. Side branches, micro-vessels in the coronary wall and distance from the tip of the guide catheter were used to ensure the measurements were made at the same points for the same vessel at different pressure range.