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Post-mortem CT-coronary angiography

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SUMMARY Despite the large number of people who die from complication of coronary atherosclerosis, the method of investigation of the coronary arteries has remained virtually unchanged since the time of Virchow. In this article we will present a method for investigation of the coronary arteries using post-mortem coronary angiography and computerized tomography. We describe how to prepare and inject the contrast medium, and how to establish a CT-protocol that optimizes spatial resolution, low contrast resolution and noise level. Testing of the method on 6 hearts, showed that the lumen of the coronary arteries could be visualized, including small side vessels normally not investigated at the routine investigation. Absolute and relative values for the degree of stenosis could be obtained, but it was not possible to distinguish vulnerable plaques from fibrotic plaques.

Keywords: atherosclerosis, angiography, computerized tomography, CT-scanning, coronary artery

INTRODUCTION
A large proportion of deceased individuals, who undergo a medicolegal autopsy, die from complication of coronary atherosclerosis. 27 % of the 100 individuals who in the period from February to July 2006 were autopsied at the Institute of Forensic Medicine, University of Southern Denmark died from a cardiovascular disease, mostly complications to coronary atherosclerosis (1). Despite the large number of people who die from this common and lethal disease, the method of investigation of the coronary arteries has remained virtually unchanged since the time of Virchow. Methods for post-mortem coronary angiography using conventional X-ray have been described before (2),(3). A CT-based minimally invasive procedure involving contrast injection through a femoral artery catheter has also been described (4). In this article we will present a method for investigation of the coronary arteries at the autopsy using post-mortem coronary angiography and computerized tomography. Computerized tomography offers improved resolution, allows three-dimensional imaging and permits precise measurements of vessel dimensions, location of pathological lesions as well as measurement of coronary calcium score.

DESCRIPTION OF THE METHOD
The first step is the preparation of the heart, which has been removed at the autopsy. The heart is rinsed with tap water for blood clots, and put in a suitable cradle for further manipulation. The aorta is cut away to a level just above the entrance of the coronary arteries (fig 2). These are then flushed with a 4 % formaldehyde solution in order to remove blood clots and initiate tissue fixation. A ligature is put around both coronary arteries, but not yet tightened. Dental floss may be used as ligature.

The contrast medium should have an X-ray attenuation of 250 HU. This value allows the lumen to be visualized, and at the same time differentiated from the vessel wall. We have used Omnipaque 300, a commonly used iodine based contrast agent, diluted to 1:64 with isotonic NaCl. Other contrast media may be used, including barium sulphate (Micromart®), which we however found had a tendency to cause sedimentation and somewhat unevenly distributed attenuation values. The correct dilution of the contrast agent was found by scanning a dilution row from 1:1 to 1:256 in plastic tubes. These dilutions also contained the ingredients mentioned below, as they also contribute to the X-ray attenuation.

The contrast medium should solidify in the arterial lumen to avoid passage through the capillaries to the veins. This can be obtained by adding 10 % gelatine to the contrast medium while this is warmed to 60 °C in a choco-late-melter. A dye should also be added, as this makes it easier to visualise how the arterial system is filled with contrast medium during the injection. We used ordinary browning used for cooking. The solution should be stirred with care to avoid bubbles in the contrast medium.

The contrast medium can be injected into the coronary arteries with a 100 ml syringe (fig 3) attached to two catheters by a two way faucet, and with the tip of each catheter inserted into the entrance

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Figure 1: The CT-scanner (Siemens Somatom Spirit)

Figure 2: The heart with the aorta cut away to a level just above the entrance of the coronary arteries.
of the coronary arteries and secured with the ligature. 15 ml contrast medium is sufficient. It is important that the injection of the contrast medium happens at a physiologic pressure, to avoid expansion artefacts. This can be ensured by connecting the syringe to an ordinary blood pressure manometer, and perform the injection at 100 mmHg. The heart should be cooled down immediately after the contrast medium has been injected. This can be done by placing the heart, secured in a waterproof plastic bag, in ice-water or in a freezer.

THE CT-SCANNER
The CT-scanner at our disposal is a dual-slice helical CT-scanner (Siemens Somatom Spirit). This scanner allows scanning with an X-ray tube voltage of 80 or 130 kV, mA-settings between 30 and 180 mA, and rotation time 1 second or 1.5 second. The maximum output power was 26 kW, relatively low compared to larger, more expensive scanners, due to the relatively low cooling capacity of the X-ray tube.

THE CT-PROTOCOL
We have established a CT-protocol that optimizes spatial resolution, low contrast resolution and noise level, using these parameters: pitch 1.7, mA 150, collimation 1.25 mm and rotation time 1.5 sec. This protocol was obtained by modifying an existing Siemens-protocol. The algorithm used for the reconstruction of the final CT-picture influences both noise level and contrast. We have used a medium soft algorithm (Siemens head medium) in order to optimize the balance between spatial resolution and low contrast resolution. The measurements were validated using a phantom (5). The CT-scanner was calibrated before each scanning.

PROCEDURE AFTER THE CT-SCANNING
The CT-scanning including preparation of the heart can be performed in 30 minutes. The heart are the returned to the autopsy room, were the usual routine investigation is carried out. This includes cross sections of the coronary arteries, transversal slices of the ventricles, opening the heart in the direction of the blood flow and – if needed – investigation of the conduction system including the SA- and AV-node. Tissue samples for microscopy are obtained from the coronary arteries, the anterior and posterior wall of the left ventricle, the septum and from the right ventricle. Extra sections from pathologic lesions in the coronary arteries, the myocardium and the conduction system are taken if needed. The heart is returned to the body after the investigation.

TESTING OF THE METHOD
The method was tested on 6 hearts, and evaluated using a questionnaire (4). The lumen of the coronary arteries could be visualized, including small side vessels normally not investigated at the routine investigation. Absolute and relative values for the degree of stenosis could be obtained using the software included in the scanners computer. It was possible to make out the arterial wall including areas of calcification, but it was not possible to distinguish lesions with small difference in X-ray attenuation, for example vulnerable plaques from fibrotic plaques (this might be possible with more powerful scanners). This is therefore still necessary to perform a microscopic investigation of suspect areas. There were no significant artefacts except a few air bubbles in one case.

ETHICS
Compared to the routine autopsy procedure, coronary angiography is less invasive, and provides better, but not qualitatively different information, and can therefore be performed without further consent from the relatives. The official procedure for autopsies allows the use of such new methods (6).

CONCLUSION
Coronary angiography is too time consuming for routine use, but may be used in cases were the investigation of the coronary arteries are of special importance, for example in cases of known or suspected myocardial infarction, in patients who has undergone a by pass-operations in the past or in the rare event of a patient with Kawasaki disease.

REFERENCE LIST