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Usefulness of coronary postmortem computed tomography angiography to detect lesions in the coronary artery and myocardium in cases of sudden death

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ABSTRACT

Coronary postmortem computed tomography angiography (coronary PMCTA) has been introduced as a routine examination procedure for autopsy at our department. Here, we reviewed eight autopsy cases in which apparent histopathological changes including acute myocardial infarction (AMI), anomalous aortic origin of a coronary artery (AAOCA), hypertrophic obstructive cardiomyopathy (HOCM) and acute myocarditis were involved in the cause of death. For investigation of the coronary artery and shape of the heart, coronary PMCTA was valuable in detecting narrowing or obstruction of coronary artery in AMI, indicating an anomalous aortic origin of the left coronary artery in AAOCA, and demonstrating septal hypertrophy and intracavitary obstruction in HOCM. However, it was debatable whether the hypervascularity demonstrated by coronary PMCTA in the case of acute myocarditis was more prominent than the vascular images obtained in other cases without inflammation. Thus, coronary PMCTA appeared to be useful not only for detection of coronary artery stenosis, but also for indicating other distinctive changes involved in AAOCA and HOCM.

1. Introduction

Postmortem computed tomography (PMCT) is becoming common in the practice of forensic medicine [1,2]. Postmortem CT angiography (PMCTA) has also proved to be a useful tool, mainly in forensic facilities and departments [3–12]. PMCTA techniques comprise angiography at the time of terminal cardiopulmonary resuscitation, whole-body angiography, and selective angiography including targeted coronary angiography. Whole-body angiography using a modified heart–lung bypass machine and high volumes of contrast medium has demonstrated the systemic vascular circulation including coronary arteries, suggesting that it can be a non-invasive or minimally invasive alternative to standard forensic autopsy [4,6]. However, this method has not yet been utilized in Japan. Postmortem selective CT angiography for individual organs has been developed as an effective adjunct in the field of forensic pathology for investigating vascular lesions of a specific organ such as the heart or brain [3,5,7,8–12], although it does not allow detailed mapping of the entire vascular system. Targeted coronary angiography can be performed using two injection routes: selective coronary angiography involving injection of a contrast agent into the aorta prior to autopsy [5,7–9], and direct introduction into a coronary artery after removal of the heart at autopsy, complementary to macroscopic and microscopic examinations [3,10,11]. Using the direct injection approach, Rah et al. have reported postmortem three-dimensional visualization of the entire coronary arterial circulation by electron-beam CT with a radiopaque silicone contrast medium [3]. Makino et al. have reported coronary postmortem CT angiography (coronary PMCTA) using X-ray CT with Omnipaque® as a contrast agent to complement standard autopsy [10]. However, silicone compounds do not remain in vessels after treatment with alcohol and xylol for preparation of paraffin-embedded tissue, and water-soluble contrast media such as Omnipaque® have some limitations including transudation into surrounding tissues. Thus, the contrast media employed had been absent from vessels in the tissue samples, making it impossible to assess the relationship between the contrast agent, arteriosclerosis and thrombus on histology [9,10]. To solve the problem of transudation, the

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Table 1
Summary of significant findings by coronary PMCTA.

Case	Sex	Age	Diagnosis	Histopathological changes	Coronary PMCTA findings
1*	M	40	AMI	High-grade coronary sclerosis with a recent thrombus and rupture of plaque in the LAD artery; myocardial scars on the anterior septum	Arterial luminal narrowing and filling defect of the LAD artery [11]
2	M	51	AMI	High-grade coronary sclerosis with a recent thrombus in the LAD artery; rupture of the anterior wall and pericardial hemorrhage; myocardial necrosis, bleeding, leukocytic infiltration, and granulation tissue in the anterior wall of the LV	Arterial luminal filling defect of the LAD artery (Supplementary Fig. 1)
3	M	58	AMI	High-grade coronary sclerosis with complete occlusion of the LAD artery accompanied by recanalization; myocardial necrosis and leukocytic infiltration from the anterior wall to the lateral wall of the LV; myocardial scars in the anterior and lateral walls of the LV	Arterial luminal filling defect of the LAD artery (Supplementary Fig. 2)
4	M	62	AMI	High-grade coronary sclerosis with a recent thrombus and rupture of plaque in the RCA	Arterial luminal narrowing of the RCA (Supplementary Fig. 3)
5	F	90	AMI	Severe stenosis of the left circumflex coronary artery; myocardial necrosis, bleeding and leukocytic infiltration in the lateral wall of the LV	Arterial luminal narrowing of the left circumflex coronary artery (Supplementary Fig. 4)
6	M	14	AAOCA	Anomalous aortic origin of the LCA followed by an interarterial course; myocardial scar in the papillary muscle of the LV	Left anomalous coronary artery originating from the right aortic sinus of Valsalva, followed by an interarterial course
7	M	20	HOCM	LV hypertrophy with asymmetric septal hypertrophy; marked hypertrophy of the cardiac myocytes, increased interstitial and focal myocardial fibrosis	LV hypertrophy with asymmetric septal hypertrophy; hyper- vascularity in the upper portion of the septum
8	F	9	Acute myocarditis	Interstitial myocarditis with infiltration of lymphocytes and myocardial necrosis in the ventricles	Hypervascularity in the LV

AMI, acute myocardial infarction; LAD artery, left anterior descending coronary artery; LV, left ventricle; RCA, right coronary artery; AAOCA, anomalous aortic origin of left main coronary artery; LCA, left coronary artery; HOCM, hypertrophic obstructive cardiomyopathy.

* Case 1 had been reported previously [11].

lipophilic contrast agent Angiofil® has been used in PMCTA, where the fat in its composition becomes deposited within blood vessels and confounds histological diagnosis of potential pre-mortal fat embolism [13]. Recently, PMCTA with use of air as contrast agent has been developed, while it remains to verify whether this PMCTA is valid for demonstration of vascular lesions [14]. Apart from those PMCTA, we have used a water-insoluble contrast for coronary PMCTA to detect stenosis in the left anterior descending (LAD) coronary artery in a case of sudden, unexpected death [11]. Coronary PMCTA was followed by dissection of the heart and microscopic examination. The angiography yielded an image suggesting an incomplete luminal filling defect of the LAD artery, which was coincident with the histological picture showing that the LAD artery was occupied by a thrombus and a small amount of contrast medium. Since histopathology showed the thrombus to adhere to the endothelium of the vessel through partial organization, it was unlikely that the pre-existing thrombus could have been replaced by injection of the gelatin-barium emulsion. Therefore, coronary PMCTA with a water-insoluble contrast agent seems valid for investigation of coronary heart disease.

Coronary PMCTA has been introduced as a routine autopsy procedure in our department, because injection of contrast medium is feasible in cases of sudden death due to fluidity of cadaverous blood. Here, we reviewed the results of coronary PMCTA in cases of sudden cardiac death, demonstrating the usefulness of this technique for detection of significant changes associated with coronary stenosis and other distinctive changes in cases of sudden and unexpected death.

2. Materials and methods

2.1. Coronary PMCTA

Coronary PMCTA was performed using a 10-mL plastic syringe connected to a digital manometer (HT-1500NM, HODAKA, Japan) to sustain an infusion pressure of 80–140 mmHg. Manual injection of approximately 4–7 mL of 5% gelatin-barium emulsion radiopaque contrast medium into either the left or right coronary artery was carried out until the anterior and posterior descending arteries were obviously filled with the white emulsion, as described previously [11]. At least one day after fixation of the heart in 10% phosphate-buffered formalin solution, X-ray exposure was performed by a sixteen-slice CT scanner (Alexion/TSX-034A, Toshiba, Japan) with the following scan parameters: field of view 18 cm, collimation 0.5 mm, reconstruction interval 0.5 mm, 120 kVp, 150 mA, 0.75 s/rotation, and pitch factor 0.75. Coronary PMCTA data were viewed and reconstructed on a workstation (Vincent, Fujifilm, Tokyo, Japan). Coronary PMCTA was followed by macroscopic and microscopic examination of the heart

2.2. Cases showing significant pathological changes in the heart

Coronary PMCTA has been introduced as a routine autopsy procedure in our department, although it has not been performed in cases of trauma or where the heart contains postmortem blood clots or shows severe postmortem change. Children less than seven years of age have also been excluded because of difficulty in introducing the contrast medium. As a result, coronary PMCTA was carried out in 102 cases between April 2015 and March 2017 at our department. From those cases, we retrospectively chose eight on the basis of cardiac histopathological change that appeared to be implicated in the cause of death. Three experienced forensic pathologists re-examined the gross macroscopic and microscopic features of the individual hearts, and three experienced radiologists who had between 6 and 9 years of experience at reviewing postmortem images at the Department of Diagnostic Radiology and Nuclear Medicine reviewed the images focusing on the coronary artery and shape of the heart demonstrated by coronary PMCTA