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Original Contribution

Diagnostic performance of smartphone reading of the coronary CT angiography in patients with acute chest pain at ED☆

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ABSTRACT

Purpose: The aims of this study were to simulate mobile consultation for the coronary computed tomography angiography (CCTA) at the emergency department (ED) and to measure the diagnostic performance of the mobile reading.

Materials and methods: A total of 107 patients with acute chest pain who underwent CCTA and coronary angiography (CAG) were included. The CCTA images were reviewed by a cardiac radiologist using a smartphone. The degree of stenosis at each coronary segment was scored with 4-point scale (score 1, <50%; score 2, 51%-70%; score 3, 71%-90%; score 4, >90%). The degree of stenosis at each coronary segments were also scored with preliminary CCTA report by on-call residents, final CCTA reports by in-house attending cardiac radiologists, and CAG. Interobserver agreement was measured using κ statistics. The areas under the receiver operating characteristic curves (AUCs) for diagnosing segments with obstructive stenosis were compared between each reader and CAG.

Results: The smartphone reader's reading was more similar to the CAG results and in-house radiologists' reports than reading of on-call residents. The diagnostic performance of smartphone reading for detection of obstructive stenosis was significantly greater than that of on-call residents (AUC, 0.89 vs 0.75; $P < .001$) and did not significantly differ from that of the in-house radiologists (AUC, 0.89 vs 0.90; $P = .05$).

Conclusion: Smartphone reading by the cardiac radiologist was superior to the on-call residents' reading. Further study with real-time mobile consultation needs to be investigated to evaluate whether improvement in diagnostic competency can make a difference in the outcome of patients.

1. Introduction

Chest pain accounts for a substantial proportion of ED visits. Approximately one third to two thirds of patients presenting with chest pain are admitted, and only 15% to 25% are diagnosed with acute coronary syndromes [1]. Therefore, efficient and accurate determination of acute coronary syndromes is important in the ED.

Coronary computed tomography (CT) angiography (CCTA) is a robust and fast tool for noninvasive evaluation of coronary artery disease (CAD) [2]. Several randomized clinical trials revealed the CCTA-based strategy for patients at low to intermediate risk of CAD is useful in the ED [1,3]. In the ED, timely and accurate CCTA interpretation is needed to reduce crowding, which is associated with adverse cardiovascular outcome in patients with chest pain [4]. For the interpretation of CCTA, the reader's level of experience is a strong determinant of proficiency [5,6]. However, the after-hour CT interpretations in the ED usually rely on less experienced on-call residents for night time coverage or training purpose [7,8]. Therefore, real-time consultation of CCTA to the specialists will be beneficial in triaging the patients with chest pain in ED.

Advancement in smartphone technology with combination of specialized medical applications has proven its value in hospital environments, especially in the ED setting [9,10]. Pocket-sized teleradiology terminals using a smartphone have been tested for its technical feasibility in consultation purposes in previous studies [11]. Many studies have

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Table 1
Display system and reading conditions for initial CT reporting and mobile consultation

	Initial CT reporting	Simulated mobile consultation
Axial images	Available	Available
Viewing mode	Standard stack view	Standard stack view
Display system	32-in liquid crystal medical display (ME 312L; Totoku Electronic Co, Ueda, Tokyo, Japan)	iPhone 5 (Apple Inc, Cupertino, California)
Resolution (pixels)	1536 × 2048	640 × 1136
Pixel pitch (mm)	0.21	0.08
Color	10-bit gray	32-bit RGB
Viewing software	G3 PACS (Infinitt Inc)	Mobile PACS (Infinitt Inc)
Reconstructed images	Available	Available
Network	100 megabits/s ethernet	Secure wireless (Wi-Fi 802.11g)
Irreversible image compression	None	Joint Photographic Expert Group, quality factor of 100
Light condition	Typically 30 lux	Normal office light
Clinical and laboratory findings	Available	Not Available
Consultation with the referring physicians	Available	Not available

suggested the potential role of off-site smartphone reading as a radiology consultant in critical situations such as acute stroke, intracranial hemorrhage, and inconclusive diagnosis of appendicitis [12–14]. To our knowledge, there is no previous study demonstrating feasibility and accuracy of off-site smartphone reading for the CCTA in the ED.

Thus, the aims of our study were to simulate mobile consultation for the CCTA at ED and to measure the diagnostic performance of the mobile consultation.

2. Materials and methods

The institutional review board approved the study protocol and waived informed consent for this retrospective study.

2.1. Study population

From January 2009 to May 2013, 155 patients with acute chest pain who underwent CCTA at the ED of Seoul National University Bundang Hospital were consecutively recruited. Among them, we included the 123 patients who underwent coronary angiography (CAG) within 2 months since the acquisition of CCTA to set CAG as the standard reference. From the 123 patients, 16 patients were excluded because 8 patients had undergone coronary artery bypass graft surgery and the other 8 patients' CT image quality was inadequate for evaluation. Finally, the study population composed of 107 patients (76 males; age, 40-87 years [mean age ± SD, 68.6 ± 10.4 years]).

2.2. Computed tomography acquisition

All patients underwent CCTA with a 64-slice (Brilliance 64; Philips Medical Systems, Best, The Netherlands) or 256-slice (Brilliance iCT; Philips Medical Systems) multidetector CT scanner. Before CCTA, all patients with a baseline heart rate greater than 70 beats/min received intravenous esmolol 10 to 30 mg (Jeil Pharm, Seoul, Korea). For the patients without contraindications to nitroglycerin, nitroglycerine 0.6 mg was immediately administered sublingually before contrast injection. Coronary CT angiography was applied with 64 × 0.625–mm section collimation, 420-ms rotation time, 120-kV tube voltage, and 800-mA tube current. During CCTA acquisition, a bolus of 80 mL iomeprol (Iomeron 400, Bracco, Milan, Italy) was injected intravenously (4 mL/s) followed by a 50-mL saline chaser. A region of interest was placed in the descending thoracic aorta, and image acquisition was automatically initiated once a selected threshold (150 HU) had been reached with bolus tracking. All scans were performed with prospective electrocardiogram gating and electrocardiogram-gated dose modulation.

2.3. Mobile viewer application

All CCTA images were transferred from the mobile picture archiving and communication system (PACS) server to the smartphone (iPhone 5, Apple Inc, Cupertino, California) via Mobile PACS application (Infinitt Inc, Seoul, Korea). The mobile PACS server delivered the requested images from the hospital enterprise PACS to the client program. Images were compressed when transmitted to the client program in the mobile device [13]. The display system and reading conditions for mobile application are described in Table 1.

The CCTA images included the axial images with 1-mm thickness, multiplanar reconstructed images of short axis view, 4-chamber view, and 2-chamber view, reconstructed with 3-mm thickness and the volume rendering images. The image sets of CCTA in smartphone viewer (Figure) were identical to the computer-based PACS (G3 PACS, Infinitt Inc) of the standard radiology workstation. One could adjust adequate window width/level and measure lengths in the image sets of the smartphone viewer using same tools as in the computer-based PACS.

2.4. Coronary CT angiography analysis with mobile viewer

CCTA images were reviewed by a cardiac radiologist (YKK, 4 years of experience in cardiac radiology), who was blind to the CAG results. The CCTA image sets were presented in random order to the smartphone reader.

The coronary arteries were segmented with the 16-segment coronary artery model [15]. All coronary segments greater than 2 mm in diameter were assessed. Segments with noninterpretable image quality or stent were excluded in the image review. In total, 1510 coronary artery segments were included in the analysis. The degree of stenosis (score 1, <50%; score 2, 51%-70%; score 3, 71%-90%; score 4, >90%) [3] were visually scored at each coronary segment.

2.5. Original CCTA reports

The original CT reports were made as follows. On-call residents (12 residents, composed of second- and third-year residents) made the preliminary reports. During the cardiac radiology training session, a radiology resident is exposed to a minimum of 60 cases of CCTA per week. Second-year residents had 2 months of exposure to CCTA interpretation (ie, >480 cases), and third-year residents had at least 3 months of exposure to CCTA interpretation (ie, >720 cases). All preliminary reports were later confirmed or supplemented by addenda made by 3 in-house attending cardiac radiologists (SIC, EJC, and YKK). In both the preliminary and final reports, the degrees of stenosis were routinely included in the reports. The degree of stenosis from both of preliminary reports by on-call residents and formal reports by in-house cardiac radiologists were scored (score 1, <50%; score 2, 51%-70%; score 3,