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AI-ECG Supported Decision-Making for Coronary Angiography in Acute Chest Pain: The QCG-AID Study

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ABSTRACT

This pilot study evaluates an artificial intelligence (AI)-assisted electrocardiography (ECG) analysis system, QCG, to enhance urgent coronary angiography (CAG) decision-making for acute chest pain in the emergency department (ED). We retrospectively analyzed 300 ED cases, categorized as non-coronary chest pain (Group 1), acute coronary syndrome (ACS) without occlusive coronary artery disease (CAD) (Group 2), and ACS with occlusive CAD (Group 3). Six clinicians made urgent CAG decision using a conventional approach (clinical data and ECG) and a QCG-assisted approach (including QCG scores). The QCG-assisted approach improved correct CAG decisions in Group 2 (36.0% vs. 45.3%, $P = 0.003$) and Group 3 (85.3% vs. 90.0%, $P = 0.017$), with minimal impact in Group 1 (92.7% vs. 95.0%, $P = 0.125$). Diagnostic accuracy for ACS improved from 77% to 81% with QCG assistance and reached 82% with QCG alone, supporting AI's potential to enhance urgent CAG decision-making for ED chest pain cases.

Keywords: Artificial Intelligence; Electrocardiography; Chest Pain; Coronary Angiography; Acute Coronary Syndrome

Accurate differential diagnosis of acute chest pain in the emergency department (ED) is crucial. By identifying patients with acute coronary syndrome (ACS), timely emergent or urgent interventions can be determined, while excluding non-cardiogenic causes can prevent unnecessary invasive testing. Electrocardiography (ECG) is widely used as an initial test for acute chest pain due to its rapid and relatively simple assessment, providing baseline clinical information for early ACS evaluation. Recently, artificial intelligence (AI) has been applied to ECG analysis, extending beyond conventional rule-based interpretation to develop models that predict various cardiovascular diseases. Previously, we have also developed an AI-based quantitative ECG analysis (QCG system) and demonstrated its favorable performance in diagnosing coronary artery disease (CAD), including ST-segment elevation myocardial infarction (STEMI) and obstructive CAD.[1-6] Prospective studies and trials are expected to determine if such AI-based ECG analysis can genuinely improve patient management and outcomes. As evidence builds, this will support the integration of AI-based ECG into real-world clinical practice.[7]

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Disclosure

Dr. Joonghee Kim, MD, is the developer of the QCG system and the founder and CEO of ARPI Inc. Youngjin Cho is the Research Director at ARPI Inc. The remaining authors declare no conflicts of interest.

Data Availability Statement

Data cannot be made publicly available due to ethical restrictions set by the Institutional Review Board of the study institution; i.e., public availability would compromise patient confidentiality and participant privacy. Please contact the corresponding authors to request the minimal anonymized dataset.

Author Contributions

Conceptualization: Park J, Kim J, Ahn S, Yoon YE, Cho Y. Data curation: Park J, Kim J, Yoon YE, Cho Y. Formal analysis: Park J, Kim J, Ahn S, Yoon YE, Cho Y. Funding acquisition: Park J, Kim J, Yoon YE, Cho Y. Investigation: Park J, Kim J, Ahn S, Yoon YE, Cho Y. Methodology: Park J, Kim J, Ahn S, Yoon YE, Cho Y. Project administration: Park J, Kim J, Yoon YE, Cho Y. Resources: Park J, Kim J, Ahn S, Yoon YE, Cho Y. Software: Park J, Kim J, Ahn S, Cho Y. Supervision: Kim J, Yoon YE, Cho Y. Validation: Park J, Kim J, Yoon YE, Cho Y. Visualization: Park J, Kim J, Yoon YE, Cho Y. Writing - original draft: Park J, Kim J, Yoon YE, Cho Y. Writing - review & editing: Park J, Kim J, Ahn S, Yoon YE, Cho Y.

In this context, before initiating a large-scale prospective trial, this pilot study aimed to evaluate whether the QCG system, an AI-based ECG analysis tool, could enhance the appropriateness of urgent coronary angiography (CAG) decisions for patients presenting with acute chest pain in the ED.

We reviewed consecutive patients aged ≥ 20 years who visited the ED at Seoul National University Bundang Hospital in 2021 for chest pain. A total of 6,224 patients were identified, and those who underwent CAG or cardiac computed tomography angiography (CCTA) to rule out ACS were selected. Patients with a history of myocardial infarction, coronary revascularization, or heart transplantation were excluded, as were those with significant bradyarrhythmia (heart rate < 40 bpm), tachyarrhythmia (heart rate > 150 bpm), or pacing support, resulting in 1,096 eligible patients. Two experts, one in cardiology (Cho Y) and one in emergency medicine (Kim J), performed a detailed medical review, categorizing patients into three groups: Group 1 included non-coronary chest pain patients with less than 50% diameter stenosis (DS) on CAG or CCTA and normal cardiac enzymes (n = 596); Group 2 included ACS patients with DS ≥ 50% but no occlusion (n = 243); and Group 3 included ACS patients with near-total or total obstruction (n = 99). From these, a final study population of 300 patients was randomly sampled: 150 from Group 1, and 75 each from Groups 2 and 3. Subsequently, the patients were exclusively categorized into three case subsets of 100 each, maintaining the group proportions.

The QCG system, a convolutional neural network-based analyzer, is approved by the Korean Ministry of Food and Drug Safety (MFDS) for AI-ECG applications.[1,2] In brief, the system analyzes ECG images as input and provides risk scores for ACS (QCG_{ACS}) and STEMI (QCG_{STEMI}) on a normalized scale (0 to 100), with higher scores indicating greater likelihood of these conditions based on the analyzed ECG data. To examine the QCG system's impact on clinical decision-making regarding urgent CAG for patients with acute chest pain, clinicians were recruited from the cardiology and emergency medicine departments. An open call led to the enlistment of six clinical fellows—three from cardiology and three from emergency medicine—actively involved in acute chest pain management in the ED. None of the participating clinicians had prior experience with QCG scores; thus, a brief introduction to QCG was given at the start, including the MFDS-approved cutoff values (19.7 for ACS and 6.6 for STEMI). Each physician was randomly assigned to one of the three case subsets, ensuring that both cardiology and emergency medicine departments evaluated each subset.

We employed a two-stage decision-making process. In the first stage, clinicians received baseline information, including demographics (age, sex, blood pressure), clinical risk factors (hypertension, diabetes, dyslipidemia, family history of cardiovascular disease, smoking, previous CAD, and recurrent angina), and initial ECG data (Step 1: clinical judgment). Based on this information, clinicians decided whether urgent CAG was necessary, within 24 hours of initial admission for acute chest pain. In the second stage, the QCG_{ACS} and QCG_{STEMI} scores were additionally provided (Step 2: clinical judgment + QCG), after which clinicians made a final decision on urgent CAG necessity. Appropriate clinical decisions were defined as withholding urgent CAG for Group 1 and proceeding with it for Groups 2 and 3. We utilized a generalized estimating equation model to assess significant changes in the proportion of appropriate decisions from Step 1 to Step 2, adjusting for baseline clinical data.[8] Appropriate decisions for urgent CAG were also determined based solely on QCG scores (QCG-alone), deemed necessary if QCG_{ACS} or QCG_{STEMI} exceeded their respective cutoffs of 19.7 and 6.6. Subgroup analyses were performed for each specialty. Finally, diagnostic performance for

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ACS was compared across Step 1, Step 2, and the QCG-alone approach, defining an urgent CAG decision in ACS (Groups 2 and 3) as a correct ACS diagnosis. All statistical analyses were conducted using R software (version 4.1.1; R Foundation for Statistical Computing, Vienna, Austria), with statistical significance set at $P < 0.05$.

The detailed baseline characteristics of the study population are summarized in **Supplementary Table 1** (median age 63 years; male 67%). The proportion of appropriate clinical decisions significantly increased from Step 1 to Step 2 in Group 2 (36.0% vs. 45.3%, $P = 0.003$) and Group 3 (85.3% vs. 90.0%, $P = 0.017$) but showed no significant difference in Group 1 (92.7% vs. 95.0%, $P = 0.125$). Notably, QCG-alone approach, solely based on QCG scores, yielded the highest proportion of appropriate decisions, outperforming Step 2 results (97.3% vs. 95.0%, $P = 0.005$ for Group 1; 58.7% vs. 45.3%, $P < 0.001$ for Group 2; and 97.3% vs. 90.0%, $P < 0.001$ for Group 3). When evaluating diagnostic performance for ACS, Step 1 achieved an area under the receiver operating characteristic curve (AUC) of 0.767, overall accuracy of 0.77, and F1 score of 0.72 (**Table 1**). Step 2 demonstrated improvements across all performance measures, achieving an AUC of 0.813, accuracy of 0.81, and F1 score of 0.78. The QCG-alone approach showed the highest diagnostic performance, reaching an AUC of 0.877, accuracy of 0.88, and F1 score of 0.86. Subgroup analyses by specialty consistently demonstrated increased appropriate decision-making from Step 1 to Step 2 in Group 2 and Group 3 (**Fig. 1**). Additionally, subgroup analysis stratified by individual clinicians yielded consistent results, with the QCG-assisted approach improving appropriate decision-making across both groups (**Supplementary Fig. 1**).

Previous studies have demonstrated the robust diagnostic capabilities of QCG for ACS and obstructive CAD[1-6]; the current findings further indicate that a QCG-assisted approach could enhance clinical decision-making for urgent CAG in patients with acute chest pain. Notably, diagnostic performance was highest when decisions were based solely on QCG scores, highlighting the potential of QCG scores as valuable digital markers for rapid and accurate decision-making. Given that ECG is typically the initial test for acute chest pain, the QCG system may enhance diagnostic accuracy at this early stage, supporting clinicians in rapidly identifying ACS patients and aiding their clinical assessment. This improvement could, in turn, lead to timely downstream testing and treatment for ACS patients.

However, it should be acknowledged that the findings of the current study are limited by the retrospective nature of the data, which were derived from a single-center study. Additionally, the number of clinicians participating in the study was relatively small. Therefore, to expand the clinical utility and generalizability of the QCG-assisted approach, further validation in more diverse clinical settings and with a larger number of clinicians are warranted. In clinical practice, ECG changes in ACS are often dynamic and may evolve with the patient's clinical course. Therefore, future studies assessing whether the QCG-assisted approach can effectively support clinical decision-making when serial ECG data are incorporated

Table 1. Diagnostic performance for acute coronary syndrome

Variables	Group 1: non-coronary chest pain (n = 300)	Groups 2 and 3: ACS (n = 300)	Sensitivity	Specificity	PPV	NPV	Accuracy	F1 score
Appropriate decision for urgent CAG	0	300						
Step 1	22	182	0.61	0.93	0.89	0.70	0.77	0.72
Step 2	15	203	0.68	0.95	0.93	0.75	0.81	0.78
QCG alone	8	234	0.78	0.97	0.97	0.82	0.88	0.86

ACS = acute coronary syndrome, PPV = positive predictive value, NPV = negative predictive value, CAG = coronary angiography, QCG = artificial intelligence-based quantitative electrocardiography analysis.

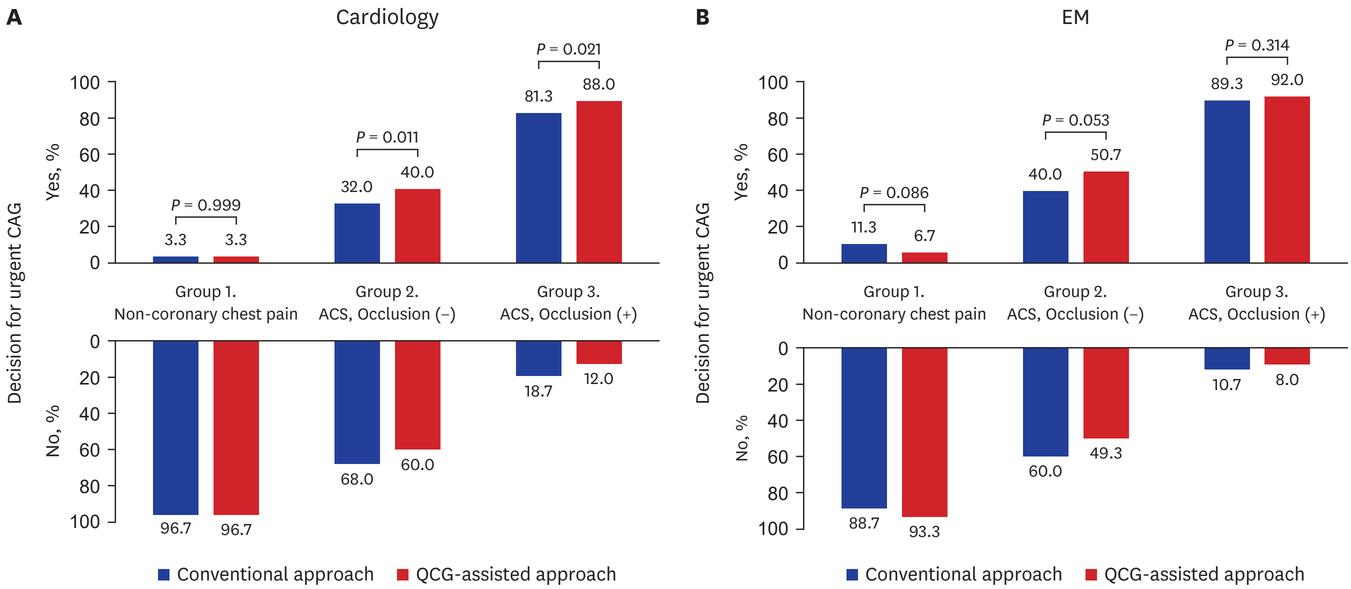

Fig. 1. Subgroup analysis of clinical decision-making for urgent coronary angiography. Subgroup analyses by specialty: (**A**) Cardiology and (**B**) EM, revealed a consistent increase in appropriate decision-making with the QCG-assisted approach across all groups.
EM = Emergency Medicine, QCG = artificial intelligence-based quantitative electrocardiography analysis, CAG = coronary angiography, ACS = acute coronary syndrome.

would be valuable. Lastly, prospective trials are essential to validate the impact of the QCG-assisted approach on clinical decision-making and patient outcomes in real-world settings. Encouragingly, our institution has integrated the QCG system into the electronic medical record system, allowing QCG scores to be automatically included with ECG tests in the ED (**Supplementary Fig. 2**). Building on this environment, we are planning a prospective study and anticipate sharing future results that will further support the practical advantages of QCG-assisted clinical approaches.

Ethics statement

This study was approved by the Institutional Review Board (IRB) of Seoul National University Bundang Hospital (IRB No. B-2309-855-302). All participating clinicians provided written informed consent, but the patient's consent was waived due to retrospective collection of de-identified clinical records.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

Baseline characteristics

Supplementary Fig. 1

Subgroup analysis of clinical decision-making for urgent coronary angiography by individual clinician. (**A**) Group 1: non-coronary chest pain; (**B**) Group 2: ACS, occlusion (−); (**C**) Group 3: ACS, occlusion (+).

Supplementary Fig. 2

Integration of QCG analyzer into EMR for real-time artificial intelligence-ECG decision support in the emergency department. The convolutional neural network-based QCG analyzer, approved by the Korean Ministry of Food and Drug Safety, is utilized in the emergency department of Seoul National University Bundang Hospital. As soon as an ECG is obtained and transmitted to the EMR, the analysis results are displayed alongside the ECG. Below, we present several real-case examples. (**A**) Sixty-three-year-old male patient who presented to the ER with chest pain. He had a history of hypertension and hyperlipidemia, with a family history of premature CAD. However, he had no personal history of CAD and was a nonsmoker. His initial blood pressure was 120/70 mmHg. The initial ECG and analysis results are as follows. The QCG analysis (right) accurately identified the rhythm as atrial fibrillation and indicated a low likelihood of ACS or STEMI (QCG_{ACS} = 9, QCG_{STEMI} = 0.5, respectively). The subsequent cardiac computed tomography angiography results confirmed the absence of significant findings. (**B**) Sixty-one-year-old female patient who presented to the ER with chest pain. She had a history of diabetes and a family history of premature CAD but no personal history of CAD diagnosis. The conventional rule-based ECG analysis (left) did not indicate a high risk of ACS. However, the QCG analysis (right) showed a high QCG_{ACS} score of 88, with a markedly elevated $QCG_{\text{myocardial injury}}$ score of 86. Subsequent cardiac enzyme (troponin) tests revealed elevated levels of 0.352 ng/mL, and CAG confirmed significant obstruction of left circumflex artery, leading to percutaneous coronary intervention. (**C**) Sixty-one-year-old male patient who presented to the ER with chest pain. He had a history of hypertension, hyperlipidemia, coronary stenting for 3-vessel CAD, current smoking, and a family history of premature CAD. He had a recent episode of anginal pain. The conventional rule based ECG analysis (left) reported right bundle branch block but did not indicate features of ACS. However, the QCG analysis (right) showed an increased QCG_{ACS} score of 57 and elevated $QCG_{\text{myocardial injury}}$ score of 58, suggesting myocardial infarction. Subsequent cardiac enzyme (troponin) tests revealed elevated levels of 0.137 ng/mL, and CAG confirmed significant re-stenosis in previous coronary stents, eventually proceeded to coronary bypass surgery. Although known CAD cases with revascularization were excluded from this study, this complex case demonstrates that the QCG analyzer can provide rapid and accurate diagnostics in the evaluation of acute chest pain, even with a complicated medical history.

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