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Mini-Review

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Diagnostic and Prognostic Utility of Comprehensive Cardiothoracic Computed Tomography in the Evaluation of Acute Undifferentiated Chest Pain in the Emergency Department

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Abstract

Acute Undifferentiated Chest Pain (AUCP) is a frequent and diagnostically challenging presentation in Emergency Departments (EDs), encompassing life-threatening conditions such as Acute Coronary Syndrome (ACS), Pulmonary Embolism (PE), Aortic Dissection (AD) and other non-cardiac etiologies. Comprehensive Cardiothoracic Computed Tomography (CCT), including Coronary Computed Tomography Angiography (CCTA) and non-coronary thoracic imaging, has revolutionized the diagnostic approach to AUCP. This review evaluates the diagnostic accuracy, clinical utility, prognostic value and cost-effectiveness of CCT in the ED, emphasizing its role in rapid risk stratification, reducing unnecessary hospitalizations and guiding therapeutic decisions. We synthesize evidence from 2015-2025 studies to highlight CCT's strengths, limitations and emerging applications. While CCT offers high sensitivity and Negative Predictive Value (NPV), considerations such as radiation exposure, contrast-related risks and resource availability necessitate judicious use. CCT is a cornerstone of modern ED diagnostics, with potential to optimize patient outcomes through precise and timely management.

Keywords: Acute chest pain; Cardiothoracic computed tomography; Coronary computed tomography angiography; Emergency department; Diagnostic accuracy; Risk stratification

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Introduction

Chest pain accounts for 5%-10% of ED visits globally, with an estimated 7.5 million annual presentations in the United States alone [1]. AUCP, characterized by chest discomfort without a clear clinical or diagnostic pattern, poses a significant challenge due to its broad differential diagnosis, ranging from benign musculoskeletal pain to life-threatening conditions like ACS, PE and AD. Misdiagnosis or delayed diagnosis can lead to catastrophic outcomes, while over-testing contributes to ED overcrowding and increase healthcare costs [2]. Traditional diagnostic pathways, including serial Electrocardiograms (ECGs), cardiac biomarkers and functional testing, are resource-intensive and often prolong ED stays [3]. Comprehensive CCT, encompassing CCTA, CT Pulmonary Angiography (CTPA) and CT aortography, provides a rapid, non-invasive evaluation of the coronary arteries, pulmonary vasculature, aorta and other thoracic structures. The Triple-Rule-Out (TRO) protocol, which assesses ACS, PE and AD in a single scan, has gained traction for its efficiency and diagnostic yield [4]. This article reviews the diagnostic and prognostic utility of CCT in AUCP, focusing on its performance metrics, impact on clinical decision-making, cost-effectiveness and practical considerations in the ED setting. We also explore emerging applications, such as Artificial Intelligence (AI)-assisted interpretation and low-dose protocols, to address current limitations.

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Methods

A systematic narrative review was conducted using PubMed, Scopus, Embase and Cochrane databases to identify peer-reviewed studies published between January 2015 and April 2025. Search terms included cardiothoracic computed tomography, coronary CT angiography, acute chest pain, emergency department, diagnostic accuracy, prognostic value and cost-effectiveness. Studies were included if they involved adult patients (≥ 18 years) with AUCP in the ED, reported diagnostic performance metrics (sensitivity, specificity, NPV, Positive Predictive Value (PPV)) or evaluated clinical outcomes (*e.g.,* length of stay, hospitalization rates, Major Adverse Cardiovascular Events (MACE). Exclusion criteria included studies focused solely on specific diagnoses (*e.g.,* ACS only), non-ED settings or pediatric populations. Data were synthesized to assess CCT's diagnostic yield, prognostic implications, economic impact and limitations.

Results

Diagnostic accuracy

CCT demonstrates exceptional diagnostic performance for AUCP. For ACS, CCTA achieves a sensitivity of 95%-99%, specificity of 87%-92% and NPV of 98%-100% for detecting significant Coronary Artery Disease (CAD) [5,6]. The ROMICAT-II trial reported that CCTA reduced the time to diagnosis by 3.4 hours compared with standard care (5.3 vs. 8.7 hours, $p<0.001$) while maintaining high accuracy [7]. For PE, CTPA has a sensitivity of 90%-96%, specificity of 95%-98% and NPV of 97%-99%, effectively ruling out embolism in low- to intermediate-risk patients [8,9]. CT aortography identifies AD with near-100% sensitivity and specificity, making it the gold standard for this condition [10]. The TRO protocol maintains comparable diagnostic accuracy across these conditions, with a sensitivity of 94%-97% and NPV of 96%-99% for detecting any critical pathology [11].

Prognostic value

Beyond diagnosis, CCT provides prognostic insights. In patients with normal CCTA findings, the 1-year MACE rate is <1%, supporting safe discharge from the ED [12]. Conversely, nonobstructive CAD detected by CCTA is associated with a 2-3-fold increased risk of future MACE, guiding preventive strategies [13]. For PE, CT findings such as right ventricular strain correlate with adverse outcomes, informing risk stratification and treatment intensity [14]. Similarly, CT aortography can identify high-risk features of AD (*e.g.,* intramural hematoma), influencing surgical decisions [15].

Clinical impact

CCT significantly enhances ED efficiency. The ACRIN-PA trial demonstrated that CCTA reduced hospital admissions by 50% compared with standard evaluation, with no increase in adverse events [16]. The TRO protocol further streamlines workflow by addressing multiple etiologies in a single scan, reducing the need for sequential testing [17]. CCT also decreases the rate of invasive coronary angiography in patients with normal or non-obstructive CAD, minimizing procedural risks [18]. In high-volume EDs, CCT's rapid turnaround time (<30 minutes) facilitates timely decision-making, alleviating overcrowding [19].

Cost-effectiveness

CCT is cost-effective in low to intermediate risk AUCP patients. A 2023 meta-analysis reported a 20%-30% reduction in ED costs with CCT compared with traditional pathways, driven by shorter lengths of stay and fewer downstream tests [20]. In the CT-STAT trial, CCTA reduced diagnostic costs by 38% without compromising outcomes [21]. However, cost-effectiveness is less pronounced in high-risk patients, where invasive angiography is often required regardless of CCT findings [22].

Limitations

CCT's limitations include radiation exposure (3-10 mSv per scan), which poses risks, particularly in younger patients or those requiring serial imaging [23]. Contrast-Induced Nephropathy (CIN) and allergic reactions occur in <1% of cases but remain concerns [24]. Incidental findings, such as pulmonary nodules, may prompt unnecessary follow-up, increasing costs and patient anxiety [25]. CCT's availability is limited in resource-constrained settings and interpretation requires specialized expertise, potentially delaying care in non-tertiary centers [26]. Over-reliance on CCT may also lead to under diagnosis of non-cardiothoracic etiologies, such as gastrointestinal or musculoskeletal causes [27].

Discussion

CCT's ability to provide a comprehensive, rapid evaluation of AUCP has transformed ED diagnostics. Its high NPV allows clinicians to confidently rule out life-threatening conditions, reducing diagnostic uncertainty and enabling safe discharge. The TRO protocol is particularly valuable in patients with atypical presentations, where multiple etiologies are plausible. Integration of CCT with clinical decision rules (*e.g.,* HEART score, Wells criteria) enhances risk stratification, optimizing resource allocation and patient outcomes [28]. However, CCT's benefits must be balanced against its risks. Radiation exposure, though reduced with modern low-dose protocols, remains a concern, particularly in younger patients [29]. CIN and contrast allergies necessitate careful patient selection, with pre-scan renal function assessment in high-risk individuals [30]. The economic advantages of CCT are most evident in high-volume EDs with access to rapid imaging and experienced radiologists. In low-resource settings, traditional pathways or point-of-care

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ultrasound may be more feasible [31]. Emerging technologies are addressing CCT's limitations. Low-dose CT protocols have reduced radiation exposure to <1 mSv in some cases, broadening its applicability [32]. AI-assisted interpretation improves diagnostic accuracy and efficiency, particularly in detecting subtle findings like non-obstructive CAD or early PE [33]. Ongoing trials are exploring CCT's role in specific subgroups, such as patients with elevated troponin or cardio-oncologic conditions, where its prognostic value may be particularly relevant [34]. For example, in cardio-oncology, CCT can assess both CAD and chemotherapy-related vascular complications, guiding tailored management [35].

Future directions include integrating CCT with advanced biomarkers (*e.g.,* high-sensitivity troponin) to refine diagnostic algorithms and incorporating machine learning to predict long-term troponin) to refine diagnostic algorithms and incorporating machine learning to predict long-term outcomes [36]. Standardization of TRO protocols and training programs for ED radiologists will further enhance CCT's accessibility and reliability [37].

Conclusion

Comprehensive CCT is a pivotal tool for evaluating AUCP in the ED, offering unparalleled diagnostic accuracy, prognostic insights and cost-effectiveness. Its ability to streamline workflow, reduce unnecessary hospitalizations and guide therapeutic decisions makes it indispensable in modern emergency medicine. However, radiation risks, contrast-related complications and resource limitations necessitate careful patient selection and protocol optimization. As low-dose imaging, AI and integrated diagnostic pathways evolve, CCT's role in AUCP management is poised to expand promising improved outcomes for patients with this challenging presentation.

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