

CLINICAL UPDATE

Computed Tomography — an Emerging Tool for Triple Rule-Out in the Emergency Department. A Review

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ABSTRACT

New imaging tools have been developed in recent years to rapidly and accurately diagnose life-threatening diseases associated with high mortality rates, such as acute coronary syndromes, acute aortic dissection, or pulmonary embolism. The concept of using computed tomographic (CT) assessment in emergency settings is based on the possibility of excluding multiple acute pathologies within one scan. It can be used for patients complaining of acute chest pain of unclear etiology with the possible association of acute coronary dissection or pulmonary embolism, but only a low to moderate risk of developing an acute coronary syndrome. One of the benefits of this protocol is the possibility of decreasing the number of patients who are hospitalized for further investigations. The technique also allows the rapid triage of patients and the safe discharge of those who show negative results. The aim of this review is to summarize the current medical literature regarding the potential use of CT for the triple rule-out (TRO) of coronary etiologies.

Keywords: CT, triple rule-out, emergency department, chest pain

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INTRODUCTION

The effective triage of patients who are admitted through the emergency department (ED) complaining of chest pain is a common challenge in the field of emergency cardiology. By achieving this goal, the patients would benefit from an accurate diagnosis and also a decreased mortality rate due to an appropriate approach and ad-

equate therapy. Chest pain is a frequent symptom for many visits to the ED. The most recent health statistics published in 2010 by the Centers for Disease Control and Prevention (CDC) emphasized that chest pain is the primary symptom in 9% of patients who present to the ED.¹ Patients with chest pain as a primary complaint can develop acute coronary syndromes (ACS), and it is important for the patient to undergo a specific treatment. Un-

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fortunately, many studies emphasized that patients with ACS are misdiagnosed and discharged unsafely, and their mortality rate reaches 2%.²⁻⁵

The first evaluation of patients who are admitted through the ED with chest pain as a primary symptom consists of blood tests analysis of the cardiac enzymes and electrocardiogram (ECG), and if these are modified, more specific invasive diagnosing procedures are needed.⁶ Currently, along with the development of imaging techniques, patients are further investigated with noninvasive procedures such as computed tomography (CT), which seems to have a good specificity in the triage of patients accusing chest pain in the ED.⁷⁻⁹ The role of CT in evaluating ACS patients with low to intermediate risk was studied in many trials that concluded that it is a safe investigation, with a sensitivity of 86–100% and a high negative predictive rate of 93–100%.¹⁰⁻¹² In a meta-analysis published in 2002, Safriel *et al.* found that CT has a sensitivity of 71.4% and a specificity of 89.5% in detecting pulmonary embolism.¹³ Another life-threatening disease that can be ruled out using CT is acute aortic dissection. Nienaber *et al.* found that CT has a sensitivity of 93.8% in detecting aortic dissection, whereas magnetic resonance imaging (MRI) was associated with a sensitivity of 98.3%.¹⁴ These three diagnoses: ACS, pulmonary embolism, and acute aortic dissection, are considered to lead to a high mortality rate and thus their early diagnose is vital.¹⁵⁻¹⁷ Aortic dissection type A is associated with a mortality rate of 1% per hour initially and almost 80% after 2 weeks, whereas aortic dissection type B has lower death rates, 10% at 30 days.¹⁸ The International Cooperative Pulmonary Embolism Registry reported a mortality higher than 15% in patients with pulmonary embolism.¹⁹ Having such a huge social impact, the need of an imaging modality appeared, that would assess, with a single examination, the pulmonary arteries, the thoracic aorta, and the coronary arteries, in order to rule out these three pathologies. Thus, the idea of triple-rule-out computed tomography (TRO-CT) emerged, which can be used in the ED for patients who present chest pain without ECG changes or high levels of cardiac enzymes, who are suspected of life-threatening diseases such as those mentioned above.

To exclude these three life-threatening diseases with one single scan, CT should be performed using an ECG-gated protocol, as the coronary arteries cannot be analyzed by regular thoracic CT. A clear imaging protocol and appropriate patient preparation are prerequisites for a good quality assessment.

CT is an imaging tool highly suitable for patients who have been evaluated as having a low to intermediate risk

of developing an acute coronary syndrome. It is not always easy for the clinician to decide whether a patient with chest pain requires hospitalization or can be safely discharged, especially in cases when ECG changes are not specific.²⁰⁻²²

Using the triple rule-out strategy in the evaluation of patients with atypical chest pain, border levels of cardiac enzymes and non-pathognomonic ECG changes can help in deciding on the best therapeutic strategy and the safe discharge of patients.

The aim of this manuscript is to emphasize the benefits of using CT in patients who present with chest pain and have been evaluated as having a low to moderate risk for developing an acute coronary syndrome. At the same time, it aims to illustrate the most recent advances regarding the ability of the scan to rule out three major pathologies associated with high mortality rates: acute coronary syndrome, pulmonary embolism, and aortic dissection.

THE ECONOMIC IMPACT OF USING TRO-CT IN THE ED

It has been proved that the CT-based assessment can significantly reduce the economic impact generated by the unnecessary hospitalizations of patients. Henzler *et al.* (2013) recently demonstrated that integrating the triple rule-out protocol in the evaluation of patients referring at the ED for chest pain reduces the number of hospitalizations and consequently the related costs. They performed a comparative assessment of the expenses related to patients whose treatment was based on standard care and patients who received the triple rule-out CT protocol. They observed that the costs were lower in the group of patients following a triple rule-out protocol, the majority of them being discharged on the same day, compared with the second group in which the patients were hospitalized and underwent further invasive diagnostic procedures.²³

Khare *et al.* (2009) agreed with these views and concluded that using this protocol the costs were lower than using other stress-based procedures for patients at low to moderate risk. Thus, they reported the costs of care associated with low risk patients who presented in the ED for chest pain as follows: the costs amounted to \$2,684 in case of patients who underwent CT compared to the \$3,265 associated with stress echocardiography.²⁴

Patients admitted with atypical chest pain, without ST-segment elevation on the ECG and exhibiting slightly modified levels of cardiac enzymes, are usually hospitalized and receive invasive coronary angiography to exclude coronary artery disease. In such cases, hospital stays are

longer, with concomitant increases in expenditure. A triple rule-out CT strategy could be helpful in reducing healthcare-related costs.

The benefits of the procedure consist in the evaluation of the three arteries and also the upper level of the chest in a single scan. The TRO-CT protocol results in a speedier examination and a safer triage. Recent studies indicated that, on average, 18% of physicians base the triage on triple rule-out CT for patients with chest pain.^{25,26}

WHICH ARE THE ELIGIBLE PATIENTS FOR THE TRIPLE-RULE-OUT CT PROTOCOL?

For a correct application of the triple-rule-out CT protocol, it is crucial to establish the exact inclusion criteria of eligible patients. First, the diagnostic protocol is used in patients with acute chest pain of doubtful etiology. Secondly, it is important to evaluate the stratification risk of developing an acute coronary syndrome. Only patients assessed as having a low to moderate risk gain an advantage from this approach. Patients who attend with acute chest pain with elevated cardiac enzymes and ST-segment elevation should not have CT as a primary strategy. The correct therapeutic approach is usually an invasive one, with time being of the essence. Yoon *et al.* (2001) stated that triple-rule-out CT should not be a routine screening tool used in the ED and should be included in the assessment of patients with suspicion of aortic dissection or pulmonary embolism.²⁸

TRIPLE-RULE-OUT PROTOCOL-BASED STUDIES

In 2008, Takakuwa *et al.* published the first large study on triple-rule-out CT protocol in which they enrolled 197 patients who accused chest pain at their visit at the ED. They observed that in 11% of the patients the chest pain was due to coronary disease that required further diagnostic testing.²⁹

Gruettner *et al.* (2013) assessed one hundred patients with acute chest pain. They performed the triple-rule-out CT protocol or coronary CT, and all patients were followed for 90 days to evaluate the rate of major adverse cardiac events (MACE). They observed that 60% of patients could be rapidly discharged on the same day, following the exclusion of non-coronary disease and concluded that triple-rule-out CT might contribute to lowering the number of diagnostic angiographies.³⁰

An aspect that should not be ignored is the high dose of radiation that is required for triple-rule-out CT. Many

studies emphasized that the high-dose radiation exposure is due to long scanning length.³¹⁻³⁴

A meta-analysis published in 2013 highlighted the radiation aspect of the TRO-CT. Ayaram *et al.* (2013) studied radiation exposure in 2,307 patients, of which 377 were included in the triple-rule-out CT group and 1,930 in the control group. A statistically significant difference was observed between the two groups, patients assessed with TRO-CT being exposed to a significantly higher dose of ionising radiation.³⁴

THE TRIPLE-RULE-OUT CT PROTOCOL

The basic technical challenge of this method is to obtain simultaneously an intense, consistent contrast enhancement in all three arterial territories. This can be accomplished only by using a tailored contrast medium administration regimen.³⁵ Usually biphasic injection is preferred, consisting of the administration of an undiluted contrast, followed by diluted contrast medium with saline. This type of contrast administration provides a highly homogeneous contrast enhancement in the aorta and coronary arteries and a slightly lower but also homogeneous contrast in the pulmonary arteries. Several variants regarding the volume and rate of contrast and saline are proposed for a scanning time of 15 seconds. A rapid flow rate in both phases is indicated to minimize venous return from the inferior vena cava, and for a good image quality it is also important to adjust the contrast dose not to have bright contrast in the superior vena cava during scanning time.³⁶ The region of interest for the triple-rule-out technique is in the left atrium, and scanning starts after 5 seconds after the threshold value is reached, in order to get the peak contrast intensity of the aorta and coronary arteries.

Similarly to a coronary computed tomography angiography (CCTA), in order to get a high image quality, triple-rule-out studies use ECG gating to reduce motion artefacts produced by cardiac pulsations, and acquisitions are performed during breath-hold to prevent respiratory movement artefacts.

To reduce radiation doses, a prospective ECG-gated acquisition is preferred, but it is only suitable in patients with a stable heart rate.

The "field of view" is another parameter that is adjusted to reduce radiation exposure. Because the radiation dose is directly proportional to the scan length, in the triple-rule-out technique the acquisition includes only the thoracic aorta and the heart, while lung apices above the aortic arch are not included.³⁷ Scans are designed to start at the base of the heart, with the superior margin at one

cm above the aortic arch. An important aspect concerning acquisition is the scanning direction, which is caudal-cranial in order to include distal pulmonary arteries at the base of the lungs, which otherwise may be visualized at a low contrast intensity.

CONCLUSION

Triple-rule-out computed tomography angiography is a relatively new technique used in the evaluation of acute chest pain in patients without invasive coronary angiography indication. Using an optimized CT protocol with tailored parameters for decreased radiation exposure concomitant with an efficient contrast medium injection, the triple-rule-out CT protocol is a powerful tool suitable for simultaneously evaluating the thoracic aorta, the coronary arteries, and the pulmonary arteries. Further data is needed to validate this protocol in the assessment of patients with acute chest pain before it can be validated as a routine emergency screening tool.

CONFLICT OF INTEREST

Nothing to declare.

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