# My Approach To Myocardial Extracellular Volume Quantification Using Cardiac Computed Tomography

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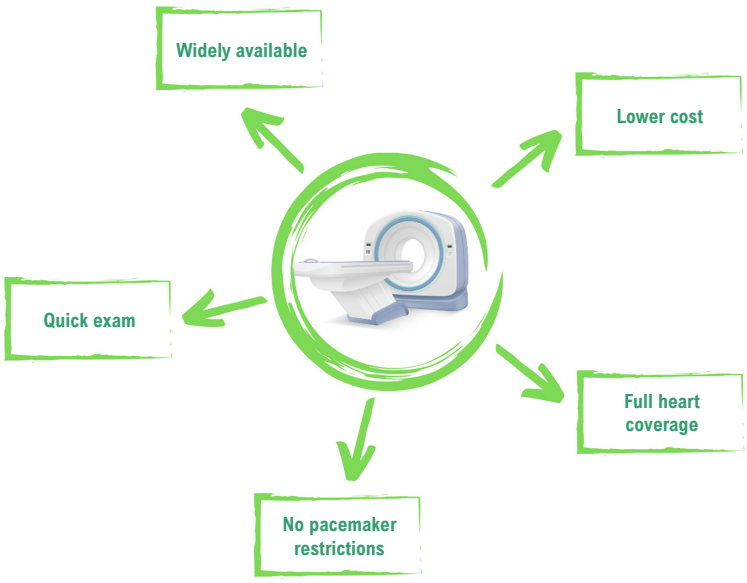
**Central Illustration: My Approach To Myocardial Extracellular Volume Quantification Using Cardiac Computed Tomography**

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*Advantages of using computed tomography compared to magnetic resonance imaging for the calculation of myocardial ECV.*

## Abstract

The quantification of myocardial extracellular volume (ECV) has demonstrated both diagnostic and prognostic value in various heart diseases. While ECV is typically assessed using cardiac magnetic resonance imaging (CMR), it can also be measured through cardiac computed tomography (CCT) imaging. This article discusses the application of CCT for myocardial ECV calculation, detailing the technique, its advantages and disadvantages, and its potential clinical applications.

Keywords

X-Ray Computed Tomography; Cardiomyopathies; Evidence-Based Practice.

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## Introduction

Myocardial tissue characterization through non-invasive imaging methods is essential for evaluating heart diseases, offering additional diagnostic and prognostic benefits beyond morphological and functional assessments.[1] Among the available techniques, myocardial extracellular volume (ECV) quantification has recently shown value in differential diagnosis and disease staging, particularly for cardiomyopathies with a hypertrophic phenotype, such as hypertrophic cardiomyopathy and amyloidosis.[2-4]

Myocardial ECV is typically obtained through cardiac magnetic resonance imaging (CMR) using gadolinium-based contrast. However, it can also be calculated using

cardiac computed tomography (CCT) with iodinated contrast, providing an alternative when CMR is unavailable or contraindicated.[5]

The technical process for obtaining this data in CCT examinations is outlined below.

## My Approach To

### Image acquisition

To calculate myocardial ECV, images of the heart must be acquired before and after the administration of iodine-based contrast, using identical acquisition and reconstruction parameters. Tomographs suitable for cardiac evaluation (minimum of 64 detector rows) are required.[6]

Given that slices with a thickness of 3 mm or more are suitable for myocardial analysis, we recommend that pre- and post-contrast acquisitions adhere to the institutional calcium scoring protocol. This protocol, which routinely employs a low radiation dose (< 1.5 mSv),[7] is widely available and easy to implement. Therefore, the pre-contrast image used for myocardial ECV calculation may also provide additional information, such as the coronary and/or aortic valve calcium score, if needed.

The protocol typically involves a prospective acquisition synchronized with the electrocardiogram, capturing images of the entire heart in diastole for patients with a heart rate of 75 bpm or lower, or in systole for those with a heart rate above 75 bpm. The tube power is set at 120 kVp, with the tube current adjusted based on the patient's weight, and the reconstructed images are generated with 3 mm thick slices.[7]

Iodinated contrast, usually in a concentration of 350 mg I/ml, should be administered at an average dose of 1 mL/kg of body weight, although this may vary depending on the patient's clinical condition and the primary indication for the examination. The contrast infusion rate does not affect the calculation of myocardial ECV and can be adjusted based on the purpose of the study (e.g., approximately 6 mL/s for coronary angiography). Post-contrast images should be obtained during the equilibrium phase (5 to 15 minutes after contrast administration),[8] using the same acquisition and reconstruction parameters as those for pre-contrast images.

Premedication, such as sublingual nitrate or beta-blockers, is not required for myocardial ECV calculation. However, these medications may be used at the physician's discretion if cardiac angiography is also performed during the same examination.

### ECV calculation

Since iodinated contrast distributes within the extracellular space, the difference in myocardial signal between the equilibrium-phase contrast images and the non-contrast images (ΔHU myocardium) reflects the extracellular space volume in this tissue.[8] By using a reference tissue, such as blood, where the ECV is readily determined by measuring hematocrit, myocardial ECV can be calculated with the following formula:

$$ECV = (1 - Hematocrit) \times (\Delta HU\ myocardium / \Delta HU\ blood)$$

Myocardial ECV can be measured either globally or regionally, depending on the clinical context. The regions of interest (ROI) selected for measurement should be identical or as closely matched as possible between the pre- and post-contrast images. These ROIs can be outlined using proprietary or open-source DICOM image analysis tools on axial, sagittal, coronal, or other oblique planes of interest. To ensure reproducibility and minimize distortions from non-isotropic acquisition and reconstruction, myocardial ECV is typically measured in the axial plane at the mid-left ventricular level. A freehand ROI is drawn in the interventricular septum, covering its entire visible thickness and length while avoiding partial volume effects at the edges (Figure 1). For the blood signal measurement, a circular ROI of approximately 1 $cm^2$ is placed in the center of the left ventricular cavity within the same plane, ensuring trabeculae and papillary muscles are excluded.

The hematocrit value used in the calculation should be obtained as close as possible to the imaging exam date.[9]

## Discussion

Myocardial ECV is a quantitative measure of the myocardial extracellular matrix and may be elevated in the presence of interstitial fibrosis[10] or in cases of storage diseases such as amyloidosis, where insoluble fibrillar proteins can accumulate in the heart muscle.[3]

As a quantitative measure, myocardial ECV has diagnostic and prognostic utility and holds potential for use in longitudinal follow-up.[11]

Although most commonly assessed by CMR, myocardial ECV can also be calculated using contrast-enhanced CCT, as the distribution pattern and kinetics of contrast media are equivalent in both imaging methods.[5]

In a meta-analysis conducted by Han et al., comparing myocardial ECV measurements by CCT and CMR, a high grouped correlation coefficient (0.90) and a small, grouped difference (0.96%) were observed, with a slight overestimation of values obtained by CCT.[12]

Although guidelines do not yet provide clear recommendations for the use of CCT in assessing myocardial ECV, its future utility has already been suggested.[13] However, CCT can be considered a viable option in cases where this measurement is clinically significant but cannot be obtained through CMR. This typically occurs due to factors such as limited availability of equipment, T1 mapping sequences, or analysis software; contraindications to performing the examination (e.g., presence of implantable devices incompatible with magnetic resonance imaging); or contraindications to the use of gadolinium-based contrast media (e.g., renal failure requiring dialysis). Chart 1 outlines the main advantages and disadvantages of using CCT compared to CMR for myocardial ECV assessment.

In addition to these scenarios, it may be beneficial to consider obtaining myocardial ECV in contrast-enhanced CT scans performed for other purposes, such as pre-transcatheter intervention coronary or aortic valve assessment, with a small modification to the protocol (e.g.,

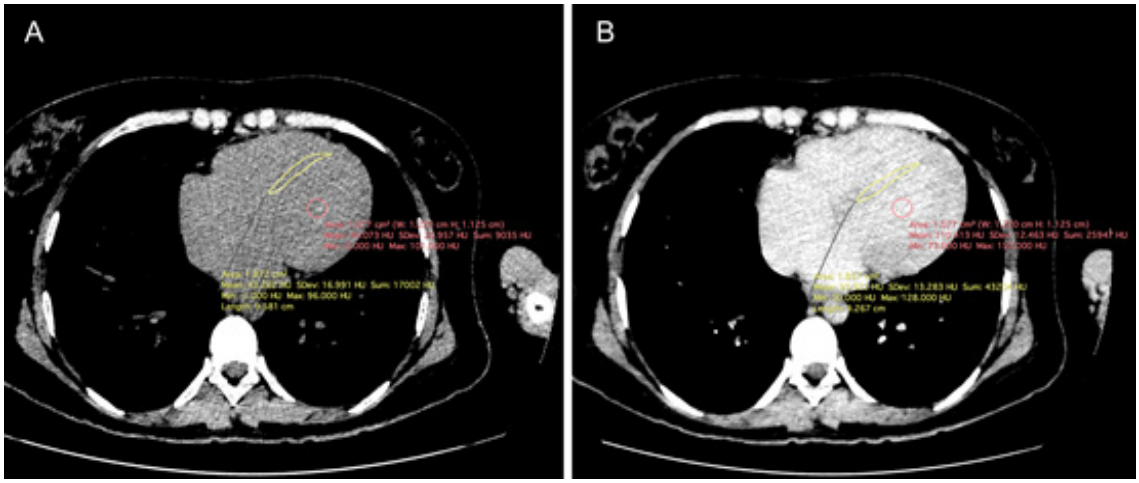


**Figure 1 –** *Calculation of myocardial ECV through CCT. Myocardial and blood signals are quantified through ROIs drawn on pre- (A) and post-contrast (B) images, in a patient with left ventricular hypertrophy, referred for coronary angiotomography due to complaints of shortness of breath. The myocardial ECV was elevated and calculated at 47% (hematocrit of 39.8%). Subsequent investigation led to the diagnosis of cardiac amyloidosis due to transthyretin.*
*ROI: region of interest.*

**Chart 1 – Advantages and Disadvantages of Myocardial ECV Calculation through CCT versus CMR**

| |
|---|
| **Advantages:** |
| More widely available equipment |
| Generally lower cost |
| Faster procedure and routinely well tolerated by claustrophobic patients |
| No restrictions for patients with implanted cardiac devices or metallic fragments in the body |
| High-resolution images with complete myocardial coverage |
| Does not require dedicated software for calculation |
| **Disadvantages:** |
| Exposure to ionizing radiation |
| Use of potentially nephrotoxic contrast |

adding a late post-contrast acquisition). In patients referred for these exams, it is not uncommon, for example, to encounter the coexistence of heart failure with preserved ejection fraction and/or left ventricular hypertrophy, clinical situations where knowledge of myocardial ECV may indicate an etiological diagnosis still unknown, in addition to providing incremental prognostic data.[14,15]

## Conclusion

Myocardial ECV is a measure of increasing clinical utility and can be obtained through contrast-enhanced CCT, using a low-dose radiation protocol and rapid execution. This approach eliminates the need for sequences and proprietary software required for calculation by CMR, without compromising accuracy compared to the latter.

## Author Contributions

Conception and design of the research: Camargo GC; writing of the manuscript and critical revision of the manuscript for intellectual content: Camargo GC, Sabioni LR.

### Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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### Study Association

This study is not associated with any thesis or dissertation work.

### Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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