

Four-Dimensional Cinematic Rendering of a Presumed Aortic Valve Papillary Fibroelastoma on Coronary CT Angiography

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Abstract

Four-dimensional cinematic rendering represents a convergence of physically based volumetric visualization and time-resolved cardiac imaging, enabling simultaneous assessment of structure and motion within a continuous spatial context. Its application to valvular pathology remains limited. We present a technical implementation of four-dimensional cinematic rendering applied to retrospectively electrocardiographically gated coronary computed tomography angiography for characterization of a presumed aortic valve papillary fibroelastoma. This approach enabled direct visualization of lesion morphology, stalk attachment, and dynamic mobility while preserving spatial relationships to valve cusps and the coronary ostium. In contrast to conventional two-dimensional and static three-dimensional techniques, four-dimensional cinematic rendering provided continuous spatial and temporal coherence, reducing interpretive fragmentation across imaging planes. Used as an adjunct to conventional cross-sectional interpretation, this method allows anatomical detail and functional behavior to be assessed concurrently, with potential implications for risk stratification and procedural planning in valvular disease.

Keywords: cinematic rendering; four-dimensional imaging; papillary fibroelastoma; cardiac computed tomography; valvular tumor; cardiovascular visualization

1. Introduction

Papillary fibroelastoma (PFE) is a benign endocardial neoplasm with disproportionate clinical significance due to its embolic potential [1–3]. Risk is driven less by lesion size than by morphology and mobility, particularly in tumors arising from the aortic valve, where pedunculated architecture and independent motion confer increased embolic risk [2]. Accurate imaging must therefore resolve both structural configuration and dynamic behavior. Echocardiography remains the primary diagnostic modality, though characterization of small lesions and their relationship to adjacent structures may be limited by acoustic window constraints. Coronary computed tomography angiography (CCTA) provides superior spatial resolution and enables comprehensive anatomical assessment, particularly in proximity to coronary ostia, where procedural implications are critical [4]. However, interpretation remains inherently segmented across multiple two-dimensional (2D) planes, and even conventional three-dimensional (3D) reconstructions incompletely convey depth and surface detail.

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Cinematic rendering (CR) introduces a physically based lighting model that enhances perception of geometry and texture through realistic light–tissue interaction [5,6]. When applied to multiphase datasets derived from retrospectively gated acquisitions, this approach can be extended temporally, generating four-dimensional (4D) representations that preserve motion within a continuous volumetric context. This enables direct visualization of dynamic phenomena without loss of anatomical fidelity. This technical note demonstrates the application of 4D-CR for evaluation of a presumed aortic valve PFE and highlights its potential as a complementary visualization tool that augments, rather than replaces, conventional cardiovascular CT interpretation.

2. Materials and Methods

An adult patient was referred for evaluation of an incidentally detected aortic valve mass on transthoracic echocardiography. Transthoracic echocardiography demonstrated a small, mobile, pedunculated, homogeneously echogenic mass with a speckled pattern and stippled edges attached to the aortic aspect of the right coronary cusp, without associated valvular dysfunction. Retrospectively electrocardiographically gated CCTA was performed for further characterization. The diagnosis of papillary fibroelastoma was made presumptively on the basis of characteristic imaging features; the mass was not resected, and histopathological confirmation was not obtained. A retrospectively electrocardiographically gated CCTA dataset was acquired using standard clinical protocols consistent with current cardiovascular imaging recommendations [7]. Image reconstruction was performed across multiple phases of the cardiac cycle to capture temporal variation in valvular motion. Imaging was performed on a Siemens SOMATOM Force third-generation dual-source scanner ($2 \times 192 \times 0.6$ mm detector configuration) (Siemens AG, Munich, Germany) at 100 kVp following intravenous administration of 80 mL of iodinated contrast (iopamidol 370 mg I/mL) at 5 mL/s through an 18-gauge antecubital catheter, followed by a 50 mL saline chaser. Images were reconstructed at a section thickness of 0.6 mm with a 0.3 mm reconstruction increment and an approximately isotropic in-plane voxel size of 0.3 mm, yielding a temporal resolution of approximately 66 ms per phase. Datasets were reconstructed at 5% increments across the R-R interval, producing 20 phases per cardiac cycle and an effective cine frame rate of 20 frames per cycle. End-diastole and end-systole were defined as the cardiac phases of maximal and minimal left ventricular cavity volume, corresponding to approximately 75% and 35% of the R-R interval, respectively. The patient was in sinus rhythm at a heart rate of 62 beats per minute during acquisition. Because retrospective gating combines data across consecutive cardiac cycles and assumes a stable R-R interval, accurate phase registration depends on a regular rhythm; the behavior of the technique in the setting of conduction disturbances and arrhythmia is considered in the Discussion. Post-processing was conducted using CR software (Siemens syngo.via VB80 Cinematic VRT (cVRT)) based on a global illumination model that simulates complex light propagation within volumetric data. Rendering parameters were adjusted to optimize endocardial surface contrast and edge definition, with emphasis on preserving fine structural detail at the valve–lesion interface. This approach enhances visualization of surface contours and spatial relationships by incorporating realistic shading and light scattering effects. Time-resolved datasets were processed to generate a continuous 4D-CR representation of intracardiac structures. Segmentation techniques were applied to selectively suppress the blood pool, thereby improving delineation of valvular anatomy and lesion attachment. The dataset was interrogated dynamically within a consistent spatial reference frame to assess morphology, attachment, and motion.

3. Results

4D-CR demonstrated a discrete pedunculated mass arising from the aortic valve with a lobulated surface architecture (Figure 1; Videos S1 and S2). A fine stalk-like attachment to the valve leaflet was clearly resolved (Video S3). The mass measured approximately 12×9 mm in maximal dimension, with a stalk that was approximately 3 mm in length and an estimated volume of 490 mm^3 . Dynamic reconstruction revealed independent oscillatory motion of the lesion throughout the cardiac cycle. The spatial relationship between the lesion, the aortic valve cusps, and the right coronary ostium remained continuously preserved (Video S4). Selective removal of the blood pool enhanced visualization of the valvular interface and clarified the point of attachment (Videos S3 and S4). Morphology, attachment, and motion were appreciable within a single cohesive representation without reliance on sequential 2D interpretation.

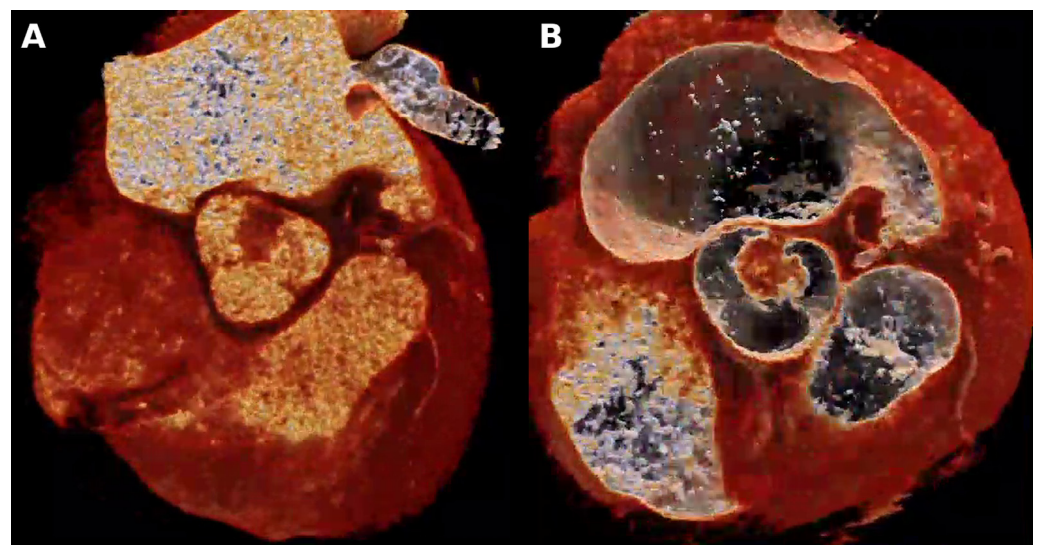


Figure 1. Representative still frames from the four-dimensional cinematic rendering. (A) Short-axis view of the aortic root with the contrast-enhanced blood pool, showing the pedunculated mass with a lobulated, frond-like surface near the commissure between the right and left coronary cusps. (B) Short-axis surgeon's view after blood-pool suppression, showing the mass relative to the three aortic cusps and the right coronary ostium.

4. Discussion

The clinical relevance of PFE lies in its embolic potential, which is closely linked to lesion mobility and attachment characteristics [1,2,8]. Imaging strategies must therefore move beyond detection and toward precise characterization of these high-risk features. CCTA provides high-resolution anatomical detail but requires synthesis across multiple viewing planes, which may limit intuitive understanding of spatial relationships [4]. Conventional 3D rendering improves visualization but does not fully replicate depth perception or surface fidelity. CR addresses these limitations through physically based illumination, enhancing visualization of fine morphological features [5,6]. The extension to 4D-CR introduces temporal continuity, enabling direct observation of lesion dynamics while maintaining anatomical context. This integrated representation reduces reliance on sequential plane-by-plane interpretation and improves direct spatial comprehension of dynamic intracardiac relationships.

In the present case, 4D-CR enabled simultaneous evaluation of morphology, attachment, and motion within a unified volumetric framework. The ability to continuously visualize the lesion relative to the coronary ostium and valve commissures has direct

implications for procedural planning, particularly in assessing embolic risk and surgical approach. More broadly, this technique points toward a complementary role for integrated spatiotemporal visualization alongside conventional anatomical interpretation. By preserving spatial coherence across time, it offers a more intuitive and potentially more clinically actionable representation of cardiovascular pathology. Several limitations should be emphasized. 4D-CR is a visualization method that is applied to the source CT data and does not provide independent tissue characterization; attenuation values and the differential soft-tissue contrast available on conventional CT are not preserved in the rendered display, so the source axial and multiplanar images remain necessary for tissue analysis and quantitative measurement. Physically based rendering and blood-pool segmentation can introduce surface artifacts, particularly in small high-contrast structures such as the proximal coronary arteries, and these should not be mistaken for pathology. Spatial and temporal resolution are constrained by the underlying acquisition: the effective frame rate is limited by the number of reconstructed phases, and rapid heart rates together with through-plane motion of the valve during the cardiac cycle can degrade phase registration and produce motion-related blurring. Because retrospective gating combines data from consecutive cycles and assumes a stable R-R interval, conduction disturbances, ectopy, and other arrhythmias can cause misregistration between cycles and reduce image quality, sometimes requiring ECG editing or limiting the technique altogether. Finally, this is a single-case demonstration without quantitative or multi-reader validation, and the diagnosis rests on characteristic imaging features without histopathological confirmation, as the mass was not resected. For these reasons, 4D-CR should be regarded as complementary to, rather than a replacement for, conventional CT review and other established imaging techniques, and its reproducibility, diagnostic impact, and integration into clinical workflows require further investigation.

5. Conclusions

4D-CR enables simultaneous visualization of morphology and motion within a single volumetric framework. In the evaluation of aortic valve PFE, this approach provides direct insight into features that determine clinical risk, including attachment and mobility. By unifying structural and dynamic assessment, it may offer a more coherent representation of valvular pathology as a complement to conventional techniques. Used alongside conventional CT, this method may enhance interpretation of time-resolved cardiac imaging datasets and support decision-making in cardiovascular care, although further validation is required.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/cardiovascmed29030023/s1>, Videos S1–S4: four-dimensional cinematic rendering sequences of the aortic valve papillary fibroelastoma, cited in Section 3; Video S1: Four-dimensional cinematic rendering in a three-chamber view demonstrating the aortic root, left atrium, and left ventricle, with early visualization of a small nodular mass arising from the aortic valve; Video S2: Short-axis aortic root view demonstrating a pedunculated mass arising from the aortic valve at the commissure between the right and left cusps, with characteristic frond-like morphology; Video S3: Three-chamber view with blood pool suppression demonstrating the relationship of the mass to the aortic leaflet and commissure, with clear visualization of a fine stalk-like attachment; Video S4: Short-axis surgeon's view of the aortic valve following blood pool suppression, localizing the mass relative to the three cusps and the right coronary ostium.

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Institutional Review Board Statement: This study was conducted in accordance with the Columbia University Human Research Protection Office (HRPO) Policy. Institutional review board approval was not required because this retrospective imaging report does not meet the federal definition of human subjects research (45 CFR 46.102(l)), as it does not constitute a systematic investigation designed to contribute to generalizable knowledge.

Informed Consent Statement: The manuscript was fully de-identified and contains none of the 18 identifiers defined by the HIPAA Privacy Rule. Under the Columbia University HRPO Policy, patient authorization is not required for a de-identified report, and written informed consent was not required.

Data Availability Statement: The imaging data underlying this report are not publicly available because they contain potentially identifying clinical information and are subject to institutional and HIPAA restrictions. De-identified data may be made available from the corresponding author upon reasonable request and with appropriate institutional approval.

Conflicts of Interest: The authors declare no conflicts of interest.

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