

Synthetic ECG-Gated Cardiac Computed Tomography for In Vivo Imaging of the Temporary Total Artificial Heart

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To date, there have been >1000 implantations of temporary total artificial hearts (TAH-t). As expected, complications related to the use of the TAH-t can occur.¹ A noninvasive imaging modality that would be capable of diagnosing mechanical failure, surgical complications, and thromboembolic phenomena related to the TAH-t is desirable.

Echocardiography is not suitable to evaluate a TAH-t because ultrasound cannot penetrate air and the polyurethane components in the TAH-t assembly. Cardiac magnetic resonance imaging is likewise unsuitable because of the susceptibility to artifacts that the titanium valve components in the TAH-t would create. Conventional computed tomography (CT) is limited by motion artifact.²

Cardiac CT (CCT) can produce motion-artifact-free images of the heart. If performed with retrospective gating, CCT can also be used to acquire time-resolved images. However, CCT requires simultaneous recording of the patient's ECG, and patients who have a TAH-t do not generate an ECG.

Consequently, a variation in technique is necessary to image patients with TAH-t with this modality.

Detailed below is a simple method of CCT for the TAH-t that uses a patient simulator device to generate a synthetic ECG signal. A patient simulator device is a readily available instrument normally used to test and calibrate ECG machines.

A 20-year-old male patient presented with severe pain in his left torso 74 days after implantation of a TAH-t (SynCardia TAH-t, SynCardia Systems Inc, Tucson, AZ). At the time of presentation, the patient weighed 90 kg and had a body surface area of 2.13 m². His creatinine and glomerular filtration rate were normal (0.87 mg/dL and >60 mL/min, respectively). The patient's surgeon requested a CCT of the thorax followed by a helical CT scan of the abdomen to help determine the cause of the pain.

A dual-source, 32-detector-row, Z-flying focal spot CT scanner (SOMATOM Definition, Siemens Healthcare, Forchheim, Germany) was used to perform the scan. The

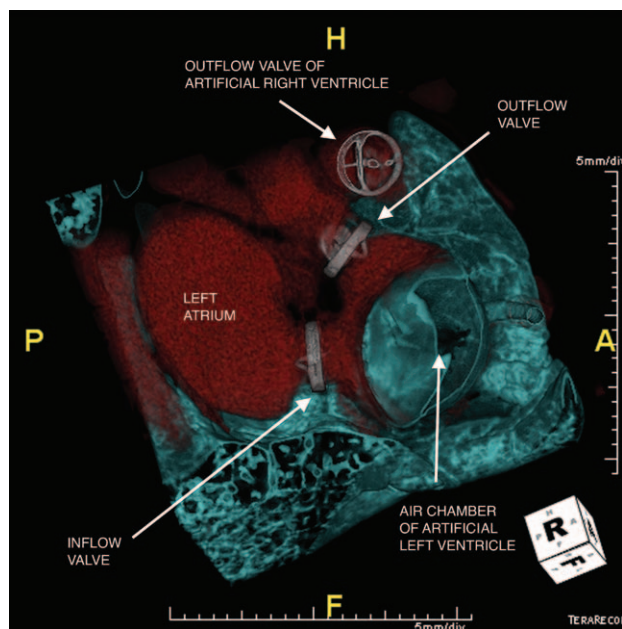


Figure 1. A 30-mm slab of a pseudo-colored, volume-rendered, midsystolic, 3-chamber view of the TAH-t. Please see online-only Data Supplement Movie I. A indicates anterior; F, feet/inferior; H, head/superior; P, posterior.

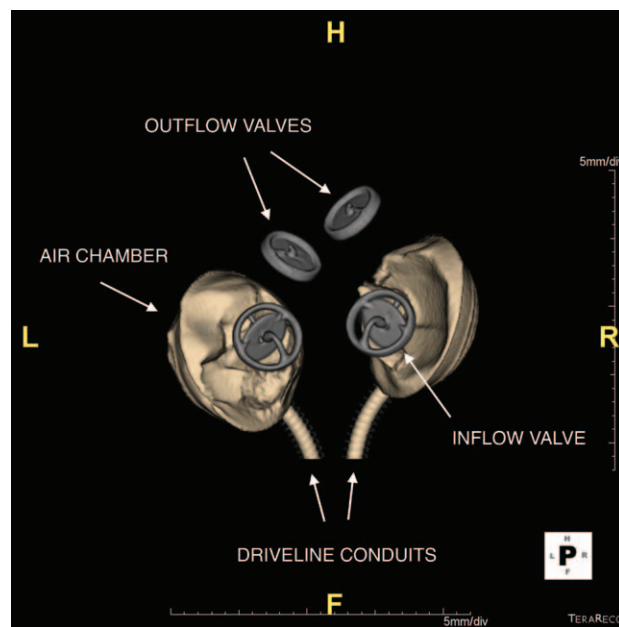


Figure 2. Pseudo-colored, volume-rendered, posterior mid-diastolic view of the moving TAH-t components. Please see online-only Data Supplement Movie II. F indicates feet/inferior; H, head/superior; L, left; R, right.

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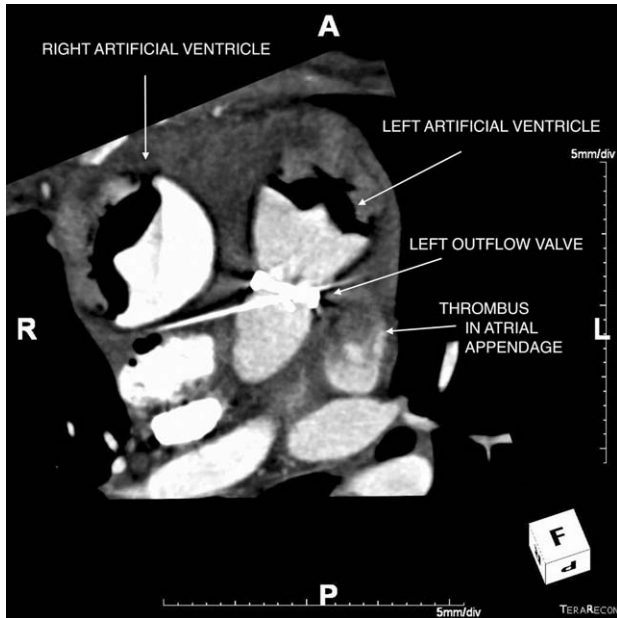


Figure 3. Double-oblique multiplanar reformat image of thrombus in left atrial appendage. A indicates anterior; L, left; P, posterior; R, right.

scanner electrodes were connected to a patient simulator device (PS-440, Metron, Grand Rapids, MI) set to the 120-bpm mode. The Freedom portable driver (SynCardia) of the TAH-t was reduced to 120 cycles/min to match the mode of the patient simulator device.

The scan was performed with retrospective gating at 120 kV (peak) with Z-axis and angular current modulation. No current modulation based on the ECG signal was performed. A dual-chamber power injector (MEDRAD 1PX1, MEDRAD, Inc, Indianola, PA) was used to inject saline and contrast in the following manner: 20-mL test bolus at 5 mL/s, 120 mL of Visipaque 320 mgI/mL (milligrams of iodine per milliliter of contrast media; GE Healthcare, Princeton, NJ) at 5 mL/s followed by a mix of 20% contrast and 80% saline at 5 mL/s, followed by a saline flush of 30 mL also at 5.0 mL/s. During the injection, scanning was triggered by use of the bolus-tracking function of the scanner.

The patient's entire chest was covered during the CCT. The dose-length product was 1310 milligray-centimeters (mGy-cm), with an estimated effective radiation dose of 18.3 millisieverts (mSv). The scan of the abdomen had a total dose-length product of 1043 mGy-cm and an estimated effective radiation dose of 15.6 mSv.

The pumps and valves of the TAH-t were shown to be working normally (Figures 1 and 2 and online-only Data Supplement Movies I and II). No surgical complications were identified. Mobile thrombus was found in the native patulous left atrial appendage (Figure 3). The abdominal CT performed immediately after the CCT revealed a splenic infarction, which was judged to be the source of the patient's pain (Figure 4).



Figure 4. Near-coronal double-oblique multiplanar reformat image of splenic infarction.

The use of this simple, modified CCT technique diagnosed the presence of left atrial thrombus and excluded pulmonary artery thromboembolism, device malfunction, and surgical complications as sources of the patient's pain. The atrial thrombus would not have been visualized without the use of the synthetic ECG signal. Although the estimated effective radiation dose for the CCT portion of the scan was higher than normal at 18.3 mSv, this is comparable to other reported CCT scans that used retrospective ECG-gating techniques.³

Synthetic ECG gating is a technique that is easy to perform and uses a patient simulator device that is readily available at most hospitals with the resources to have a CCT scanner. Until a CT vendor solution is available, it will remain the easiest way to perform CCT in patients with a TAH-t.

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Disclosures

None.

References

1. Copeland JG, Copeland H, Gustafson M, Mineburg N, Covington D, Smith RG, Friedman M. Experience with more than 100 total artificial heart implants. *J Thorac Cardiovasc Surg.* 2012;143:727–734.
2. Canter L, Howell EA, Morris R, Torigian DA. Chest radiographic and computed tomographic findings of the temporary total artificial heart (TAH-t). *J Thorac Imaging.* 2008;23:269–271.
3. Sabarudin A, Sun Z, Ng KH. A systematic review of radiation dose associated with different generations of multidetector CT coronary angiography. *J Med Imaging Radiat Oncol.* 2012;56:5–17.

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