The ONE Guides Cardiac Imaging

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WARNING: Any reference to x-ray exposure, intravenous contrast dosage, and other medication is intended as a reference guideline only. The guidelines in this document do not substitute for the judgment of a healthcare provider. Each scan requires medical judgment by the healthcare provider about exposing the patient to ionizing radiation. Use the As Low As Reasonably Achievable radiation dose principle to balance factors such as the patient’s condition, size and age, region to be imaged, and diagnostic task.
Aquilion ONE™ is the world’s first dynamic volume CT system. It provides whole-heart coverage in as little as a single gantry rotation within one heartbeat. The resulting images are reconstructed at a single instant in time, ensuring uniform contrast enhancement and motion-free images throughout the entire volume.

With prospective triggering, exposure is limited to just a small portion of one R-R interval, providing high-quality coronary CTA images at an ultra-low exposure dose. Functional assessment of the myocardium is possible by extending the exposure to cover a full heartbeat.

Toshiba’s clinically proven SURECardio™ technologies, including automated parameter selection, adaptive multisegment reconstruction and phaseXact, have been extended to the Aquilion ONE platform to achieve the most robust cardiac imaging possible.
The following workflow is suggested to select the most suitable scan mode.

- **Functional Analysis?**
  - **YES**
    - CTA/CFA
  - **NO**
    - Prospective CTA

**CTA/CFA** scan mode is a scanning technique in which exposure is performed during the entire R-R interval over one or more heartbeats. Functional analysis can be performed using the data obtained. Multisegmental reconstruction is available for patients with high heart rates in whom multiple beats are scanned. ECG dose modulation is also available for reducing the mA during portions of the R-R interval in which high-resolution imaging is not necessary.

**Prospective CTA** scan mode is a low-dose scanning technique in which exposure is performed for only a portion of the R-R interval (generally diastole). The desired exposure phase is set as a percentage of the R-R interval, so the actual exposure time varies depending on the patient’s heart rate. The exposure phase setting can be expanded to include systole if the heart rate is high, and a function is provided to perform such setting based on the results of breathing exercise. Multisegmental reconstruction is also available for patients with high heart rates in whom multiple beats are scanned. Functional analysis is not possible in this scan mode because exposure does not cover the entire R-R interval.

**Target CTA** scan mode is a low-dose scanning technique in which the exposure time and a single target phase are manually preset before scanning to ensure that the patient receives a consistent exposure dose. This is useful for pediatric examinations, in which a low exposure dose is critical. As such, arrhythmia rejection software does not apply to this scan. The target phase is selected, and the number of phases available for reconstruction depends on the exposure time and heart rate.
Guidelines for Coronary CTA Examinations

1) Patient Preparation & Positioning

- 4-Hour fast. NO caffeine!
- Give the patient a full explanation of the procedure.
- Place a 20- or 18-gauge IV cannula in the RIGHT arm.
- Position the patient for an AP scanogram.
- Place the patient’s arms above their head with the ECG electrodes outside the scan range.
- At many sites, sublingual nitrates may be administered about 5 minutes before the CTA scan.

Confirm that a clean ECG signal is displayed before continuing!

2) Station Breath-Hold Training

The patient should practice breath-holding before the examination is started. The CT Station should be set up to perform this directly from the CT gantry, so the recorded voice the patient hears during the scan is used for breath-hold training. This should be a single “Breathe in and hold.” instruction.

The patient should be instructed to hold their breath at about 75% of maximum lung capacity (“Take a comfortable breath in.”) and to take the same size breath each time they are told.

This important step has two purposes:

- To ensure that the patient is familiar with the instructions given during scanning.
- To monitor the patient’s heart rate during breath-holding. Make sure that a steady heart rate is displayed with a clean ECG signal.

* The patient’s heart rate should not fluctuate by more than ±10% during breath-hold training.

* Refer to the guidelines for beta-blocker administration on page 21.

3) Cardiac Scanning

Select and execute the required scan protocol.

- Cardiac Prospective CTA (function not required)
- Cardiac CTA/CFA (function required)

1. Acquire AP and lateral scanograms.

2. Position the volume scan to cover the entire heart.
   - Visually set a plan to cover the range from the bifurcation of the trachea to below the apex of the heart.

3. Reduce the display FOV to about 200-220 mm.
   - A smaller FOV results in a higher in-plane spatial resolution.

4. Place the SUREStart™ S&V slice at the center of the volume scan.
4) Selecting the Exposure Dose

SUREExposure™ Cardiac is used to automatically select the mA based on the patient size. The following settings are recommended for SUREExposure.

<table>
<thead>
<tr>
<th>SD</th>
<th>SUREIQ™</th>
<th>Max mA</th>
<th>Min mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca Score</td>
<td>55 Cardiac Ca Score</td>
<td>580</td>
<td>40</td>
</tr>
<tr>
<td>CTA</td>
<td>33 Cardiac CTA</td>
<td>580</td>
<td>40</td>
</tr>
</tbody>
</table>

The kV can be adjusted by selecting the lowest kV where the mA graph does not reach the maximum.

Lower kV is desirable as the HU value of iodine is increased at lower kVs. Increasing the enhancement of vascular structures allows you to potentially reduce the volume of contrast required.

5) SURECardio Breathing Exercise

The SURECardio automated breathing exercise feature is used to automatically select all of the other scan parameters according to the patient’s heart rate to ensure high-quality images.

- Open the SURECardio menu by clicking the heart icon in scan plan.
- Click the “Breath Ex.” icon to start the automated breath-hold practice routine.
- SURECardio monitors the patient’s heart rate during breath-hold training.
- The patient’s recorded heart rate range is displayed, and the scan parameters to ensure optimal temporal resolution and the appropriate phase window are automatically set.

TIP: Scan Delay After Breathing Instruction

The patient’s heart rate is often unstable for the first 2 seconds after the start of breath-holding.
A 2 second delay time is set as system default for all ECG gated scans. This option is in the Set-up utility menu.
6) Guidelines for Contrast Protocol

As a general rule:
- The injection rate and contrast volume should be increased for larger patients.
- CTA requires the use of contrast medium with an iodine concentration of at least 350 mgI/mL.

There are two different injection protocols for coronary CTA:
- A protocol that ensures complete washout from the right side of the heart. Streak artifacts from undiluted contrast medium are eliminated, providing excellent visualization of the RCA.
- A protocol that maintains some contrast in the right side of the heart. This reduces streak artifacts in the SVC and right heart, but maintains adequate opacification of the right ventricle. This may improve the detection of the ventricular septal wall for CFA.

<table>
<thead>
<tr>
<th>Single-Phase Contrast With Saline Flush</th>
<th>Biphasic Injection With Contrast/Saline Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1</strong> (Contrast)</td>
<td><strong>Phase 1</strong> (Contrast)</td>
</tr>
<tr>
<td>70 mL @ 5 mL/s *(14 s)</td>
<td>60 mL @ 5 mL/s *(12 s)</td>
</tr>
<tr>
<td><strong>Phase 2</strong> (Saline)</td>
<td><strong>Phase 2</strong> (Mix)</td>
</tr>
<tr>
<td>50 mL @ 5 mL/s</td>
<td>30 mL @ 5 mL/s</td>
</tr>
<tr>
<td></td>
<td>30 % Contrast/70 % Saline</td>
</tr>
<tr>
<td></td>
<td><strong>Phase 3</strong> (Saline)</td>
</tr>
<tr>
<td></td>
<td>50 mL @ 5 mL/s</td>
</tr>
</tbody>
</table>

* The injection rate and contrast volume should be increased for larger patients to ensure adequate iodine flux, and as a result, good arterial enhancement. Similarly, for smaller patients, the injection rate and volume can be reduced. In both cases, to ensure consistent results, the duration of injection should be maintained.

7) SUREStart Setup

- Acquire the SUREStart planning image.
- Confirm that the descending aorta can be clearly identified.
- Place the SUREStart ROI within the descending aorta as shown above.
- Set the SUREStart trigger to 180 HU.

8) Acquiring the CTA scan

Final checks:
- Reassure the patient that it is normal to experience a sensation of warmth following contrast administration.
- Inform the patient that the next breath-hold is the last one for the examination.
- Confirm that the patient’s heart rate is steady.
- It is a good idea to have someone monitor the first few seconds of contrast administration to minimize the risk of extravasation.

OK to go.
- Contrast injection and scanning are started simultaneously.
**Arrhythmia Rejection**

The arrhythmia rejection software is an outstanding feature that is clinically useful only with the whole-heart scan range available with Aquilion ONE dynamic volume CT.

The arrhythmia rejection software monitors the patient’s heart rate during scanning and automatically detects and rejects an abnormal heartbeat such as a PVC. In the case of an abnormal beat as shown below, the system captures the next available beat. As a result, the quality of the examination is ensured, reducing the need to perform repeat or alternative examinations.

This innovative software is always active in the Prospective CTA and CTA/CFA scan modes.

![Expected Heart Rate](image)

Example: The first beat is arrhythmic, with an unexpectedly short R-R interval. The system can recognize this during scanning in real time and acquires the following beat.

Clinical Example: In this example of a ONE-beat prospective CTA scan, a PVC occurred during the first beat. The second beat was also abnormal. In the first two beats, exposure was started but was immediately terminated by the system when the peak of the R wave arrived early. The scanner used the third, normal, beat for reconstruction.

**Guidelines for Coronary Artery Bypass Graft Scanning**

The coronary artery bypass graft protocols employ the same scan methods as for a standard coronary CTA examination. The main difference is the total scan range required, so in this case, the wide-volume switch is turned on.

In the wide-volume scan technique, two or more separate volumes are acquired along the scan range. The data is stitched together after the scan, permitting seamless analysis of one continuous volume.

A scan range from above the aortic arch to below the heart normally requires a two-volume scan in most patients.

- Ensure the entire heart is captured in the second volume.
- Place the S&V slice for SUREStart at the level of the aortic arch.
- Set the SUREStart trigger to 180 HU in the aortic arch.
Guidelines for Contrast Protocol

Since the acquisition time is longer than for a regular CTA scan, the contrast protocol should be based on the total scan time.

Refer to the suggested guidelines below for calculating the contrast protocol.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 (Contrast)</td>
<td>XX mL @ 4-5 mL/s</td>
</tr>
<tr>
<td>Phase 2 (Saline)</td>
<td>50 mL @ 4-5 mL/s</td>
</tr>
</tbody>
</table>

XX = (Scan time + 10) x injection rate

Coronary CTA

phaseXact - Fully automated phase selection software

The phaseXact software automatically determines the optimal cardiac phase for motion-free imaging. Phase selection is performed in the raw data domain and requires no operator intervention.

• phaseXact is set ON in the eXamplan.
• Select “Best Phase”.

After the eXam Plan is completed, phaseXact finds and reconstructs the best motion-free cardiac phase. The adjacent cardiac phases at ±20 ms are also generated to provide a 40-ms temporal window. This temporal window permits better assessment of the proximal and distal coronary arteries if there are minor variations in movement.

imageXact - Guided image-based phase selection software

In rare cases, phaseXact may not be able to automatically determine the best motion-free cardiac phase. In such cases, imageXact can help by guiding the operator through a simple and precise manual phase selection process.

The concept of imageXact is to perform reconstruction at an absolute time point after the R wave (R + ms). Phase selection is performed using a single image located at the mid-heart level and reconstructed throughout the entire cardiac cycle.
### Cardiac Reconstructions

**CFA (Cardiac Functional Analysis)**

Available only in CTA/CFA scan mode

CFA is performed to evaluate left ventricular function. Quantitative measurements, including the ejection fraction etc., can be obtained from the same data as that acquired for the CTA examination when a full R-R interval has been scanned.

In order to perform CFA, we recommend that reconstruction be performed for 10 phases from 0% to 90% at 10% intervals. The spatial resolution is not of primary importance in CFA, so the amount of data can be reduced by reconstructing volumes with a 1-mm slice thickness and 1-mm slice interval.

CFA reconstructions should be programmed into the eXam Plan to automatically perform reconstruction after scanning is completed.

### Guidelines for Calcium Score Scanning

Calcium score scan mode provides a volume in a single predetermined cardiac phase. The phase is automatically selected based on the results of breathing exercise.

- Select the Calcium Score eXam Plan

1. Acquire AP and lateral scanograms.
2. Position the volume scan to cover the entire heart.
   - Visually set a plan to cover the range from the bifurcation of the trachea to below the apex of the heart.
3. Reduce the display FOV to about 200-220 mm.
   - A smaller FOV results in a higher in-plane spatial resolution.
4. Open the SURECardio menu by clicking the heart icon in scan plan.
5. Click the “Breath Ex.” icon to start the automated breath-hold practice routine.
6. SURECardio monitors the patient’s heart rate during breath-hold training. The patient’s recorded heart rate range is displayed, and the scan phase is automatically selected.
7. Confirm the scan plan and acquire the scan.
   - A 0.5 mm volume and axial images (3 mm/3 mm) are reconstructed.
Why Beta Blockade?

The use of beta-blockers to reduce the patient’s heart rate has become a widely accepted standard of care in cardiac CT imaging. The benefits of a slow and steady heart rate are directly reflected in the image quality obtained, reducing the time needed for image interpretation.

Perhaps even more importantly, a slow and steady heart rate can also make it possible to reduce the exposure dose to the patient.

While the technology of Aquilion ONE provides whole-heart coverage and excellent temporal uniformity compared to multidetector imaging, the physiology of the heart remains the same.

A slow and steady heart rate allows a short exposure window to be set in Prospective CTA studies. When functional imaging is required, a low and steady heart rate makes it possible to minimize exposure to just one heartbeat.

If the heart rate does change during the scan (which is always possible), the Aquilion ONE SURECardio software automatically adapts to each patient’s heart rate to maximize image quality at the lowest possible exposure dose.

In my opinion the use of beta blockers is essential for cardiac CT. The images improve dramatically with a lower less variable heart rate and the radiation doses can be significantly reduced. Both oral and intravenous beta blockers are extremely safe and well tolerated. We use beta blockers in all patients referred for cardiac CT. While the Aquilion ONE can do patients with a higher heart rate, we prefer to lower the heart rate which gives us the ability to do the study with the whole heart coverage in less than a single heartbeat.

Tony deFrance, MD, FACC
Clinical Associate Professor at Stanford Medical School, SCCT Board of Directors, National Director of SCCT Workgroups

Guidelines for Use of Beta-Blockers in Cardiac CT Studies

The following protocol is intended to serve as general guidelines for the use of beta-blockers (specifically metoprolol) in cardiac CT studies.

Each site should evaluate their policies and procedures regarding the use of beta-blockers.

Beta-blockers are administered if the patient is found to have an average resting heart rate of >70 bpm (regular rhythm) or >65 bpm (irregular rhythm).

Note: Patients should be screened for any contraindications to the use of beta-blockers. Exclude patients with systolic blood pressure <100 mmHg.

1) Administer 50 mg of metoprolol as a single oral dose. (Exclude patients who have received medicinal beta-blockers within the previous 4 hours.)
   • Monitor the patient every 15 minutes for 1 hour to check whether the heart rate has fallen to within the desired range of ≤70 bpm (regular rhythm) or ≤65 bpm (irregular rhythm).

2) If the patient’s heart rate has not fallen to within the desired range after 60 minutes, additional metoprolol can be administered intravenously.
   • Administer 2.5 mg of metoprolol by slow intravenous push over 1 minute while monitoring the patient’s heart rate and checking the blood pressure every 2 minutes.
   • If the patient’s heart rate remains high after 5 minutes and there is no evidence of hypotension, additional 2.5-mg doses of metoprolol may be administered up to a maximum of 15 mg.

Post-procedure guidelines

1) Patients who have received only oral metoprolol should remain in the department for 15 minutes after the study. The blood pressure and heart rate should be checked. Patients who are free of abnormal signs or symptoms may be released.

2) Patients who have received intravenous metoprolol should remain in the department for 30 minutes after the study. The blood pressure and heart rate should be checked. Patients who are free of abnormal signs or symptoms may be released.