Coronary artery graft patency assessment using a Volume CT protocol - How we do it.

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Learning objectives

The purpose of this exhibit is to provide information on the protocol that we use for performing a coronary artery graft patency analysis with a Dual Volume Acquisition of the chest on a Toshiba Aquilion One CT scanner.

CONTENT ORGANISATION

Information will be given specifically focussing on:
• Patient selection
• How to plan the scan to ensure that the native coronary artery origins do not lie at the level of the point of stitching
• Contrast injection protocol to ensure that there is sufficient contrast opacification in the native coronary arteries, coronary artery grafts and the aorta.
• Our protocol for B-Blocker and GTN administration
• How to ensure a low dose examination
Background

Initial investigation of bypass grafts was done exclusively with invasive angiographic imaging. With the development of CT - this offered an alternative method of imaging grafts, with single-slice scanners. (1) With progress of CT technology; the addition of ECG gating and the improved capabilities available with 4 and 16 slice MDCT there was gradual increase in the accuracy of imaging of bypass grafts. (2-4).

With 64-slice scanners and dual-source CT scanners, improved temporal resolution (up to 83 msec) and spatial resolution can now be achieved. This has resulted in a reduction in cardiac and respiratory motion resulting in improved assessment of graft stenosis and occlusion. (5)

Numerous studies (6-8) have now shown that cardiac CT can accurately evaluate the proximal and distal anastomoses as well as the presence of graft disease, such as stenoses, occlusions and plaque formation.

Further studies using 64-slice MDCT have reported sensitivity and specificity values of 93.3% to 100% and 91.4% to 100%, respectively, for graft occlusion and high-grade stenosis (>50% luminal narrowing). (9-12)

The latest development in CT is volume imaging and the purpose of this educational exhibit is to describe our procedure and protocol for obtaining the best quality images via this novel method.
Imaging findings OR Procedure details

In the assessment of coronary artery grafts by cardiac CT there are several parts to take into account:

1) How many grafts are there?

2) Are the grafts patent? This requires visualisation of the proximal anastamosis, distal anastamosis and assessment of the length of the graft looking for in graft disease.

3) Which grafts are present?

LIMA: Typically the left internal mammary artery is used as a graft to the LAD/Diagonal artery. This is used as an in-situ graft given its location close to the LAD and the high patency rates following its use. The vessel arises from the left subclavian artery and passes within the anterior mediastinum. Often it can be somewhat obscured by the numerous surgical clips which can make interpretation of the mid graft difficult.

Saphenous Vein Grafts: Saphenous vein grafts are harvested from the lower limbs. They are attached to the ascending thoracic aorta and are distally attached beyond the level of the stenotic lesion. Aortic attachment is usually by a direct anastamosis though sometimes an anastamotic device is used which attached to the aorta between the graft and the aorta itself. There are usually fewer surgical clips related to saphenous vein grafts meaning that they are less likely to be obscured.

Others: Right internal mammary grafts and radial artery grafts are less frequently used.

Volume Cardiac CT (VCCT) allows for the whole of the chest to be imaged in 2 volume scans which involve a short breath hold and a single table movement. This has the perceived advantages of:

1) VCCT means that the entirety of the chest can be covered in 2 volumes. Since a single volume is acquired in <1/3rd of a second then the total breath hold required in ~2-3 seconds. With a 64 slice scanner longer breath holds can be required and particularly in acutely short of breath patients this can result in image degrading and reduction in the diagnostic value of scans. Volume imaging therefore allows for improved temporal resolution as well as a reduced risk of respiratory motion artefact degrading images.
2) VTRO utilise the sophisticated arrhythmia rejection techniques to both reduce dose and reduce the chance of a non-diagnostic scan. Since all information is acquired in a single heart beat - a single heart beat of reasonable RR length is required to obtain good quality images in that volume. Again compared to 64 slice imaging this has consequences for both dose (if a retrospective analysis has to be performed) and final image quality.

In our institution we use a Toshiba Aquilion One 320 slice CT scanner. The scanner is equipped with 320 rows of detectors with a maximum coverage of 16cm, based on the width of a single detector element of 0.5mm.

All patients were positioned on the couch in a supine position, head first.

Dual scan topogram was used for planning the examination and used to determine the anatomical range which needed to be covered. This allows for an ECG gated volume acquisition and allows us to cover the entirety of the chest in 2 volumes. When a single volume is acquired, the shape of the volume is not a perfect rectangle but rather has slightly sloping edges at either end (due to the cone beam) which gives the maximal volume of 16cm. When two volumes are acquired, the maximal "rectangular" component of the scan in 232mm, with the coned edges giving extra coverage of the chest (265mm total).

The important criteria to ensure that correct visualisation of the coronary arteries is obtained requires:

1) Correct patient selection

Patients need to be able to hold their breath steadily for only a very short period of time ~6-7 seconds and need to be able to keep still.

Our very initial attempts with the volume scanning showed that if patients breathed/moved then the stitching at the point of the two volumes was not correctly lined up.

To ensure a low-dose one beat scan the patient should have a heart rate <65 beats per minute. In those with heart rates above this threshold we use a cardio-selective beta-blocker (Metoprolol) to slow their heart. So where Beta-blocking is contra-indicated; those with asthma, sinus bradycardia, hypotension, congestive cardiac failure, shock, 2\textsuperscript{nd} or 3\textsuperscript{rd} degree heart block and active bronchospasm, such patients would not be suitable for a triple rule-out scan.

2) Optimisation of the Coronary artery imaging. This is with IV metoprolol aiming for a heart rate of <65 beats per minute. When the heart rate is controlled to <65 beats per
min, the scan is performed in a single rotation - this obviously has an impact on dose. In addition controlling heart rate is the single most important factor in achieving good coronary artery images. 500 micrograms of sublingual GTN are given to cause dilatation of the coronary arteries. (See appendix A below for B Blocker protocol)

3) A variable sliding scale of KV and mA is used depending on the patients BMI. The purpose of using a sliding scale is to obtain the best quality images while giving the patient the smallest dose. For patients with a BMI of <28, a 100kV technique is used while patients from 28-35 use a 120kV technique and >35BMI use a 135kV technique.

4) The scan is set up such that the upper border of the lower volume sits at the level of the carina and therefore this volume will be above the level of the LMS origin. The consequence of this is that the upper volume extends ~1-2cm above the level of the chest but if the volume is centred to only cover the chest then the second volume will dissect the LMS/LAD. This however has the advantage of ensuring that that the origin of the LIMA graft from the subclavian artery is completely covered. Although the stitching of the two volumes is near perfect - the slightest variation in the position of the coronary artery could cause the LMS/proximal LAD segment to become uninterpretable.

At the planning stage the lower volume position is adjusted so that its superior border lies just below the level of the carina and therefore the entirety of the native coronary artery system will be included in the lower volume.

5) The scan is triggered by Bolus tracking of contrast in the ascending aorta. A dual injector is used with an initial 100mls of 350mg/ml iodine concentration contrast at a rate of 5ml/s followed by a 15ml Saline chaser at the same rate. This is injected via a 21G cannula sited in the right anticubital fossa. When attenuation within the ascending aorta is at the level of 180HU the VCCT is initiated after a breath-hold command. The bottom volume is scanned first (this has the advantage that if patient has limited breath hold then the more mobile native coronary arteries will be more still) followed by the upper volume.

6) The scanner joins the two volumes together and the whole dataset can then be analysed to look at the native and the graft vessels.

**APPENDIX A**

**CARDIAC CT - B Blockade**

All patients prior to their Cardiac CT scan require:
• B Blockade with Metoprolol (oral or iv)
• GTN Spray x2

ORAL: Intersubject plasma levels achieved are highly variable after oral administration, although they show good reproducibility within each individual. Peak plasma concentrations are attained after approximately 1.5 to 2 hours with conventional metoprolol formulations, and after approximately 4 to 5 hours with slow-release formulations. Elimination is mainly by biotransformation in the liver, and the plasma half-life averages 3.5 hours (range: 1 to 9 hours).

IV: Following i.v. administration of metoprolol, the half-life of the distribution phase is approximately 10-12 minutes. Equivalent maximal b-blocking effect is achieved with oral and i.v. doses in the ratio of approximately 2.5:1.

IV Metoprolol should be given to patients on the CT table if their heart rate is greater than 60 beats per minute and titrated up in ampoules of 10mg up to 40-50mg maximum. Equivalent maximal beta-blockade with oral:IV metoprolol is 2.5:1 (eg total dose of 150 mg po daily is approximately equivalent to 60 mg IV daily.)

The aim is to reduce the heart rate to <60 beats per minute.

POTENTIAL HAZARDS OF PARENTERAL ADMINISTRATION

• Cardiac failure
• Severe sinus bradycardia: antidote - atropine
• Partial heart block: antidote - atropine; if unresponsive isoproterenol or temporary pacing
• Bronchospasm: antidote - salbutamol
• Profound beta-blockade: antidote when other measures have failed - glucagon

TREATMENT OF COMPLICATIONS

If adverse cardiovascular effects are observed, IV therapy should be stopped immediately and the patient observed

• Bradycardia and Hypotension: Atropine 1 to 2 mg initially should be given i.v.
• Hypoglycaemia: Glucagon (1 to 10 mg) can be administered
• Bronchospasm: Salbutamol inhaler
• Cardiac Failure: IV frusemide 20-40mg

CONTRAINDICATIONS
B Blockers are contraindicated in patients with:

- Asthma
- Sinus bradycardia
- Hypotension: BP <90 systolic
- Overt heart failure
- Cardiogenic shock
- 2nd or 3rd degree block
- Right ventricular failure secondary to pulmonary hypertension

Observe the patient for 10 mins after completion of the scan and then discharge. Inpatients for Cardiac CTs should all come down to the department in a bed.
Fig. 0: ECG trace shows that each volume requires a single exposure within a single R-R interval.

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Fig. 0: Coronal reconstructed image. The stitch point between the two volumes is difficult to clearly identify.

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Fig. 0: 3D image showing the amalgamated 2 volumes

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Fig. 0: 3D image showing the amalgamated 2 volumes

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**Fig. 0:** Arrow points to the fusion point between the two volumes. The native coronary arteries have been included in the lower volume.

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**Fig. 0:** Coronal image

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Fig. 0: Sagittal image

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**Fig. 0:** Sagittal image

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**Fig. 0:** Sagittal image with arrow pointing to the origin of the LIMA graft

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Fig. 0: Coronal image with arrow pointing to the origin of the Saphenous vein graft

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Conclusion

Volume Cardiac CT offers an easy and low dose method of imaging native coronary arteries and coronary artery grafts. We have described the method and protocols that we use to obtain good quality examination on the Toshiba Aquilion One Volume CT scanner in our institution.
Personal Information
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