There is a wide range of CT scanners on the market that can be cardiac enabled. Choosing the right machine for your site may be dependent on both the amount of cardiac CT you intend to perform and the funds you have available. Replacing a scanner is, of course, an infrequent privilege, so generally you will be required to do the best you can with your existing equipment. The aim of this article is to highlight the areas that all scanner operators can focus on to get the best quality examination possible, regardless of the technology they have available.

**Patient preparation**

The patient has a significant role to play in ensuring the examination is as successful as possible. It is therefore important to ensure all possible steps are taken to benefit from their cooperation. This begins with the information supplied to them when booking the scan, which should be clear and unambiguous. It should tell them how to prepare, travel options, where to park if driving, how much this might cost them, where they should report to and at what time. This will help them stay relaxed and less stressed. They should be instructed to avoid stimulants that cause increased heart rates, ie caffeine and cigarettes. Providing the patient with a list of caffeine-containing products can be useful.

**Calcium score**

If performed, a calcium score scan can offer some useful information. Firstly, it is used to make an assessment of the calcium burden with a view to abandoning the angiogram if the Agatston score is above a pre-agreed local threshold, eg 1,000. This is good practice as it can avoid unnecessary irradiation by then progressing to a higher dose CT coronary angiogram. Secondly, it can be used to establish the cranio-caudal extremes of the coronary arteries, remembering that the left main often curves superiorly from its origin. This information then allows the CT angiogram to be accurately planned so as to avoid unnecessarily covering any anatomy superior and inferior to the coronary arteries (figure 1). For retrospective helical scanners it is quite possible that the total dose of the calcium score can be more than saved by using this technique. The question, however, arises for lower dose scanners such as those offering step and shoot, ultra-helical or single shot acquisitions; here the dose of the angiogram may be little if at all higher than the calcium score. In this case it may be difficult to justify performing one scan to avoid a second when they are of a similar dose – you may as well just scan the angiogram.

**Breath-holding**

For older technology machines scan times can be lengthy, so practising breath-holding in advance with patients can be advantageous as it gives them an idea of what is expected. It also gives the operator an idea of what is achievable by the patient. For poor breath HOLDERS options include hyperventilating to delay the urge to breathe, increasing the acquired slice thickness to shorten the scan time (though this is not desirable), using a faster scan mode (though this will compromise temporal resolution – see later) or, if the limitation is significant, to abandon the test altogether.

There are benefits in instructing the patient to hold their breath with just a small breath in. Firstly, it will avoid both the possibility of them performing a Valsalva manoeuvre, which raises the pressure in the right side of the heart and blocks contrast from entering from the superior vena cava (figure 2). The result is an under-enhanced examination. Secondly, it will prevent an overly large initial breath lowering the pressure in the chest and right side of the heart, drawing unopacified blood from the inferior vena cava and diluting the contrast bolus.

Additionally, patients should be instructed to keep the breath-hold size as constant as possible each time they hear the instruction. This will ensure the heart is in the same position for both planning and acquisition scans.

**Cannulation, contrast media and timing**

The requirement is for high concentration contrast media to be within the coronary arteries for the duration of the acquisition. This can be achieved by using a relatively rapid injection via a good sized cannula. The antecubital fossa is preferable to the back of the hand as more proximal veins generally cope with higher flow rates, as well as being closer to the heart. Rates of 4–5ml/second should be achievable through an 18 gauge cannula. With the introduction of iterative reconstruction techniques however, scan exposures have reduced and more acquisitions are achievable at lower...
kVps. As this offers brighter enhancement of contrast, some units have been able to reduce flow rates while maintaining enhancement. The decision on contrast volume and flow rate needs to take into account the length of time for contrast to reach the coronary arteries (transit time), the scan acquisition time (dependent on technology available) and the patient size. Therefore, contrast volumes required could appropriately range from 40 to 150mls on differing systems. Contrast should always be saline chased, or possibly mixed if there is a preference locally to visualise the right heart. Timing needs to be accurate, so the scan start delay should never be guessed. Bolus triggering should always be used, or alternatively a timing slice for ultra-helical systems such as the Siemens Definition Flash.

**ECG and heart rate**

Obtaining a good heart trace is important to ensure accurate gating. Manufacturers’ recommendations need to be considered to ensure correct placement of leads and the skin should be prepared to ensure good contact. Shaving may be necessary, followed by the use of abrasive contact gel and then drying the skin before sticking the pads. Pay particular attention to sweaty or flaky skin. Avoid pressing the pads in the middle when sticking as this can eject the contact gel. Try to avoid areas of skin which will fold when the arms are lifted up as this can tend to peel off the stickers. Ensure the leads are well supported to avoid muscle tremor which can result in electrical noise (figure 3). Place the leads along the bed so that the weight of them is not tugging on the pads. If the patient has a pacemaker, there may be a recommended setting for this within your scanner gating box.

The optimum heart rate differs with individual scanning systems but usually slower is better. Firstly, this widens the window of opportunity where the heart becomes stationary so that movement-free data can be acquired. Secondly, it will ensure that the most dose efficient scan mode available can be used. Generally beta blockade will produce dose benefits and a higher success rate, and so should be used for all current CT technology. They can be given either orally or intravenously. The oral method requires administration an hour or so prior to the scan, so can make for a more complicated workflow. For this reason many centres solely use IV beta blockade as the effect is immediate. If the heart rate cannot be controlled and is higher than the recommended maximum for all scan modes available, then the correct decision may be to abandon and thereby not irradiate the patient. This should also be a consideration for patients in atrial fibrillation, although some ultra high end scanners that require only one heartbeat to acquire the whole of the coronary arteries, such as the Toshiba Aquilion One, can cope with this rhythm. Unless such a scanner is available, the best approach is to discuss atrial fibrillation with the cardiologists and ask them not to refer this group of patients in the first place.

**Scan modes**

All cardiac enabled scanners have several scan modes available. These may include retrospective helical (half or segmented reconstruction), retrospective helical with ECG modulated mA, step and shoot, ultra-helical or single shot. Some, but not all, of these will be available on any cardiac enabled scanner. Differing scan modes offer the ability to resolve different time periods of cardiac stillness, ie have differing temporal resolutions. The appropriate mode chosen therefore will be governed by the patient’s heart rate. Generally, on any particular scanner, scan modes offering better temporal resolution give a higher patient dose (figure 4). This is why it is better to increase the length of time the heart is stationary by using beta blockade than to use an alternative scan mode. Higher dose scan modes invariably require more heartbeats, and so the chance of hitting an ectopic beat is higher, breath-hold times are longer and scan success is likely to be lower. It is therefore important that radiographers are aware of the scan modes available, understand them and are able to decide the correct one based on heart rate and breath-hold ability of the patient. They should also understand the likely dose implications of using each mode. The recommended scan mode, based on the heart rate during breath-holding, is usually provided by the manufacturer in the form of a look-up table which may be on paper, or built into the scanner software.

**Exposure**

Many scanners now offer automated mA modulation based on the patient size. This should be optimised and used wherever available. Where not offered, operators should produce a recommended kV and mA table based on a patient variable that can easily be obtained such as BMI, antero-posterior chest diameter or patient weight. Iterative reconstruction is now available on many scanners and has allowed radiation doses to be reduced without reducing image quality. Lower kVps can now often be used, which has the benefit of improved contrast enhancement.

**Other considerations**

Nitrate will dilate the coronary arteries which can increase the perception of coronary artery disease, although these can have the unwanted effect of increasing heart rate if not adequately beta blocked.

Scanner raw data can be reconstructed with a range of algorithms. Some will be more suited to particular body areas and applications, so it is important that time is spent optimising these. Algorithms have an affect on signal to noise ratio, so it is important to remember that on some systems, changing the primary reconstruction algorithm will have an influence on the mA chosen by the automatic dose control software.
Finally, thought should be given as to the service offered. While it is possible to demonstrate left ventricular function, compared with a coronary artery-only examination there is a significant dose penalty on most scanners, so is it necessary? Can you lower the image quality for pulmonary vein isolation left atrium studies? Do you need to even gate them at all? How do you proceed with grafts? How do you deal with patients in atrial fibrillation?

Perhaps the most successful American basketball coach of all time, John Wooden, gave us two quotes that are entirely appropriate here: “It’s the little details that are vital. Little things make big things happen,” and “If you don’t have time to do it right, when will you have time to do it over?”