Setting Up An Efficient Cardiac Computed Tomography Service - What you need to have? What you need to do?

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IPPT
INSTITUT PERUBATAN DAN PERGIGIAN TERMAJU
KOMPLEKS PENYELIDIKAN HAIWAN
ANIMAL RESEARCH COMPLEX

Outlines

Service Set Up

- Staff
- Equipment
- Patients

Patient Preparation

- Screening
- Drug Administration

Efficiency

- Workflow
- Process Mapping

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Guidelines

SCCT guidelines for the performance and acquisition of coronary computed tomographic angiography: A report of the Society of Cardiovascular Computed Tomography Guidelines Committee Endorsed by the North American Society for Cardiovascular Imaging (NASCI)

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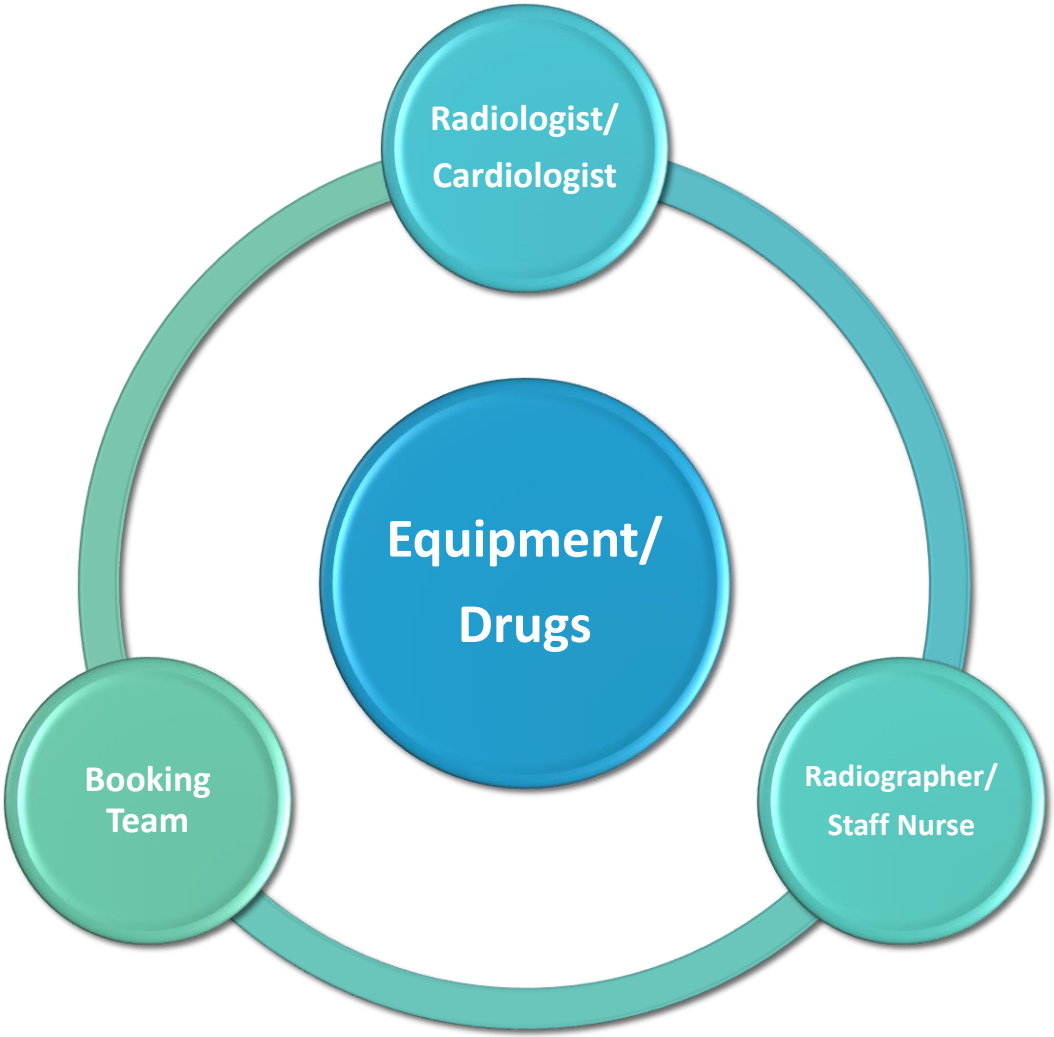
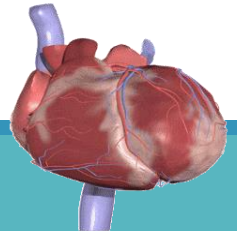
Efficient Service Set Up



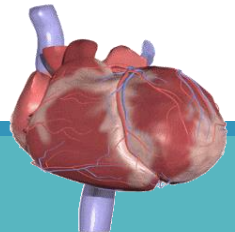
Radiologist/Cardiologist

- At least level 2-trained in Cardiac CT (CCT), also in one more modality
- Ability to assess coronary arteries, cardiac and pericardial structures, great vessels and extra-cardiac structures within the acquired field of view
- Lead of service, write and develop the protocols
- Responsible for maintaining the quality of the imaging and reporting
- Responsible for optimising the radiation dose, adequate knowledge of the ALARA (As Low As Reasonably Achievable)
- Continuing education and audit
- Motivate and educate other members of the team



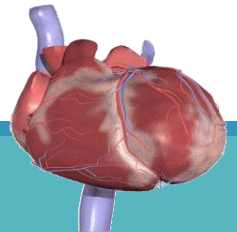
Radiographer/Staff Nurse

- Two to three radiographers trained in CCT
- Adequate training (other sites, courses, CT application specialists)
- Assist in developing protocols and optimising radiation dose, including adequate knowledge of the ALARA principle
- Image review - trouble shooting
- At least one person with appropriate training in inserting intravenous access (peripheral) is required for patient preparation
- At least one person certified in advanced cardiac life support has to be readily available during the acquisition
- A person with adequate training in administering medications such as beta-blockers and nitroglycerin must be available



Booking Team

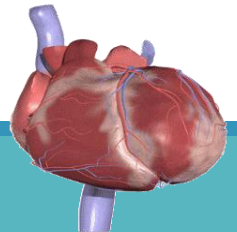
- Important members of the team
- Basic understanding of patient preparation for CCT especially CT Coronary Angiography (CTCA)
- Know general contraindications (e.g. renal impairment, patients on metformin) and able to provide information if contraindications exist
- Rapid dispatch of reports



SIEMENS
syngo Acquisition Workplace
syngo.via

Equipment
CT scanner

- Multislice CT scanner (≥ 64-slice) with ECG gating hardware
- CT systems with fast gantry rotation (equal or less than 350 ms) should be utilised
- With prospective gating, 80-120 kVp, iterative reconstruction algorithms
- Camera to monitor patients



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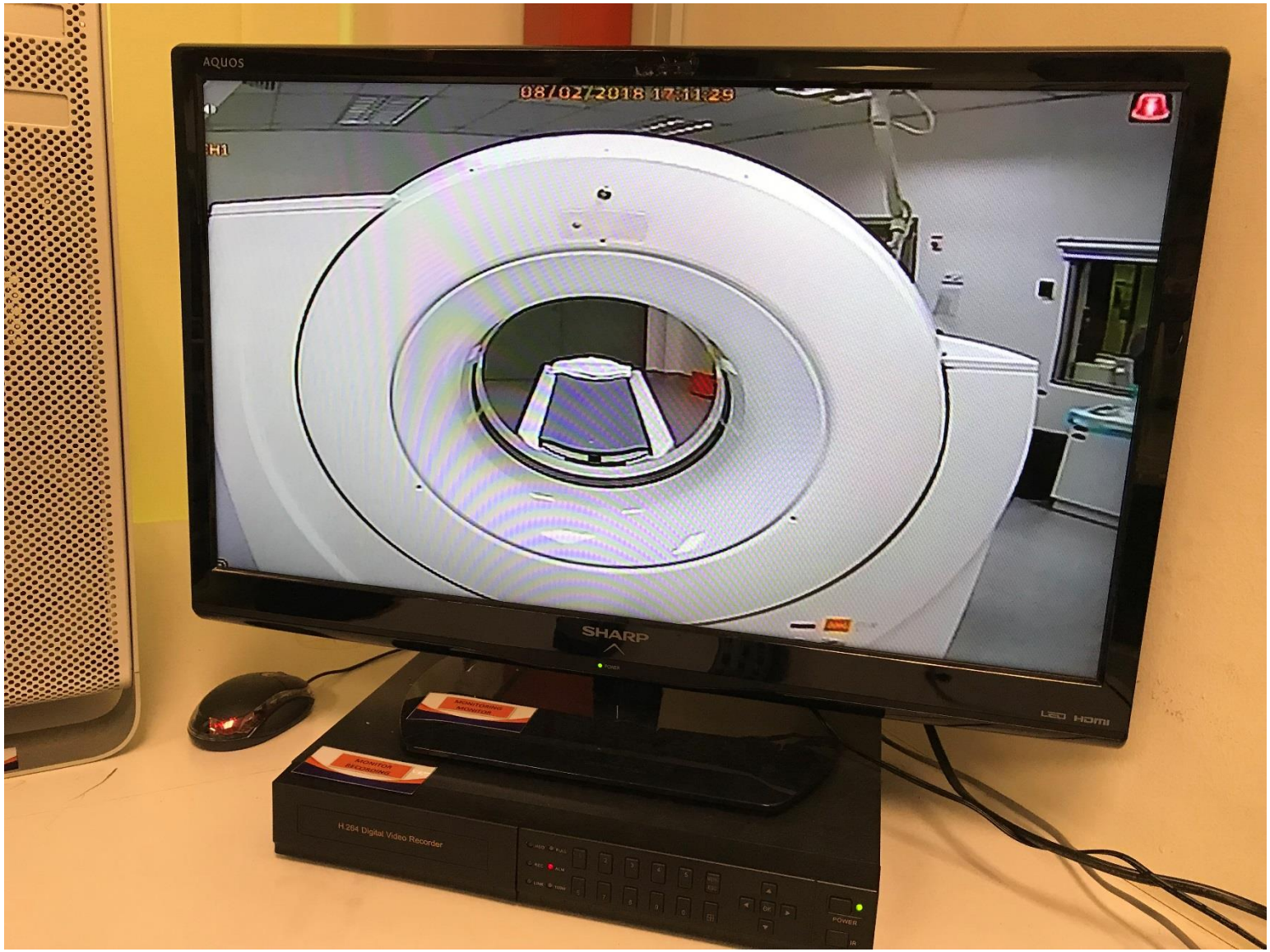
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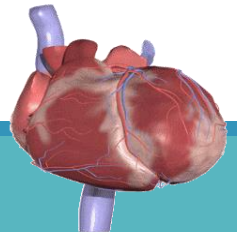
SHARP
H.264 Digital Video Recorder

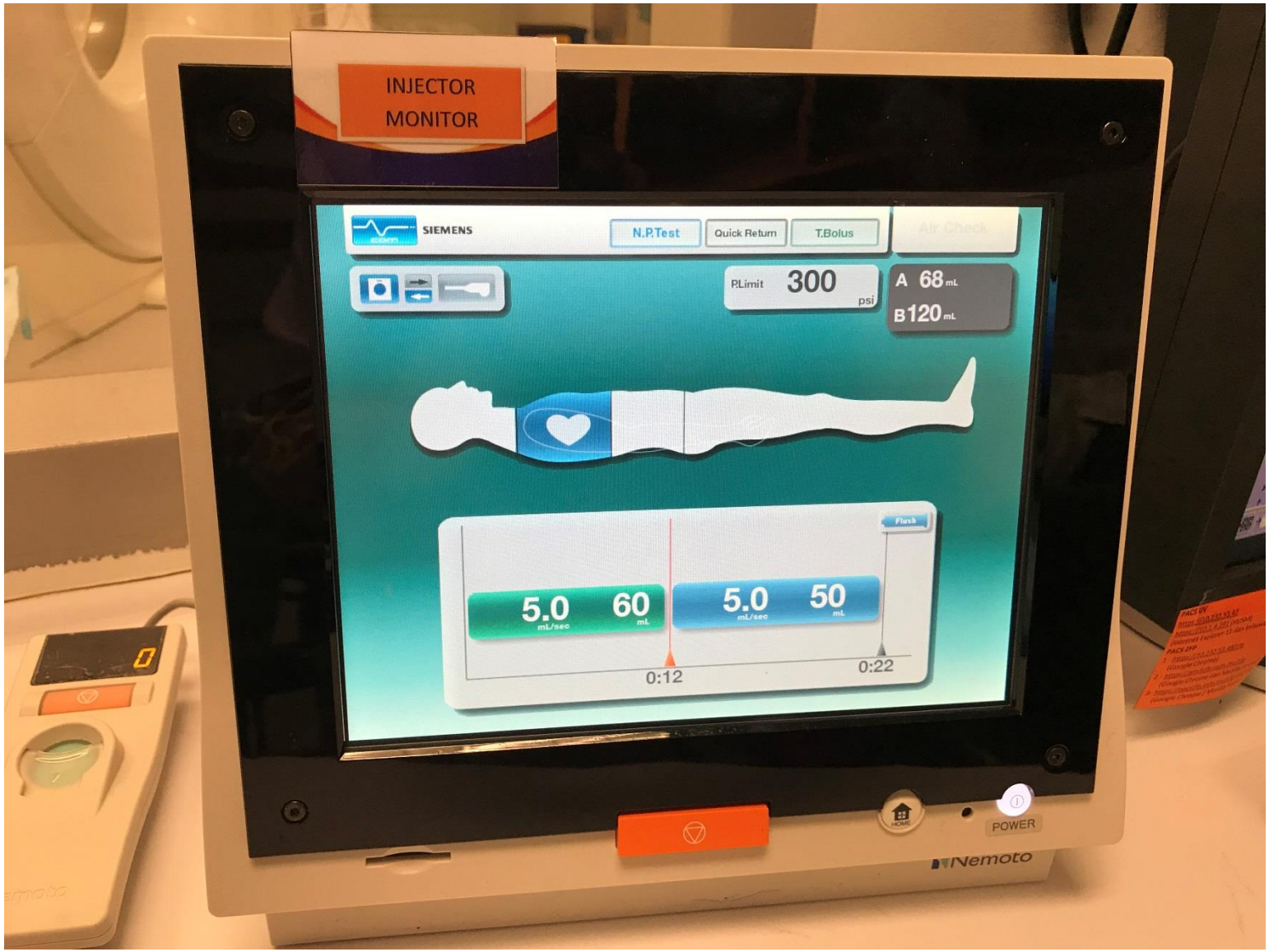
Dual Head Injector

- Dual head injection pumps that allow biphasic or triphasic injection protocols with high injection rates (4-7 ml/s) are recommended, although single head injection pumps can yield appropriate results
- Two or three phase injection:

  1st Phase - Contrast bolus

  2nd Phase - 50% contrast + 50% saline
- Ability to provide saline chase
- Transfer of contrast data to PACS




INJECTOR
MONITOR
SIEMENS
N.P.Test
Quick Return
T.Bolus
Air Check
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300
psi
A 68 mL
B 120 mL
Flush
5.0
mL/sec
60
mL
5.0
mL/sec
50
mL
0:12
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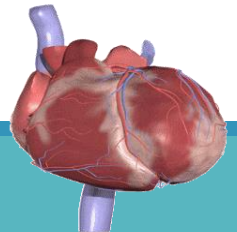
HOME
POWER
Nemoto

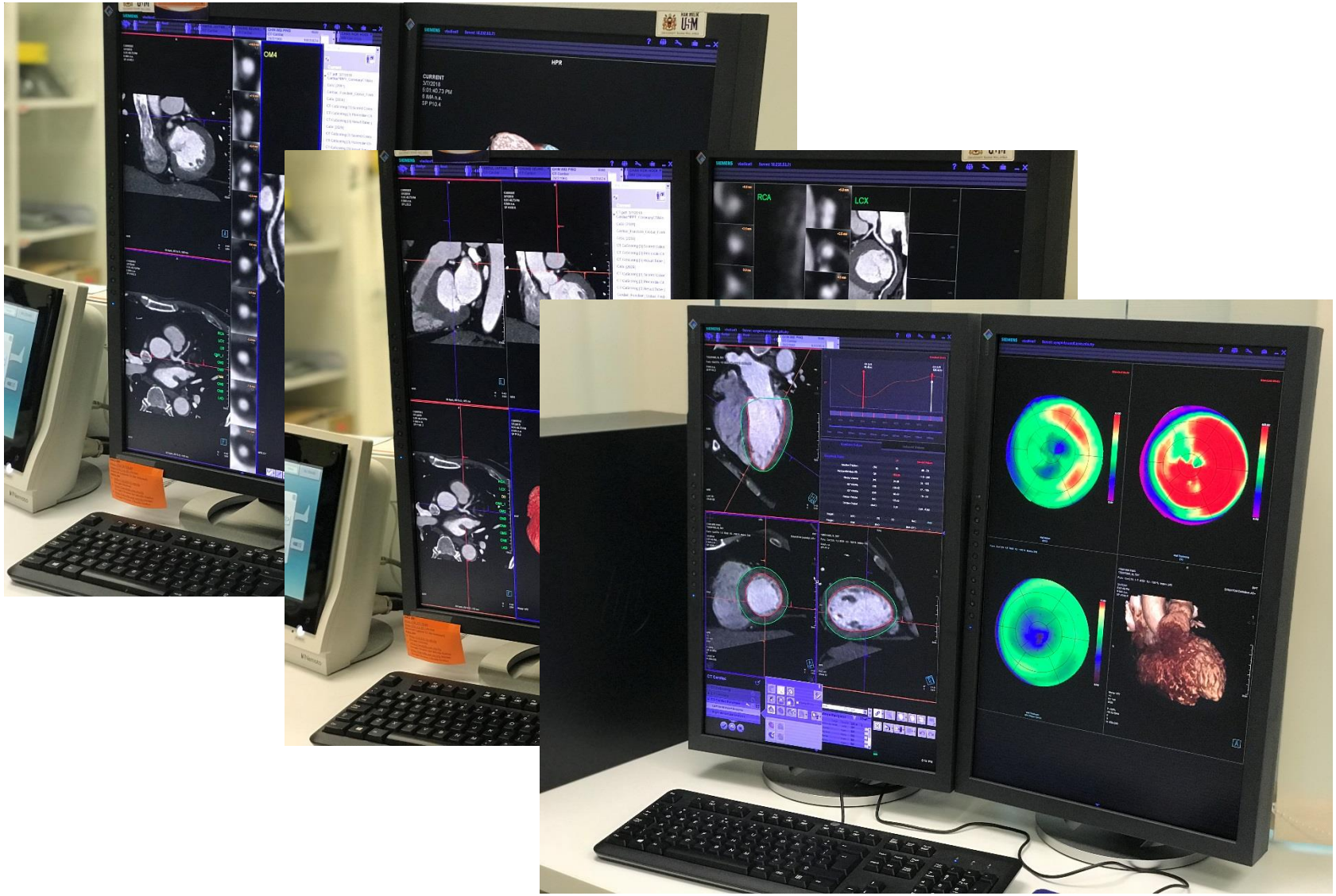
Contrast Media

- Low osmolar contrast media (350 or 370 mg Iodine/ml)
- 18/20G cannula preferably in right arm

Post Processing Software

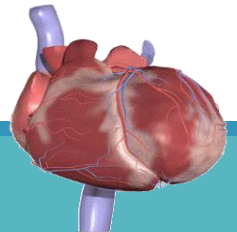
- Advanced post-processing CCT software
- Thin or thick client
- Multiple licences depending upon number of users
- MPRs - oblique, curved
- Stenosis quantification
- Plaque analysis
- Chamber volume/function
- Transcatheter Aortic Valve Implantation/Replacement (TAVI/R)




OM4
HPR
RCA
LCX

Heart Rate and Blood Pressure Measurement/Monitoring Device

- Measure baseline heart rate, blood pressure, O_2 saturation
- Further monitoring if required



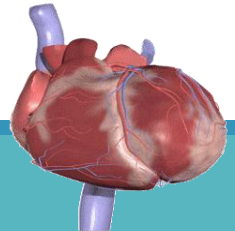
99
98
113 74 81

Drugs

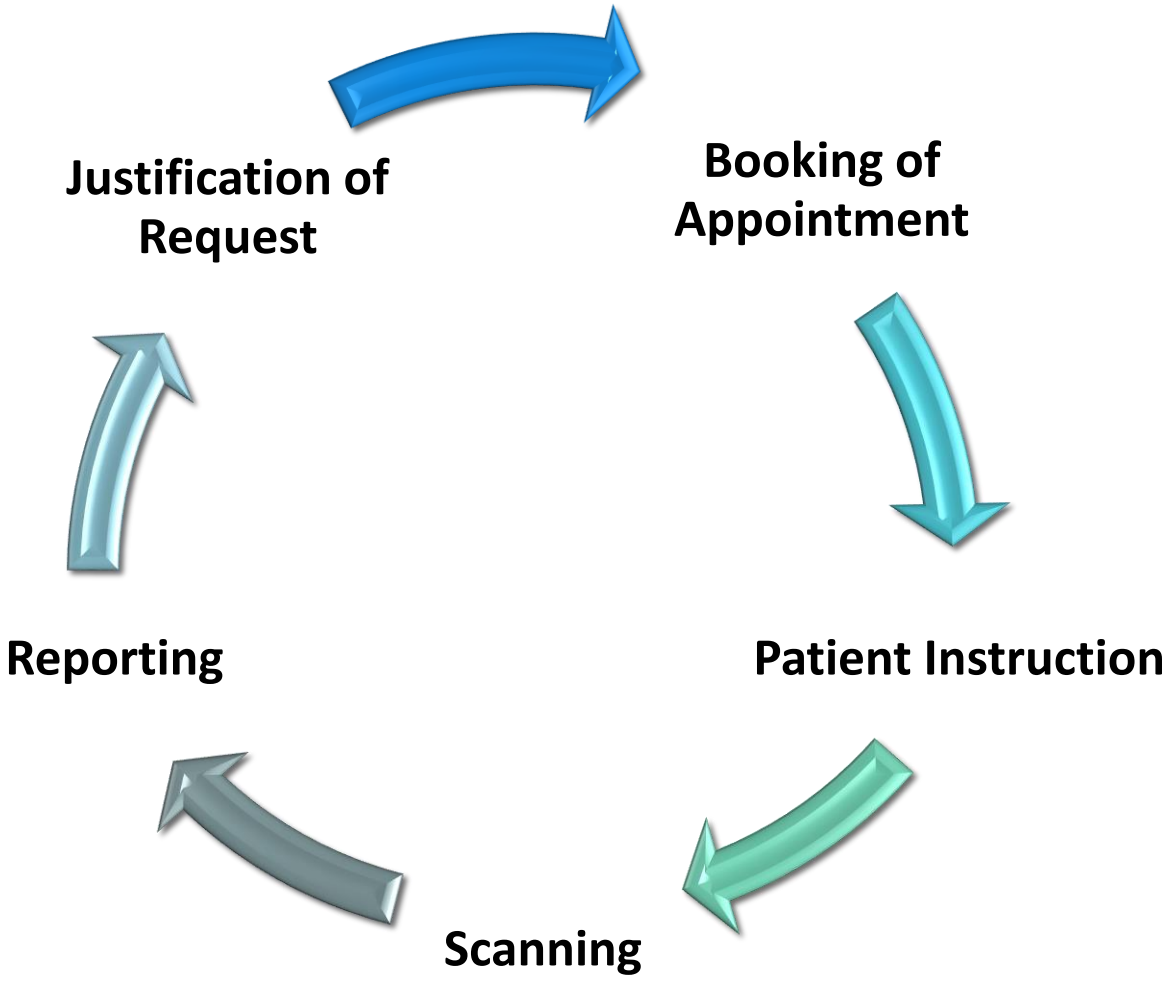
- Beta blockers [Oral and Intravenous (IV)]

  Metoprolol

  Ivabradine
- GTN (Oral or Spray)
- Resuscitation trolley with all necessary drugs



Cardiac CT Workflow



Justification of Request

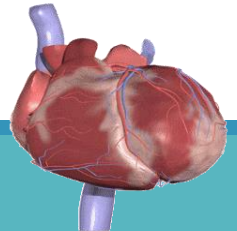
- Justification and authorisation of requests [Ionising Radiation (Medical Exposure) Regulations 2000]
- Appropriate clinical information (SCCT/AHA Appropriateness Criteria 2010, NICE 2010, ESC 2014)
- Protocols

  Prospective/Retrospective

  Native/Graft/delayed/additional areas

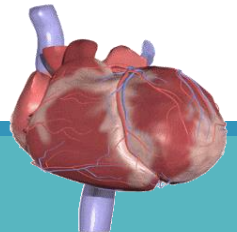
  Contraindications to beta-blockers

  Renal impairment/Metformin
- Turn around time 24-48 hours



Appointment and Patient Preparation

- Booking appointments
- Patient letter
  - Asks to contact if asthma, allergy, kidney problem, diabetes
  - Staff training to answer above queries
  - Continue to drink fluids
  - No tea, coffee or caffeine drinks for 3-4 hours before
- 2-3 patients per hour for CTCA
- Patient to come 30 minutes to 1 hour before appointment



ACR Manual on Contrast Media

Version 10.3

ACR Committ
Contrast Med

The Committee recommends that patients taking metformin be classified into one of two categories based on the patient's renal function (as measured by eGFR).

Category I

In patients with no evidence of AKI and with eGFR ≥30 mL / min/1.73m^2, there is no need to discontinue metformin either prior to or following the intravenous administration of iodinated contrast media, nor is there an obligatory need to reassess the patient's renal function following the test or procedure.[1]

Category II

In patients taking metformin who are known to have acute kidney injury or severe chronic kidney disease (stage IV or stage V; i.e., eGFR< 30), or are undergoing arterial catheter studies that might result in emboli (atheromatous or other) to the renal arteries, metformin should be temporarily discontinued at the time of or prior to the procedure, and withheld for 48 hours subsequent to the procedure and reinstituted only after renal function has been re-evaluated and found to be normal.

ACR
American College of Radiology
Quality is Our Image

INTRAVASCULAR IODINATED CONTRAST MEDIA (ICM) ADMINISTRATION

ESTIMATED GLOMERULAR FILTRATION RATE (eGFR)

Using the Modification of Diet in Renal Disease (MDRD) equation.
The four-variable MDRD equation takes into account age, race, gender, and serum creatinine level.

eGFR (ml/min/1.73 m2) = 175 × (serum creatinine in mg/dl)$^{-1.154}$ × (age in years)$^{-0.203}$ × (0.742 if female) × (1.212 if African American)

*30-day interval between baseline renal function assessment and contrast medium administration in at-risk patients.

1 - 59 ml/min/1.73 m^2

1 - 29 ml/min/1.73 m^2

Any ICM should be avoided in this patient group

Consult Radiologist(s) and refer Physician(s)

Proceed with alternative imaging examination

30 - 59 ml/min/1.73 m^2
(Relative contraindication)

Consult Radiologist(s) and refer Physician(s)

Proceed with alternative imaging examination

If no alternative imaging examination ∴ proceed with CT, however with;

- Use of **low osmolality contrast media** (LOCM)
- Provide **intravenous volume expansion** prior to ICM administration.
  Isotonic fluids are preferred (Lactated Ringer's or 0.9% normal saline) e.g. 0.9% saline at 100 mL/hr, beginning 6 to 12 hours before and continuing 4 to 12 hours after (inpatient setting). Oral hydration may also be utilised.
- Recheck serum creatinine at 24 to 48 hours after ICM administration.

≥ 60 ml/min/1.73 m^2

Proceed with ICM administration and CT

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1. Nama : ..... PID : .....

2. Tarikh Pemeriksaan : ..... Hari: ..... Masa: .....

BORANG PERSEDIAAN PESAKIT UNTUK PEMERIKSAAN CT SCAN

Persediaan bagi pemeriksaan berkontras

Untuk pemeriksaan CT Scan yang melibatkan kontras media, pemeriksaan pagi : Anda dikehendaki berpuasa selama 6 jam sebelum pemeriksaan (melainkan minum- disyorkan tidak lebih dari 100 ml air kosong).

Jika pemeriksaan pada waktu petang 2-5 petang : Anda dibenarkan mengambil sarapan pagi yang ringan (makanan tanpa serat seperti sup kosong dan mee segera tanpa daging) dan berpuasa selepas itu.

- ☐ Pemeriksaan bagi wanita hendaklah dijalankan 10 hari dari tarikh pertama haid melainkan pesakit telah **'menopause'** atau pesakit yang mengambil pil pencegah kehamilan.
- ☐ Pengambilan ubat-ubatan perlu diteruskan kecuali dinasihatkan untuk berhenti.
  1. Pesakit kencing manis dinasihatkan supaya mengambil ubat kencing manis. Bagi ubatan yang mengandungi *Metformin*, konsultasi dengan doktor diperlukan
  2. Pesakit hipertensi atau sakit darah tinggi juga dinasihatkan mengambil ubat.

Persediaan bagi Pemeriksaan CT Scan Abdomen/Pelvis

- ☐ Ambil satu hingga dua tablet Dulcolax sehari sebelum pemeriksaan
- ☐ Kontras melalui mulut mungkin boleh diberikan satu jam sebelum pemeriksaan di Unit Imejan IPPT.
- ☐ Untuk CT Pelvis, 'vagina tampon' perlu dimasukkan semasa di wad bagi wanita yang sudah berkahwin. Kontras melalui rektum hanya diberi sejurus sebelum pemeriksaan bermula.
- ☐ Bagi bayi dan kanak-kanak yang masih dalam peringkat penyusuan, penyusuan terakhir adalah 2 hingga 3 jam sebelum pemeriksaan bermula.
- ☐ Bagi kanak-kanak dan orang dewasa yang tidak dapat berkerjasama, pelalian yang berkesan adalah diperlukan
- ☐ Lain-lain persediaan : .....

PERINGATAN PENTING
Pesakit adalah dinasihatkan untuk mengikuti segala peraturan pemakanan yang telah ditetapkan.
Ini adalah amat penting untuk memastikan pemeriksaan dapat dijalankan dengan lancar.

*** Dengan ini saya mengesahkan bahawa saya memahami dan mematuhi segala arahan dan peraturan yang diberikan. Saya dengan ini membenarkan pihak Unit Imejan IPPT untuk menjalankan prosedur rawatan seperti yang diterangkan di dalam borang ini.**
*** Saya juga membenarkan imej pemeriksaan ini digunapakai bagi tujuan pengajaran dan penyelidikan.**

Tandatangan Pesakit **Tandatangan Juru X-ray/Jururawat**

....

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SENARAI SEMAK PESAKIT BERISIKO

Nama Pesakit : _____ No. PID : _____

Jenis Pemeriksaan : _____ Melibatkan Kontras Media ☐

Creatinine Result : _____ Tanpa kontras Media ☐
Normal Range Creatinine result : (58-96 m mol/l)

Borang ini hendaklah diisi dan ditandatangani oleh doktor yang memohon pemeriksaan radiologi yang memerlukan kontras intravascular.

Sila beritahu Juru X-ray/Pegawai yang bertugas sekiranya pesakit:

	Ditanda oleh		Disemak oleh	
	YA	TIDAK	YA	TIDAK
1. Asma *(Asthma)*				
2. Sejarah apa-apa jenis alahan yang jelas. *(ubat-ubatan / makanan laut / produk tenusu / lain-lain.....)* *(History of known allergic reaction eg: medications / seafood/ lactose intolerance / other.....)*				
3. Sejarah reaksi pada kontras pada pemeriksaan dahulu. *(Previous history of allergic reaction to radiologic contrast media)*				
4. Dehidrasi *(Dehydration)*				
5. Penyakit buah pinggang *(Renal disease)* *(BUSE & Creatinine: .....)*				
6. *Multiple myeloma*				
7. Anemia sel sabit *(Sickle cell anemia)*				
8. Penyakit jantung *(Heart disease)*				
9. Mengandung atau disyaki mengandung. *(LMP : ...../ Pregnant.....week/month)*				

Sekiranya **YA** bagi salah satu di atas, sila analisa kembali keperluan pemeriksaan ini. Sila bincang dengan pakar radiologi jika ada pemeriksaan lain yang lebih sesuai dengan keadaan pesakit.
Pesakit kategori 1 hingga 3 memerlukan steroid sebelum menjalani pemeriksaan:
Tab. Prednisolone 50mg 13, 7, dan 1 jam sebelum pemeriksaan dijalankan.
(Dos ini adalah untuk orang dewasa. Sila sesuaikan dos untuk kanak-kanak)

Tandatangan / Cop Jari Pesakit / Keluarga / Penjaga	**Doktor Yang Merawat (Doktor Yang Memohon)**	**Disemak Kembali Oleh Juru X-ray**
.....	.....	.....
Nama :	**Nama :**	**Nama :**
K/P :	**K/P :**	**K/P :**
Tarikh :	**Tarikh :**	**Tarikh :**
	Cop Rasmi :	**Cop Rasmi :**

On Arrival

- Patient in the department - Radiographers, staff nurses
- Anxious patient - Confident and reassuring, putting patient at ease
- Explaining the procedure

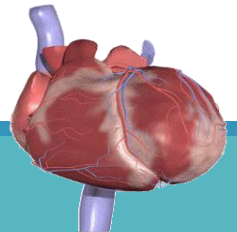
  Is this the right patient for CCT? Too large?

  Contraindication to beta-blockers?

  Irregular rhythm?

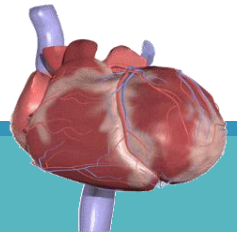
  Unable to lie flat or raise arms above shoulders

  Unable to hold breath or follow commands



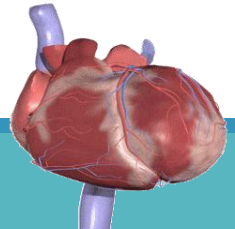
On Arrival

- Information about
  - Renal function
  - Diabetic on Metformin
  - Potential pregnancy
  - Allergic reactions to contrast previously



Managing Heart Rate

- Requirement of slow and stable heart rate (≤ 65 bpm) - scanner dependent
- To obtain optimal quality images - less motion
- To allow prospective gating - lower radiation dose
- If ≥ 65 bpm, check for contraindications to beta-blockers e.g. severe asthma, severe heart failure, severe aortic valve stenosis, hypertrophic obstructive cardiomyopathy (HOCM), pericardial constriction, calcium channel blockers



Beta-Blocker

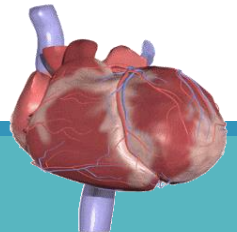
- Only oral, Oral followed by IV if required, Only IV
- If no contraindications

  Start with 50 mg oral Metoprolol (100 mg if weight > 100 kg)

  Check after 30 min, if still > 65 bpm, give another 50 mg

  After 15-20 minutes of 2nd dose, start with the calcium scoring

  If HR > 65 bpm, give additional IV Metoprolol up to 30 mg



Beta-Blocker

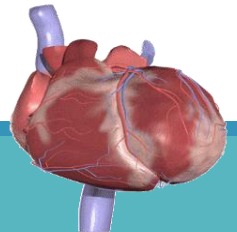
- Other options

  Only IV Metoprolol (up to 40 mg, in boluses of 5-10 mg followed by saline)

- If contraindication to Beta-blockers

  Oral Ivabradine 5mg x bd (start 2-3 days in advance)

  IV Verapamil/Diltiazem



The British Journal of Radiology, 85 (2012), e424–e428

Safety and efficacy of oral ivabradine as a heart rate-reducing agent in patients undergoing CT coronary angiography

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Objective: To investigate the role of oral ivabradine as a heart rate reducing agent in patients undergoing CT coronary angiography (CTCA). Despite the routine use of β-blockers prior to CTCA studies, it is not uncommon to have patients with heart rates persistently above the target range of 65 bpm. Ivabradine is a selective inhibitor of the I_f current, which primarily contributes to sinus node pacemaker activity, and has no significant direct cardiovascular effects such as reduction of blood pressure, cardiac contractility or impairment of cardiac conduction.
Methods: We investigated 100 consecutive patients who had been referred for CTCA for the evaluation of suspected coronary artery disease (CAD). Patients were randomised to receive either of the following two pre-medication protocols: oral metorprolol or oral ivabradine.
Results: Ivabradine was significantly more effective than metorprolol in lowering the heart rate; the mean percentage reduction in heart rate with ivabradine *vs* metorpolol was 23.89±6.95% *vs* 15.20±4.50%, respectively ($p=0.0001$). Metoprolol significantly lowered both systolic and diastolic blood pressure while ivabradine did not. The requirement of additional doses to achieve a target heart rate of <65 beats per min was also significantly more frequent with metoprolol.
Conclusion: Ivabradine is a potentially attractive alternative to currently used drugs for reduction of heart rate in patients undergoing CTCA.

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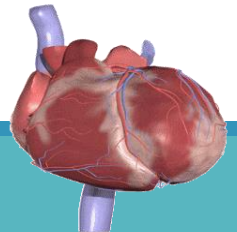
Nitrates

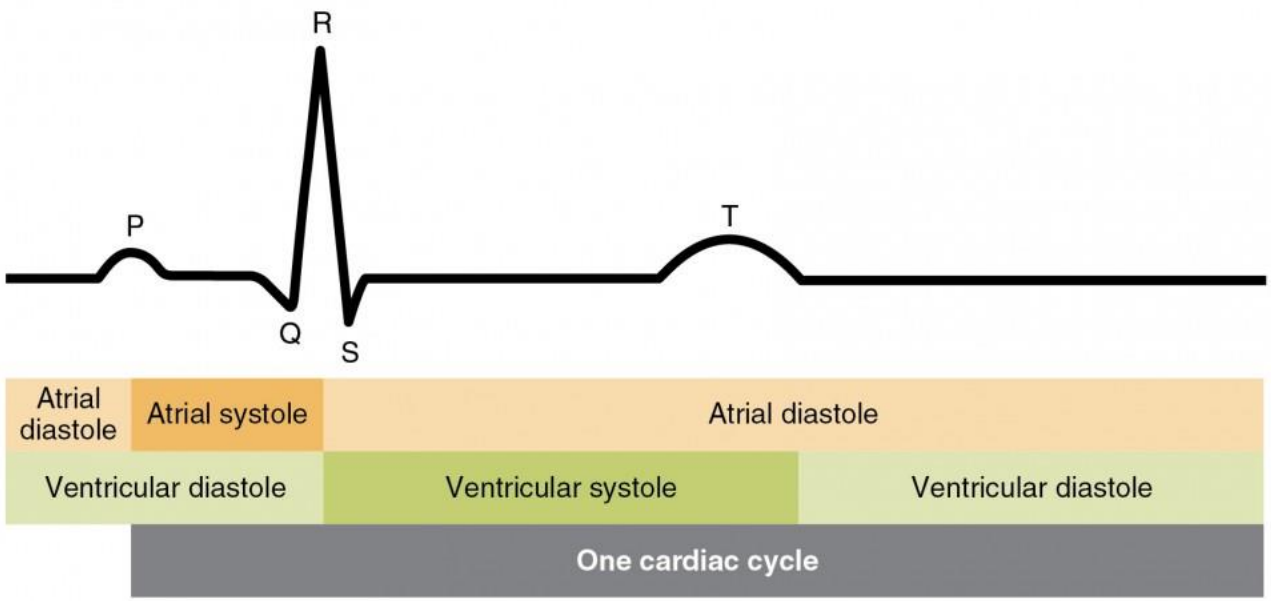
- To dilate the coronary arteries and improve image quality
- 400-800 µg (1 or 2 puffs) sublingually before Cardiac CT
- Contraindications - Hypotension (systolic < 100 mmHg), taking Viagra, severe aortic valve stenosis, HOCM

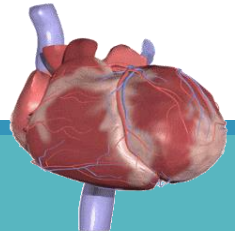


Patient Positioning

Ideal ECG

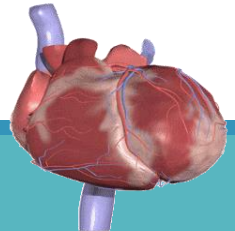
- Regular/Good R wave/Flat T-P interval

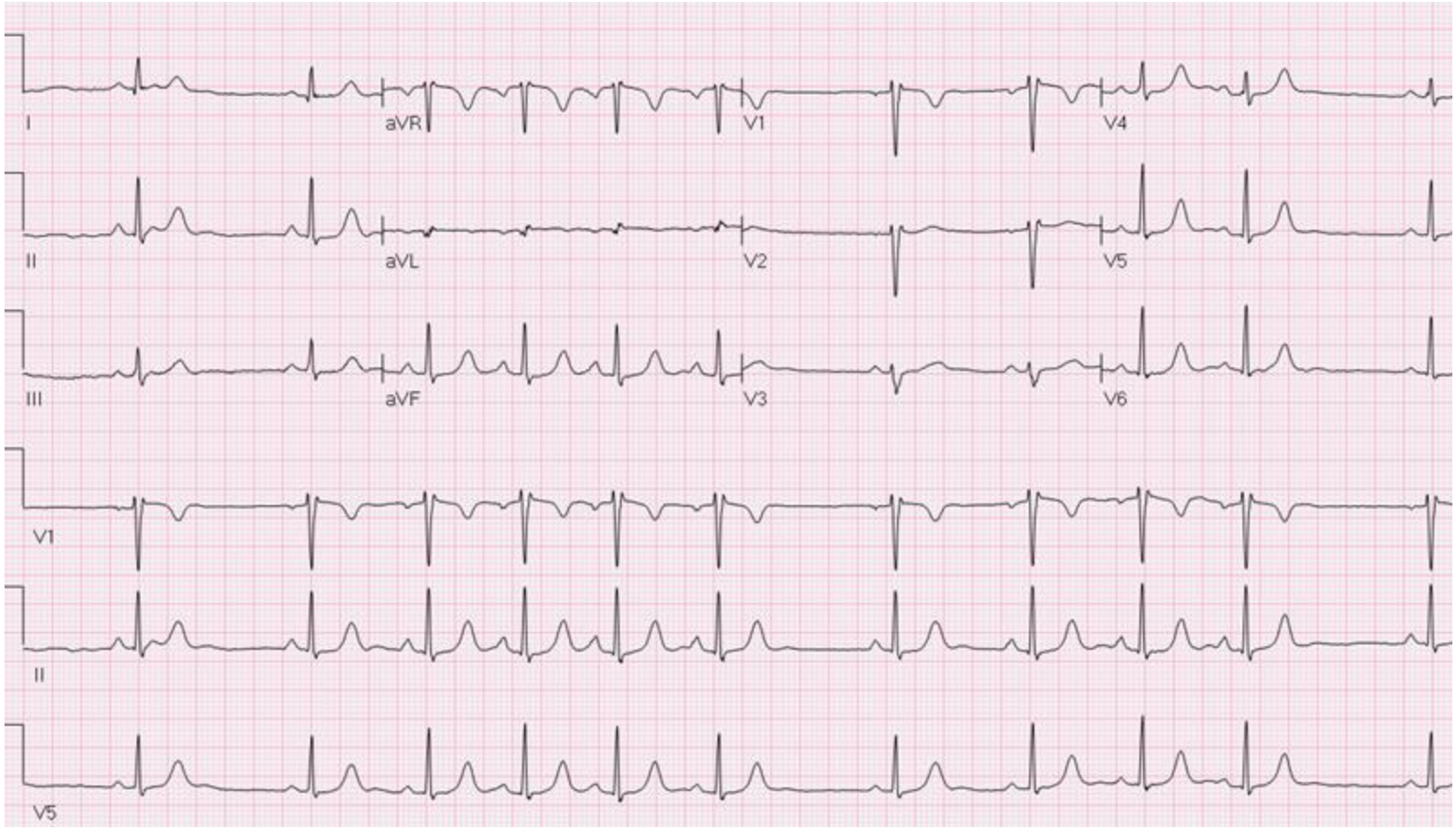




Real ECG

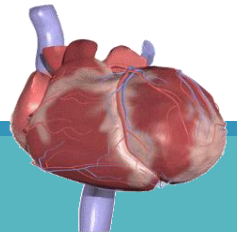
- Large T waves could be read as R wave by scanner
- Fluctuating baseline - is this interference or heart movement?
- Change lead selection - may reduce T wave amplitude
- Ensure no muscle tremor
- Consider moving ECG position
- Post processing ECG edit (where available)




I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5

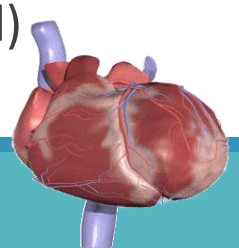
Practice

- Breath-holding
  - Essential for good image quality
  - ¾ size gentle breath, not Valsalva manoeuvre
- Practice with patient
  - Ensure patient can hold breath for the duration
  - ECG signal is good and steady, confirm before continuing
- Confidence and reassurance
  - Make the patient comfortable and relaxed
  - Reassure them and give them a smile



Achieving Optimal Opacification

- Contrast flux (Rate x Concentration)
  - Rate of contrast injection (4-7 ml/s)
  - Contrast concentration (> 350 mg I/ml)
- Patient's body weight/BMI
  - Increased image noise in larger patients, increased flux required
- Circulation Time
  - Time to peak enhancement, cardiac output
- Volume injected
  - Affected by scan length (native coronaries vs grafts)
  - Scanner speed and protocol (any extra areas to be scanned)

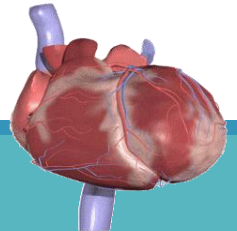


Contrast Protocol

- Low osmolar contrast media (350 or 370 mg Iodine/ml)
- The maximum recommended total dose of iodine in adults is **86 grams**

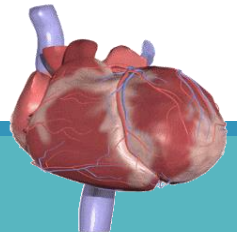
Phase	Biphasic	Triphasic
Phase 1	75* ml @ 5 ml/s (≈ 15s)	60 ml/s @ 5 ml/s (≈ 12s)
Phase 2	40 ml saline @ 5 ml/s	50% contrast + 50% saline xx ml @ 5 ml/s (xx = scan time x 5)
Phase 3		40 ml saline @ 5 ml/s

*100-120ml for triple rule out (CAD, pulmonary artery embolism and aortic dissection)



CCT Protocol

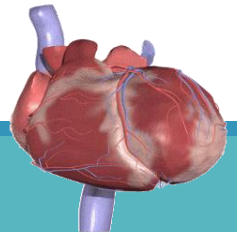
- Just CT calcium scoring
- CT calcium scoring with CTA of native coronaries
- CTA of native coronaries
- CTA of bypass grafts
- TAVI/R protocol
- Any delayed phase
- Any extra scans - chest, abdomen



Using The Right kVp

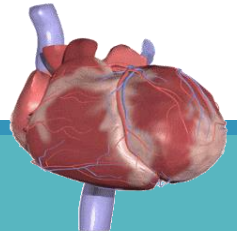
- In borderline body size, if calcium or stents or graft, use higher kVp
- Each 20 kVp decrease reduces radiation dose by 40-50%

kVp	Body Weight (kg)	BMI
120 kVp	> 90	> 30
100 kVp	70-90	23-30
80 kVp	< 70	< 23



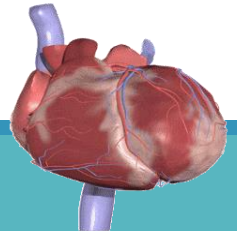
Scanning

- If only CT calcium scoring then **JUST SCAN** (ECG-gating)
- For CTCA, requires ECG-gating, beta-blockers, nitrates, IV contrast



Calcium Scoring Scan Protocol

Factor	Range	Depends upon
kV	120	Constant, irrespective of scanner
mA	80-350	Patients' body size
Slice thickness	2.5/3.0 mm	Constant, irrespective of scanner
Slice increment	2.5/3.0 mm	Constant, irrespective of scanner
Rotation time	0.35 s	CT scanner
Breath hold time	10-15 s	CT scanner
Kernel	Cardiac	

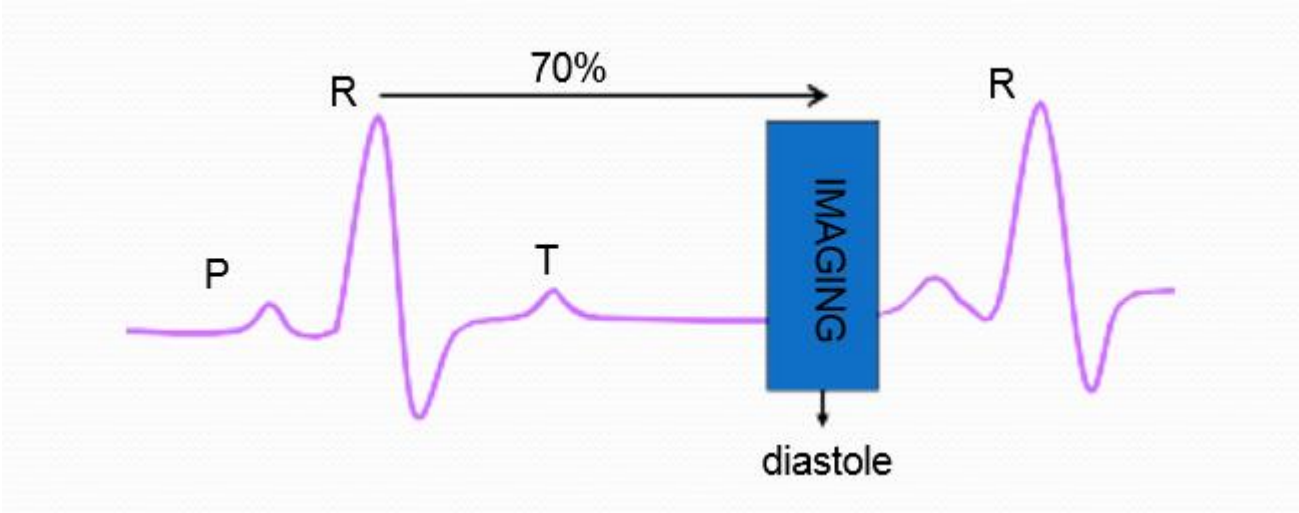


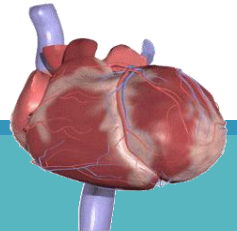
Topogram

Prospective STEP and SHOOT/ Single beat

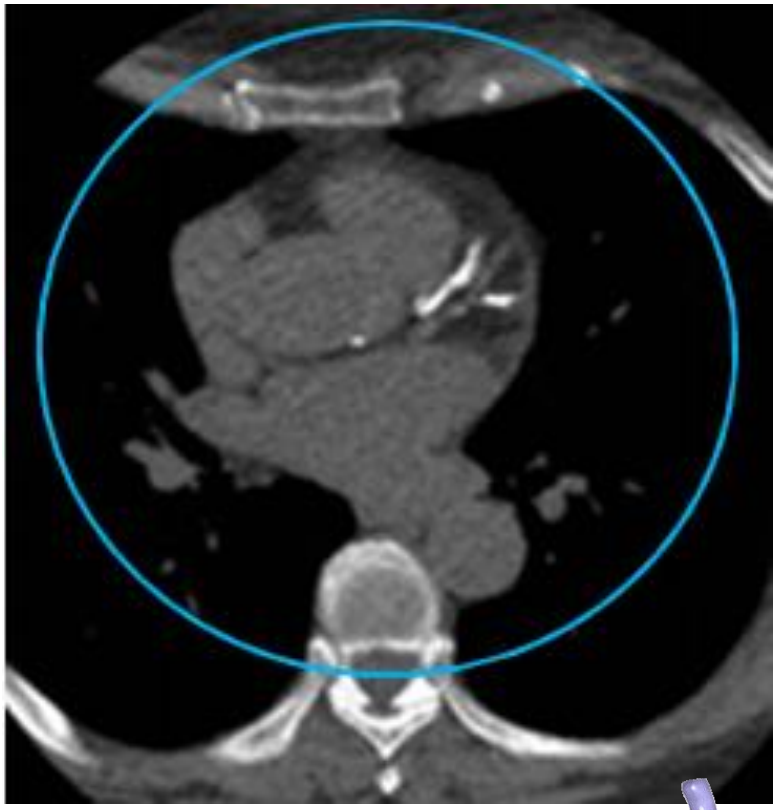
- One heart beat is necessary to move the table between scans
- Slower scan times and more heart beats to cover the entire heart
- On wide detector scanner, no table movement as acquisition in single heart beat (80-160mm detector width)

Prospective ECG gating



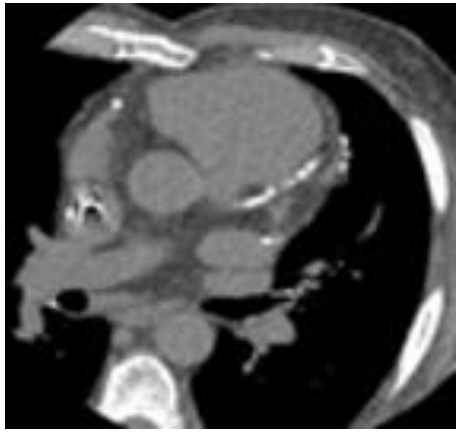


- Set a small FOV 25cm
- Improves spatial resolution



Standard Reconstructions

- Small FOV 2.5/2.5 mm on Cardiac Kernel



- Full FOV 0.625/0.625 mm on Lung Kernel

CT Coronary Angiography

- Administer beta-blockers to HR < 65 bpm (scanner dependent)
- Administer GTN
- Breath-holding exercise

  Heart rate and variability

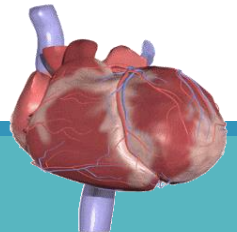
  Prospective/Retrospective/Padding (multislice)

  Acquisition window

  Pitch and Tube rotation time

  Reconstruction mode

  Adaptive gating activation



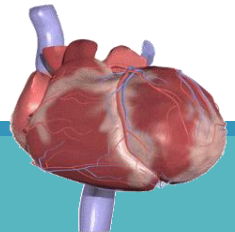
Topogram

- Planning for native coronaries

Level of carina to below the inferior border of the heart/apex

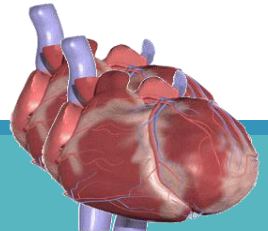
- Planning for bypass grafts

From above the mid clavicles to below the inferior border of the heart/apex



CT Coronary Angiography Protocol

Factor	Range	Depends upon
kV	80-120	Patients' body weight and BMI
mA	250-350	Patients' body weight and BMI
Slice thickness	0.5-0.625 mm	CT scanner
Slice increment	0.3-0.6 mm	CT scanner
Rotation time	0.25-0.35 s	CT scanner
Breath hold time	10-20 s	CT scanner and Protocol
Kernel	Cardiac, Sharp	



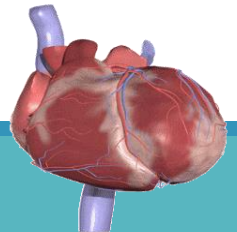
Protocol

- **PROSPECTIVE** vs **RETROSPECTIVE**
- Choose **PROSPECTIVE** (with or without padding) as default **unless**

  HR < 65 bmp (or as per your scanner) cannot be achieved

  Irregular rhythm

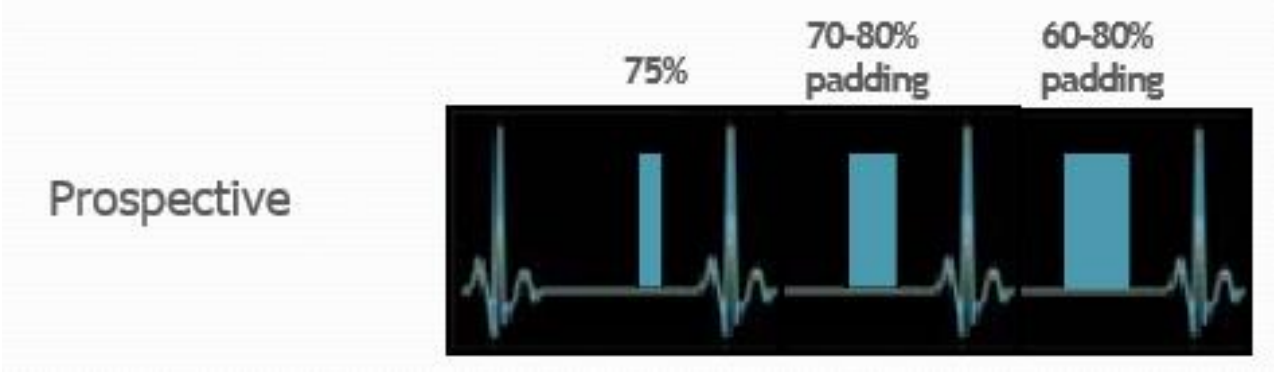
  Evaluation of aortic valve, function
- HR < 65 bpm (depends upon scanner) - Prospective 70-80%
- HR 65-75 bpm - Prospective 30-50% systolic
- HR > 75 bpm - Prospective 40-80% or Retrospective with ECG modulation 40-80%

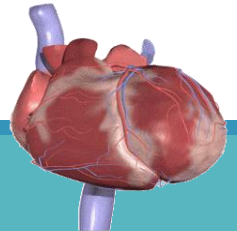


Prospective ECG gating

- HR < 65* bpm with variation <10% = End-diastolic (ED) (70-80%)
- HR > 65* bpm and/or variation >10% = End-systolic (ES) (30-50%)
- HR > 75* bpm and/or variation >10% = ES-ED (40-80%)

*depends on CT scanner



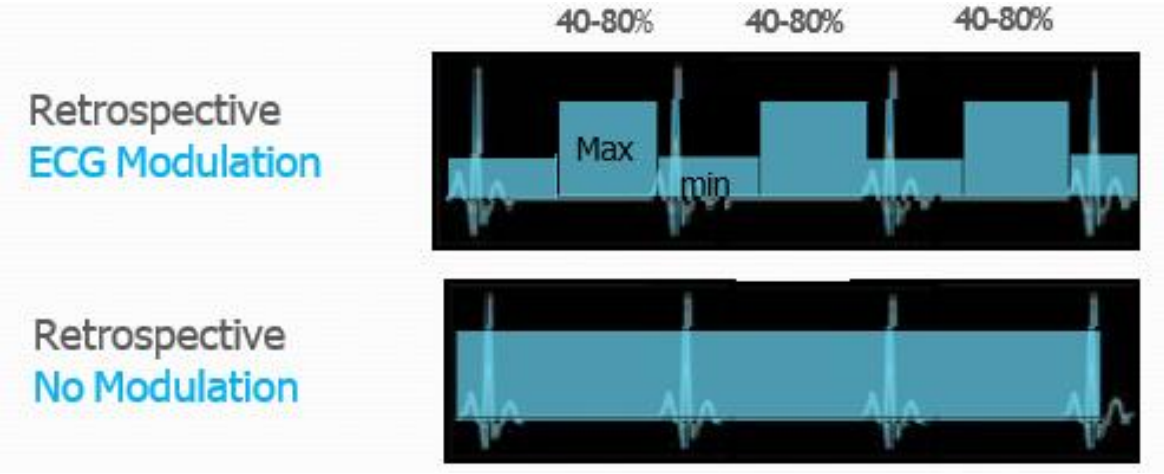


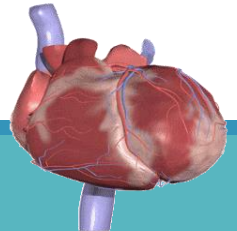
Retrospective ECG gating

- Not applicable for wide detector CT scanners
- For other, HR > 70-75* bpm and/or variation > 10% =

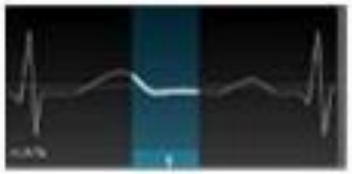
  ES-ED (40-80%) for coronaries

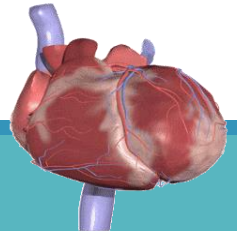
  ES (20-40%) for TAVI





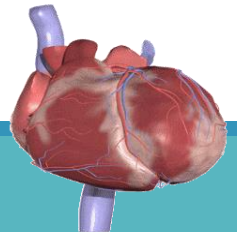
Wide Detector ECG gating

Low Heart Rate <60bpm		75%
Moderate Heart Rate 60-70 bpm		70-80%
Intermediate Heart Rate 70-80 bpm		40-80%
High Heart Rate >80bpm		40-55%



Contrast Timing

- Time from contrast injection to commencement of scan
- Depends on
  - Venous access and flow rate
  - Cardiac output
- Two methods
  - Test bolus
  - Bolus tracking



Test Bolus

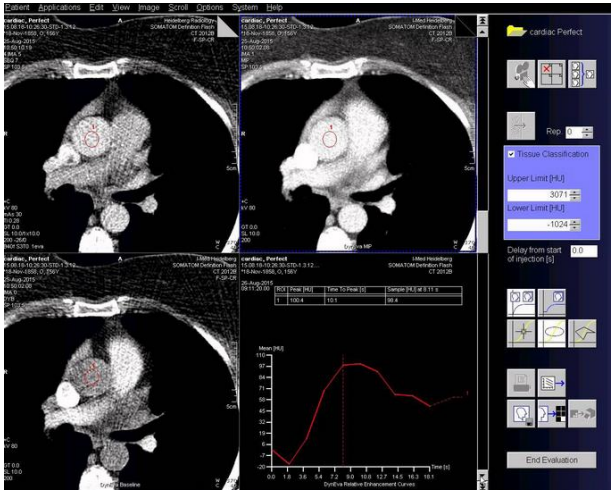
- 10-20 ml contrast followed by 20 ml saline @ 5ml/s
- Advantages

  Timing of the scan is known beforehand

  Patient knows what to expect for the main injection
- Limitations

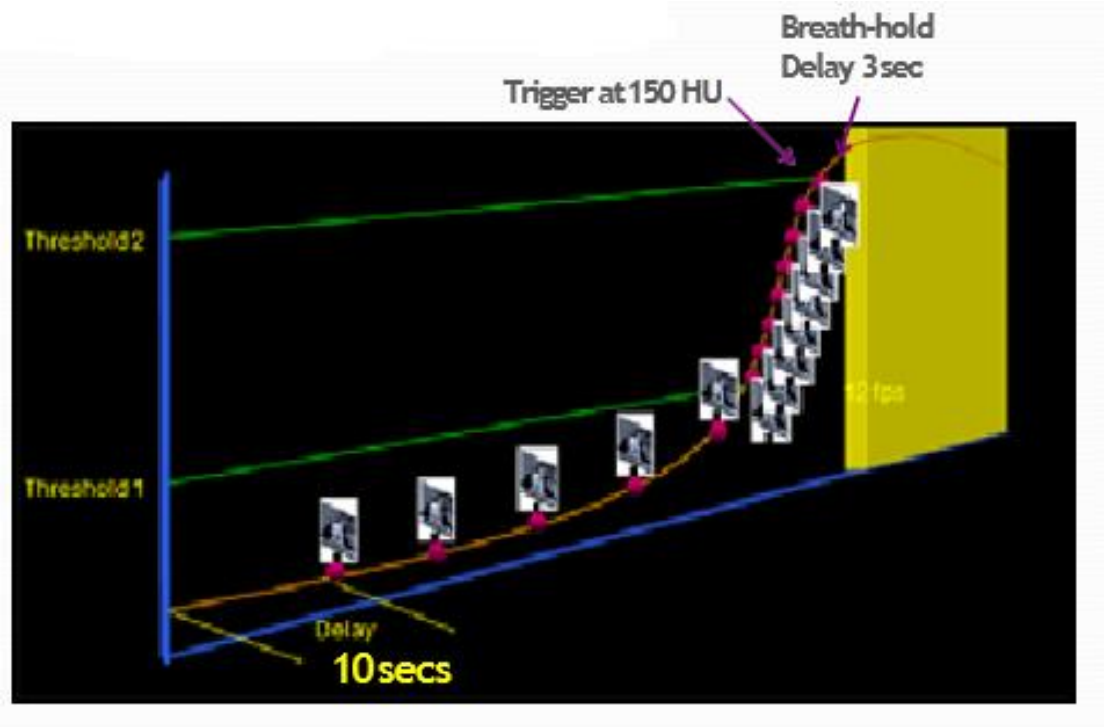
  Extra contrast

  Takes more time



Bolus Tracking

- Dynamic or manual trigger on vessel of choice



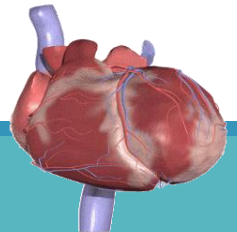
Just Before Scanning

- Tell patient that exam is almost complete
- Inform patient

  Hot feeling from contrast, try to ignore

  Concentrate on same breathing as practised

  Keep nice and still, try not to move
- Confirm good ECG signal and steady heart rate
- Start contrast injection and monitoring (or acquisition) simultaneously

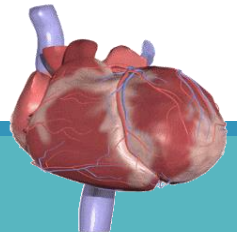


During Scanning

- ECG remains stable
- Patient is not distressed - check for possible contrast extravasation
- Patient is able to follow breathing instructions
- As soon as scan is acquired, check for

  Adequate coverage

  Adequate contrast opacification



After Scanning

- Patients status reassessed

  Reassure hot flush will wear off quickly

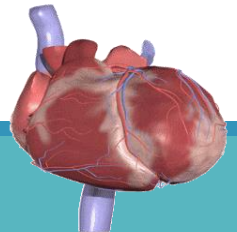
  Look for reactions to contrast, beta-blockers or GTN

- Good images obtained?

  Cannula and ECG are removed

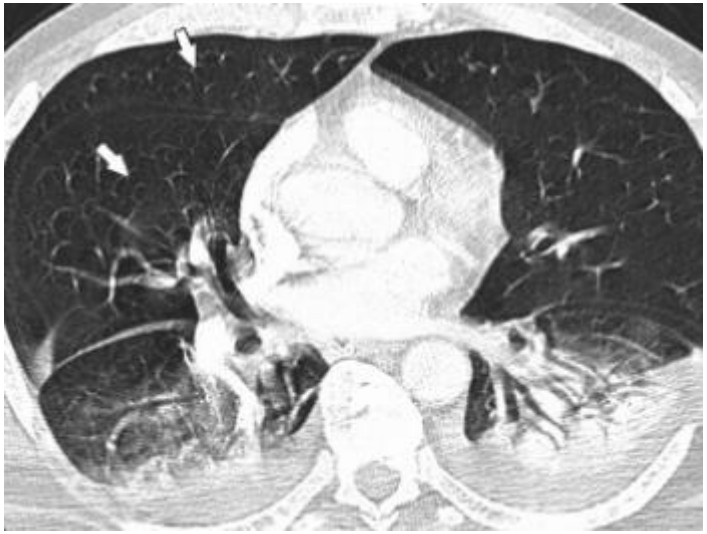
- Patient leaves department after 10-15 mins

  Inform patient they may continue normal activities but ideally not to drive for a few hours if beta-blockers given



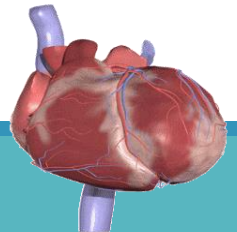
Breathing Artefacts

- Breathing during the scan results in poor image quality
- Only solution is PREVENTION
  - Assess breath-holding capacity
  - Breathing instructions
  - Breathing exercise
  - Putting patient at ease



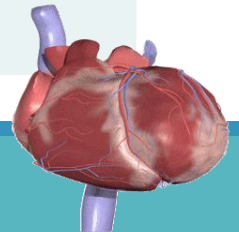
Retrospective gating ECG editing

- Specific to each scanner
- Important for radiographers/supervising doctors to know limitations
- Can improve image quality



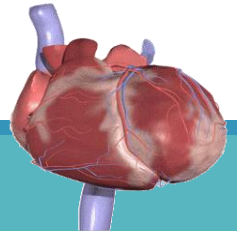
Reconstructions

Recon	Slice Thickness/Interval	Window
Coronaries/Grafts **Prospective** ❖ Single phase ❖ Padding (e.g. 70-80% @ 5% interval) **Retrospective** (Do every 10% during best quality interval)	0.5-0.6/0.3-0.6 mm @ 5 or 10% interval	Cardiac
Function if performed retrospective 0-90% at 10% intervals (retrospective only)	1.0-2.0/1.0-2.0 mm	Cardiac
Full FOV at 75%	1.0-2.0/1.0-2.0 mm	Cardiac
ECG, Radiation dose summary		



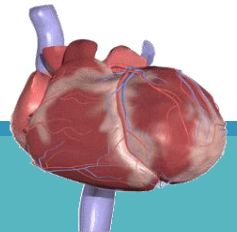
Finally

- Radiographer has to ensure that
  - Reconstructed and checked the images as per the protocol
  - Transferred the images to relevant archive destinations
  - Filled in the procedure information on the patient safety questionnaire
  - Scan completed



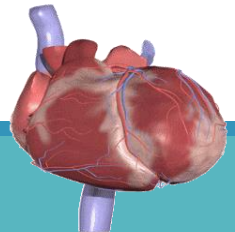
Reporting

- Radiologist/Cardiologist to report within their session or accepted time frame
- Send key images/cines to PACS/CD
- Report to be dispatched externally to referring physician/team



Summary

- Training, motivation and defined work flow
- Correct protocol is understood
- Region to be scanned
    - Gating
    - kVp
    - Appropriate heart rate control
- Patient is relaxed



Any Questions?

Thank You

Radiation Protection CME 2018 Revisiting The Heart: Computed Tomography Based Seminar