The Royal Australian and New Zealand College of Radiologists®

AIT
(Applied Imaging Technology)
Paper 1

Tuesday, 16 March 2019

Please write your answers in the books provided, starting each question on a new page.

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Case 1

Section 1 (Radiation Biology and Safety)

Question 1

a) In the context of the biological effects of ionising radiation, explain what is meant by deterministic effects (also known as tissue reactions). Relate your answer to the type of damage that may be caused at the cellular level and the dose-response relationship of such effects. **(3 marks)**

b) Following a lengthy neurointerventional procedure, the total air kerma incident on an area of the patient's skin is estimated to be 4 Gy. State what tissue reactions the patient *may* experience, with approximate timeframes. **(3 marks)**

c) The neurointerventional lab is equipped with a state-of-the-art fluoroscopy unit with flat panel digital detector. It is used clinically under Automatic Exposure Rate Control. List 4 practical procedural measures that you might implement to ensure that the patient entrance skin dose is minimised, with a brief explanation for each measure. **(4 marks)**

Question 2

a) A 20-year-old female patient is 6 weeks pregnant and has suspected pulmonary embolism. Her referring doctor is considering a CTPA scan

The foetal dose associated with this procedure has been estimated by the medical physicist as 0.05 mSv.

i) Briefly describe the potential radiation risks to the foetus and how you would communicate these to the referring doctor. **(2 marks)**

ii) The medical physicist offers to estimate maternal organ doses. State, with reasons, which organ dose you consider most relevant for this patient. An estimate of organ dose is not required. **(2 marks)**

iii) You recommend that a chest radiograph is performed first to rule out other causes of the symptoms. List 3 strategies you would employ to minimise the maternal and foetal radiation dose, with brief reasons. **(3 marks)**

b) One of your radiology colleagues informs you that she is pregnant.

i) What is the regulatory dose limit to the foetus for a pregnant radiation worker? **(1 mark)**

ii) Over the full term of the pregnancy, what dose reading would you allow on her personal radiation monitoring badge to ensure that the regulatory limit is met? Give a reason for your answer. **(2 marks)**

Question 3

a) Working in a DSA suite, what personal protective equipment should you expect to be provided by your employer? **(3 marks)**

b) List the major components of a program you would initiate for the safe management of your X-ray protective gowns (often referred to as lead aprons). **(2 marks)**

c) Briefly explain:

i) the concepts that are used to develop an effective dose (mSv) from an external source of air kerma (mGy) delivered from a diagnostic imaging procedure. **(3 marks)**

ii) why is it *inappropriate* to use effective dose, E (mSv), as an individual risk estimate for a specific patient undergoing a diagnostic imaging procedure? **(2 marks)**

Case 2

Section 2 (Basic Physics & Technology including Mammography, Fluoroscopy & DSA)

Question 1

a) Briefly describe the impact of 3 factors that have a substantial effect on limiting spatial resolution in projection radiographic imaging. **(3 marks)**

b)

i) With regard to image noise, what is 'quantum mottle' (QM)?

ii) What determines the amount QM present in an image? **(2 marks)**

c) What are the clinical uses for the exposure modes of acquisition and fluoroscopy as used in angiographic procedures? For an average sized patient, what is the approximate ratio of the dose rates between the two modes? **(3 marks)**

d) A referrer mentions that the x-ray images from your facility are diagnostically adequate but noisier than those from another service provider. Under what conditions could you justify the quality of these images from your facility. **(2 marks)**

Question 2

a) Identify and describe the principal atomic interaction responsible for the scatter x-ray component production during a diagnostic x-ray examination. **(2 marks)**

b) Define what is meant by the term Contrast to Noise Ratio (CNR) in the context of digital image quality. Describe how this concept can be applied in a clinical context. **(2 marks)**

c) Identify 3 factors that can be altered during x-ray image acquisition that can favourably improve the Contrast to Noise Ratio in a planar digital radiograph. With each identified factor please also supply the reason why the CNR is improved. **(6 marks)**

Question 3

a) Explain the *intent* behind the operation of an Automatic Exposure Control (AEC) system used with a Digital Radiography system. A description of the technology is not required. **(2 marks)**

b) A wall mounted vertical Bucky typically has three ionisation chambers located on the patient side of the image receptor. What is the position of the grid in relation to the ionisation chambers and the image receptor? In the context of Chest AP imaging explain why there are 3 chambers, and how these can be used effectively. **(3 marks)**

c) What is meant by the term 'modulation transfer function' (MTF) for an image receptor? **(2 marks)**

d) The figure shows hypothetical MTF curves for two mammographic systems: one screen film and the other digital. Which system represents the digital system? Justify your choice. Discuss the reasons why the image quality of this system is judged superior to the other. (3 marks)

Case 3

Section 3 (CT, MRI, US & Nuclear Medicine)

A CT exam is performed where the exposure factors are 120 kV, 150 mAs, a pitch of 1:1. Automatic current modulation is not employed.

The reconstruction is performed using filtered back projection with a bone filter, and the reconstructed slice width is 1 mm.

The signal to noise ratio (SNR) of the resultant images is too low.

The patient is rescanned with the mAs increased to 300 mAs, and all other factors unchanged.

Question 1

a) Explain why this will increase the SNR. **(2 marks)**

b) Describe the effect on effective dose, and why. **(2 marks)**

c)

i) List two ways that the initial data set could have been reconstructed to improve SNR without having to rescan the patient.

ii) For each, briefly explain why the SNR is improved. **(4 marks)**

d) A multislice CT scanner has 32 detector rings each 0.625 mm in length along the z (long) axis. If a single tube rotation resulted in 16 slices, and all of the detector rings were exposed, what is the

i) nominal beam width (ignore overbeaming)? (1 mark)

ii) acquired slice width? (1 mark)

Question 2

a) From the perspective of radiation protection of the patient, what is main advantage of MRI over CT? **(1 mark)**

b) With regard to the chemical shift artefact in MRI, briefly describe

i) its appearance and (1 mark)

ii) its cause. **(3 marks)**

c) For each patient device, list *one reason* why it may contraindicate an MRI:

i) Cardiac pacemaker (1 mark)

ii) Aneurysm clip (1 mark)

d) Aside from the slice section gradient, two other types of gradient fields are applied during MRI image acquisition to encode spatial information. The se are applied to encode what rotational information for the precessing net magnetic moment in a voxel? **(2 marks)**

e) Briefly describe the key difference between the inversion recovery sequence and the spin-echo sequence. **(1 mark)**

Question 3

a) Diagnostic ultrasound imaging is mostly performed using sound with frequencies in the range from around 2 MHz to around 15 MHz. General abdominal ultrasound imaging generally uses probes with a frequency in the range 2 MHz - 5 MHz. However, for imaging superficial structures higher frequency probes, in the range of 5 MHz - 15 MHz would normally be used.

Explain why probes having the frequencies in ranges noted above are used in these two types of imaging applications. **(4 marks)**

b) The image below shows a colour Doppler scan and the colour map on the left shows that blue is the 'toward' colour and red is the 'away' colour. The scan is of the common femoral artery (in red) and vein (in blue).

The artery shows a patch of blue (arrow). Assuming flow in the vessel is not turbulent, what does the blue in the artery indicate and explain why this has occurred. **(3 marks)**

c) In general, pulsed Doppler has the greatest potential for inducing thermal bioeffects in tissues.

i) Give two reasons why this is true. (2 marks)

ii) Modern diagnostic ultrasound equipment provides on screen feedback to the operator via two on screen numerical parameters that indicate the risk of bioeffects. State one of these parameters. (1 mark)

Question 4

a) Briefly describe the physical principles of image acquisition in PET imaging. (Note: do not describe methods of PET radioisotope production). **(5 marks)**

b) A colleague suggests increasing the activity used for FDG PET scans for a 70kg patient by 20% from 300 MBq to 360 MBq as a means to reduce imaging time and increase throughput.

Comment on any risks to patients and staff that this would impose. **(3 marks)**

c) For PET imaging there is a fundamental physical factor related to the positron emission energy that limits the ultimate spatial resolution achievable by a PET camera

Ga-68 is a position emitting isotope that is now widely used in addition to F-18 for PET imaging. The maximum energy of positrons for Ga-68 1.92 MeV compared to 0.65 MeV for F-18.

Explain why positron energy affects the spatial resolution achievable in a PET image and as a result make a conclusion about whether Ga-68 or F-18 images will have the best achievable spatial resolution. **(2 marks)**