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Radiation Protection in Cardiac and Interventional Procedures

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Radiation Protection in Cardiac and Interventional Procedures

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Abstract.

With the development of interventional radiology and the recent increasing use of interventional techniques in cardiology and radiology, radiation protection has become increasingly important for both patients and staff. Radiation effects from prolonged screening have even given rise to deterministic effects. The Ionising Radiation Regulations 1999 and the International Radiation (Medical Exposure) Regulations 2000 have been formulated to control medical exposure. They emphasize staff training and the setting up of diagnostic reference levels (DRLs) to optimize radiation exposure. At present there is wide variation in the DRLs being recommended in different centres and countries. Dose reduction requires careful attention to equipment specification and purchase, noting that manufacturers are including effective dose reduction packages but that these are optional. Review of existing equipment is important in terms of potential modifications, such as increasing filtration of low energy radiation to reduce dose, while maintaining diagnostic image quality and involvement of a radiation expert is essential. Consideration must also be given to operational and behavioural factors that increase dose, such as multiple image acquisitions rather than review of fluoroscopy images and inappropriate positioning of X-ray tube and image receptor. All attempts should be made in interventional centres to tailor doses to individual patients and to conform to good radiation practice at all times. Education and training and is necessary to achieve this with at least annual updates. Setting of local standards with regular local audit is important to raise radiation awareness and to improve dose reduction taking into account, local equipment and operators. However it is also important to continue research and communicate on an international basis to produce effective guidance.
Introduction and Background

This lecture does not cover all any interventional radiologist or cardiologist needs to know but does give an overview, emphasize important areas and direct to where all of the important information is available.

Ionising radiation exposure is made up of many sources of which medical exposure is only 20%. However, it is the largest source of man made exposure and is increasing.

Figure 1. Sources of radiation

1.1 Discovery of X Rays

Radiology began with the discovery of X-rays by William Conrad Roentgen in 1895 but it was not long after that the discovery of harmful effects was published. The first report of harmful physical effects was made in the British Medical Journal on 18th April 1896 [ref1]

The early workers developing the technique in the UK all had radiation injuries by 1903 and one died in 1911 after taking photographs of his hands showing progressive bony damage.

Public concern after the death of one of the first radiologists, (William Ironside Bruce) from radiation induced injuries in 1921, led to the setting up of the British X-Ray and Radium Protection Committee [2]. After the Second, International Congress of Radiology in Stockholm in 1928 their recommendations were adopted and the International (X-ray and Radium) Protection Committee began. This was later to be renamed the International Commission on Radiation Protection and, of course, still exists today.

1.2 Biological Effects of X rays

There are two types of effects; stochastic and deterministic. A stochastic effect is a probabilistic event. It always produces cell damage, which is not specific and may be reparable but may result in cancer production. Since the transfer of energy occurs quickly i.e. approximately $10^{-17}$ seconds any radiation protection must be before irradiation. There is no threshold and the probability of the event increases with the dose. The severity is considered maximum, that is, equivalent to a fatal event.
Table 1 Stochastic (random) effects?:

<table>
<thead>
<tr>
<th>Risk of death per year from common causes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking 10 cigarettes/day</td>
</tr>
<tr>
<td>Natural causes (40 year old)</td>
</tr>
<tr>
<td>Accidents on road</td>
</tr>
<tr>
<td>Accidents at work</td>
</tr>
<tr>
<td>Cancer from radiation exposure of 1 mSv</td>
</tr>
<tr>
<td>Majority of NHS staff (&lt;0.3mSv per year)</td>
</tr>
</tbody>
</table>

Deterministic effects have a threshold below which no effect is observable. Above this the severity of the effect increases with the dose. Examples include lens opacities and skin lesions such as erythema, epilation and even necrosis. Some interventional procedures with long screening times and multiple image acquisitions e.g. PCI (percutaneous coronary intervention), RFA (radio-frequency ablation) may give rise to deterministic effects [4].

Table 2 Deterministic effects [5]:

<table>
<thead>
<tr>
<th>Injury</th>
<th>Threshold Dose to Skin (Sv)</th>
<th>Minutes fluoro at 0.02Gy/min</th>
<th>Minutes fluoro at 0.2Gy/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transient erythema</td>
<td>2</td>
<td>100</td>
<td>&lt;&lt;1</td>
</tr>
<tr>
<td>Permanent epilation</td>
<td>7</td>
<td>350</td>
<td>35</td>
</tr>
<tr>
<td>Dry desquamation</td>
<td>14</td>
<td>700</td>
<td>70</td>
</tr>
<tr>
<td>Dermal necrosis</td>
<td>18</td>
<td>900</td>
<td>90</td>
</tr>
<tr>
<td>Telangiectasia</td>
<td>10</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>Cataract</td>
<td>&gt;5</td>
<td>&gt;250 to eye</td>
<td>&gt;25 to eye</td>
</tr>
</tbody>
</table>

1.3 Development of Interventional Radiology

The possibility of intervention started with the development of angiography in the late 1920s by a Portuguese group. There have been many individuals involved in its progress since then; notably Dr Werner Forssman who performed the first cardiac catheter on himself in 1929, using a ureteric catheter and Dr Charles T. Dotter who introduced the concept of remodelling the artery by transluminal angioplasty in 1964 [6].

Coronary angioplasty began in humans with the first case in 1977 by Andreas Gruentzig and has since developed rapidly with almost 2 million being performed in 2001 and an estimated annual increase of 8% [7]. It was the successful use of angioplasty in an evolving myocardial infarct by Dr. Geoffrey Hartzler in 1980 and the development of stents in the late 1980s, which widened the indications and reduced the complications of the procedure making it widely acceptable and now the most common interventional procedure in the world.

Interventional radiology in other anatomical systems has also developed dramatically and can be classified into types of procedure e.g. drainage, coil embolization, filter placement, stenting, foreign body retrieval etc or into anatomical system such as vascular, gastrointestinal, urological and so on. The most frequently performed are angioplasties in peripheral as well as coronary arteries.
2 Regulatory Bodies and Regulations

Ionising Radiation Regulations 1999 relate to public and staff safety and require all staff that may encounter radiation, however briefly, to undergo training.

Ionising Radiation (Medical Exposure) Regulations IR(ME)R 2000 [8] govern the fate of patients undergoing a medical exposure.

These regulations delineate the duties of all bodies—the employer, practitioner, operator and referrer. They require the justification of all medical exposures such that the net benefit outweighs any potential harm. All exposures must be optimised and comply with the ‘as low as reasonably practicable’ (ALARP/ALARA) principle while being consistent with the intended purpose. All members of staff are required to undergo training.

There is an emphasis on patient dose and the requirement for exposures to be within diagnostic reference levels (DRLs) where they exist. The establishment of these reference levels is the preferred method of optimising radiation exposure.

There is also a requirement for employers to produce ‘Local Rules’ i.e. policies for the safe use of radiation in the individual areas where radiation is used to ensure safety of staff, patients and the public.

There are a number of other bodies, which give advice and monitor radiation for example: NRPB- involved in producing documents such as the "Patient Dose Reduction in Diagnostic Radiology" and “Guidance notes for the protection of persons against ionising radiations arising from medical and dental use” [9].

ICRP-2000 guidance- on avoidance of medical injuries from medical interventional procedures was issued on the basis that interventional radiological techniques i.e. fluoroscopy guided techniques were being used by an increasing number of clinicians not adequately trained in radiation safety or radiobiology. Consequently some patients were suffering radiation induced skin injuries and young patients an increased risk of future cancer. Staff also could be exposed to high doses as a result. The recent guidance also recommended recording the cumulative skin dose in interventional radiology [10].

In America, also, there is increasing awareness of the potential impact of medical irradiation. The Food and Devices Agency (FDA) have recently proposed nine amendments to their recommendations for new fluoroscopy equipment. Three of these:

1. Display the rate, time, and cumulative total of radiation emission
2. Filter out more of the lower energy x-rays to reduce dose to patient skin
3. Collimate the x-ray field more “tightly” so that it’s used more efficiently

have been evaluated both in life and financial terms by Stern et al [11]. The projection is of 723 lives per year spared radiation-induced cancer mortality 30 years from the start of implementation of amendments. The average annual financial savings of $519M in the first ten years of implementation greatly exceeds estimated average annual cost of $49M to manufacturers and the FDA.

Other bodies particularly interested in cardiac interventions and offering advice on equipment, practice and training include national specialist societies such as ACC, BCIS, and European Commission’s Radiation Protection Research Program DIMOND III etc.
3  Dose

3.1 Definitions

Gray – the absorbed dose is the energy absorbed per unit mass. In diagnostic radiology this is also equal to KERMA, which is the energy transferred (but not necessarily absorbed) by the radiation to the unit of mass of the material.

Sievert – the equivalent dose is the absorbed dose multiplied by a radiation-weighting factor, which in diagnostic radiology equals one, making equivalent dose equal to absorbed dose but measured in Sieverts.

Effective dose can be used to give an estimate of patient risk and is calculated from the equivalent dose in each organ and tissue multiplied by a tissue-weighting factor and summed over the whole body.

DAP – dose area product (Gycm²) is the product of the incident dose and the area of the X-ray field. This is the most reliable measurement for dynamic examinations such as fluoroscopy in which the projection direction and technique parameters are continually varying.

Entrance skin dose - absorbed dose in the skin at a given location on the patient (Gy). It includes the back-scattered radiation from the patient and is very good for single exposure studies. It may be particularly relevant in difficult and lengthy screening procedures where the incident beam is in the same place for a prolonged period of time but if the X-ray tube is moved around the dosemeter will not remain in the beam and dose will be underestimated.

3.2 Dose Limits

The dose limits laid down by the IRR 99 regulations are shown in Table 3 and these must not be exceeded under any circumstances. These regulations fall under the Health and Safety legislation and a breach is considered a criminal offence.

<table>
<thead>
<tr>
<th>Classified staff</th>
<th>Unclassified/trainees</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>20 mSv</td>
<td>6 mSv</td>
</tr>
<tr>
<td>Eyes</td>
<td>150 mSv</td>
<td>50 mSv</td>
</tr>
<tr>
<td>Organs</td>
<td>500 mSv</td>
<td>150 mSv</td>
</tr>
<tr>
<td>Fetus</td>
<td>1 mSv</td>
<td>1 mSv</td>
</tr>
</tbody>
</table>

Classified workers are those who are likely to receive a dose of more than the dose limits for unclassified staff. This clearly requires careful dose monitoring over time.

Usual monitoring includes a film badge at waist level under the lead apron and a TLD (thermo-luminescent dosemeter) at collar level. Some laboratories only monitor with one film badge in which case it should be at collar level outside the lead apron. Although hand dose will be highest, as the operator’s hand is closest to the beam, very few centres monitor hand dose.
3.3 Dose to patient

There are currently no dose limits for patients but all exposures should comply with the ALARA or ALARP principle and IR(ME)R regulations.

All radiation exposures must be ‘justified’. Local protocols should cover this area, including patient identification and consent to ensure that the benefit outweighs the risk in each individual patient.

Dose reference levels should be set for each category of procedure, which is performed with a frequency of at least 20 per annum. Ideally at least 100 cases should be used to determine a DRL. This should be by DAP (dose area product) or ESD (entrance surface dose) if available but by screening time and mAs if not. The level set should be such that 10% of cases are expected to breach the level and are thus identified for review of technique and radiation practice.

There are currently no national DRLs for cardiac angiography but the National Radiation Protection Board (NRPB) has proposed a reference dose of 36 Gy cm² for a coronary angiogram based on a large UK survey [12]. There are also reported values for individual centres in the UK and other European countries [13,14,15]. It is, however, important to set local DRLs to take account of local equipment and to improve practice wherever possible.

Table 4. Typical values of DAP and effective doses (ED) for some common cardiac angiographic procedures in Newcastle [13]

<table>
<thead>
<tr>
<th>Procedure</th>
<th>DAP cGycm²</th>
<th>ED mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary angiography</td>
<td>3040</td>
<td>5.6</td>
</tr>
<tr>
<td>PTCA</td>
<td>3760</td>
<td>6.9</td>
</tr>
<tr>
<td>Ca + ad hoc PTCA</td>
<td>5060</td>
<td>9.3</td>
</tr>
<tr>
<td>PTCA + stent implantation</td>
<td>4920</td>
<td>9.0</td>
</tr>
<tr>
<td>Ca + ad hoc PTCA + stent implantation</td>
<td>7070</td>
<td>13.0</td>
</tr>
</tbody>
</table>

The European DIMOND approach to defining dose reference levels however has proposed 45 Gy cm² for coronary angiography and 75 Gy cm² for PTCA [16].

It is clear from these values and other studies [17] that there is significant variation both within and between centres and countries for which there may be a number of reasons including complexity of PCIs, differing approaches to intervention, e.g. direct stent or predilatation, different X-ray equipment, differing awareness and education of staff in radiation dose reduction etc.

4 Dose Reduction

4.1 Equipment - design and developments

There have been many advances, some recent, which have allowed the possibility of dose reduction:

- The change from cine to digital acquisition for cardiac work allowed the possibility to reduce the frame rate and thereby at least halve the dose. Interestingly many centres
persisted in using higher frame rates for some time. This may have been due to habit and lack of radiation awareness or knowledge of the equipment.

- The ability to reload previous studies may reduce the need for as many angiographic views to determine anatomy.
- Pulsed fluoroscopy allows significant dose reduction particularly in difficult interventions when screening time can be long.
- Selection from a number of fluoroscopy dose rates is now possible so that straightforward procedures on small patients can be performed at much reduced doses, while if necessary a higher dose rate can be selected in order to reduce procedure difficulty and time.
- Last image hold allows the operator to view the current situation without having to screen continuously.
- ‘Replay fluoro’ allows review of the previous dynamic images without a repeat acquisition.
- Creation of a ‘road map’ image allows review of anatomy also without re-acquisition.
- Review of previous acquisitions can be magnified on replay by electronic means rather than using a smaller field of view and therefore a higher dose on the image intensifier.
- Flat panel detectors allow easier stent visualisation but the magnification described above is not available.
- Selection of kV/tube mA combinations for different imaging scenarios is available to allow dose optimisation on image acquisition.
- Selection of various frame rates on acquisition allows higher rates for specific purposes; for example fast heart rates in children, and rate reduction when possible.
- Intelligent filtration control also allows satisfactory image quality while minimizing skin dose.
- Image processing software including frame averaging, recursive filtering and edge enhancement improves image perception while minimizing dose.
- Virtual collimation is one of the recent advances, which allows appropriate positioning of filters and collimators before fluoroscopy.

Unfortunately dose reduction features from most manufacturers are optional and in order to control costs some purchasers do not include them with new equipment. As dose awareness increases manufacturers include more and more dose reduction features but it is interesting that they still remain optional.

Most of the recent improvements to cardiology equipment have been driven by the need to visualize metal stents clearly and to improve the ease of PCI. Many of these have been image post processing and therefore have not directly affected dose. However, the ability to easily image stents may have contributed to their increased usage and perhaps the willingness to tackle more and more complex cases, with consequently increased radiation doses. On equipment where the fluoroscopy image is not sufficient to see the stent and potential complications clearly, there is more tendency to perform multiple acquisitions and therefore drive the dose up. This may partly account for some of the wide variation seen in different centres. When new equipment is purchased old habits may continue unless careful attention is paid.

4.2 Modification of existing equipment

Additional filtration can be added if used for long screening procedures and in older rooms, without pulsed fluoroscopy, satisfactory doses can be achieved by this means for procedures such as pacing.
Work done testing reduction of dose, by increasing filtration and reducing image intensifier request from factory settings, resulted in significant dose reduction in a clinical setting [18]. This reduced the dose for PCI from 79 Gy cm\(^2\) to 56 Gy cm\(^2\) but as can be seen from Betsou’s data [13] some centres have doses of 37.6 Gy cm\(^2\) without modification of the equipment. Although the conditions were not identical it is clear that the issue is a complex one. There are many factors that affect radiation dose and the balance between image quality and dose reduction is an important one. Speed of procedure and patient safety may depend on the ability to spot complications early.

**4.3 Operational and behavioural factors**

Betsou et al have shown that dose can be reduced in cardiac angiography and PCI by selecting ‘shallower’ angles for each view [13]. This is extremely helpful to raise awareness of the radiation dose implications of choosing steeper angles but should not give rise to ‘rules’ since without the appropriate angle to show the anatomy clearly procedures may be more prolonged and subject to difficulty. One situation of particular concern is the use of the lateral view with the tube close to the patient when skin doses will be high [17]. In the case of prolonged screening it is important to adjust tube positioning to reduce dose to specific areas of skin and attention should be paid to tube distance from patient.

There are many other, well recognised and simple, methods of reducing patient exposure in day to day work including careful collimation and avoiding the ventriculogram. [19,15]. Arterial access should be carefully considered as the radial approach is associated with higher doses than the femoral. Stenting strategy is also important since direct stenting (deploying the stent without pre-dilatation) reduces dose significantly [15].

Operator fatigue has been muted as an influence on dose by [20] as the doses for complex procedures increased during the day in his study. This may warrant further consideration. The contention by Arthur et al [21] that radiographer operated acquisition results in higher radiation doses is less clear as this depends greatly on the training and experience of whoever performs image acquisition and the Hawthorne effect cannot be entirely excluded in the study.

It is well know that dose is affected by screening time and image acquisition. These may be varied by quality of equipment available and by operator experience and preference but continuous monitoring is essential. Size of patient is also an issue as variation in patient size can increase exposure rate by a factor of 10 [14]. This means that any effort to optimize patients position, for example lying patient as flat on the table as possible and stretching arms comfortably above the head, is well spent. It is also helpful to acquire images on inspiration as this reduces the patient’s density. It is worth a few seconds to teach the patient a ‘good breath-hold’ at the beginning of the procedure in order to improve the image quality and reduce the dose.

It is important to achieve high standards of equipment maintenance and robust quality assurance programmes and to develop procedures and protocols to ensure they are maintained. This involves understanding by staff of equipment features and radiation issues. These can be achieved by appropriate training with annual updates. However, most important in the consideration of radiation dose is awareness and therefore regular measurement of patient dose and feedback to operators through a regular audit programme is essential.
5 Special Cases

5.1 Cardiology

Much of the discussion so far has been about angioplasty but some of the highest skin doses have been recorded during electro-physiological studies (EPS) and radio-frequency ablation (RFA). Vano et al report on several cases of skin injury and make various recommendations including education and training in the medical practice of interventional radiology and cardiology. Specifically in relation to the results from their study they point out that the X-ray equipment should be checked regularly and again that awareness of doses to patients is of paramount importance [22].

Intravascular brachytherapy is another technique that has emerged in cardiology over the last ten years [23]. It uses local beta irradiation to prevent in-stent restenosis. This requires special attention to radiation protection issues with specific training and protocols. With the advent of drug-eluting stents it is unlikely that these procedures will become widespread.

As further developments occur in imaging it must be remembered that not all investigations or treatments need to involve ionising radiation. It has already been pointed out that the left ventricular angiogram can be avoided during cardiac catheterisation. This is on the basis that the information required could be achieved using other modalities such as ultrasound or magnetic resonance imaging (MRI). Any investigation that involves radiation must be carefully considered in terms of alternative possibilities. I have not mentioned radio-isotope scanning but this is also a contributor to the irradiation of cardiac patients and scans such as Thallium scans have doses greater than those produced in many cardiac interventions. A brief discussion of the particular staff and patient issues can be found in the ACC expert consensus document [24].

CT angiography is now developing to a level where coronary angiography by this technique is possible, although so far fairly limited in application. The dose to the patient must be considered carefully as a patient may have a CT before moving on to a coronary angiogram and then intervention in the catheter laboratory. It is important that the accumulated dose is remembered rather than the techniques being viewed in isolation.

5.2 Radiology

Dose ranges depend heavily on the type and site of intervention [25]. These can be classified into vascular such as angioplasty and coil embolization, drainage procedures, stent placements and biopsies. The main difference between radiology and cardiology is that the X-ray tube is less likely to be rotated and moved during the procedure and the position of the operator is more variable, depending on the procedure. The same principles apply in terms of dose reduction to the patient. Dedicated and appropriate X-ray equipment should be used and other modalities such as ultrasound where possible.

CT is now used commonly to guide interventional procedures. It has been shown that CT fluoroscopy markedly reduced patient dose compared to conventional CT [26]. There were a number of factors, but the main two were the decreased tube current and intermittent acquisition mode. The procedures were also found to be easier using fluoroscopy allowing decreased operation times. However, on dose criteria ultrasound must be first choice when possible.
5.3 **Paediatrics**

Children are a special case as they are relatively more radiosensitive than adults and have a longer mean life expectancy [27]. This increases the lifetime cancer risk, shown in figure 2.

**Figure 2. Lifetime risk of cancer from X-ray radiation**

Cardiac catheterisation for the treatment of congenital heart disease may produce high doses since the X-ray equipment used is usually biplane and also used for adult patients. Where possible it should be set up with specific programmes for paediatric cases. For small children the grid should be removed and an air gap used to minimize image degradation due to scatter.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>DAP cGcm²</th>
<th>ED mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetralogy of Fallot</td>
<td>670</td>
<td>8.4</td>
</tr>
<tr>
<td>Closure of persistent ductus arteriosus</td>
<td>450</td>
<td>3.8</td>
</tr>
</tbody>
</table>

The occupational dose to staff tends to be high compared with other radiological procedures [29] and the same staff tend to be used regularly for similar procedures so staff protection issues need to be stressed. Although it is difficult to use satisfactory mobile screens when the patient is small, as they tend to obstruct patient access every attempt should be made to heighten radiation awareness and training for all personnel, including anaesthetists etc who may not often work in a radiation environment.

Mindful of the risks to paediatric patients there are now efforts being made to develop MR imaging for use in interventions in this group [30]. This is in its infancy but may well develop into the preferred modality for formerly high dose interventions in some groups.
6 Limitation of staff dose

So far I have concentrated on patient dose but there are some considerations for staff working in interventional radiology and cardiology. Anything that limits patient dose will also limit staff dose. However there are additional precautions, which will further reduce exposure.

Equipment factors should be considered first. The X-ray equipment should be dedicated interventional equipment with an appropriate specification. For example radiology intervention should be performed on equipment with an under-couch tube, as an over-couch tube would increase the operator dose. Vano [22] noted occupational dose reductions of approximately 20% with highly filtered X-ray beams with automatic kV reduction. There should also be comprehensive maintenance and quality assurance programmes.

The occupational exposure is from scattered radiation from the patient as no member of staff should ever be in the primary beam. There are therefore three basic ways to minimise dose:

1. Reduce time of exposure
2. Use the inverse square law-doubling your distance away will quarter your exposure
3. Use shielding by a barrier

Reducing the time of exposure relates to awareness and good practice. This is best achieved by education and training, including regular updates and practical tips. For example knowing that the exposure is caused by back-scatter from the patients means that if the radiation beam is horizontal, or nearly so, the operator should stand on the image intensifier or receptor side or at least step back. If the beam is more vertical it is important to keep the tube under the patient.

Table mounted lead screens are usually supplied with the equipment but many operators find them annoying so they are removed early in the equipment life and not replaced. They are an extremely useful way of reducing dose [20]. Ceiling mounted screens are also extremely valuable and their proper use reduces exposure by a factor of 3 [22]. In addition operators should wear wrap around lead aprons of 3.5 to 5mm lead equivalent, lead glasses and thyroid collars. It should be noted that lead aprons are not thick enough to protect from the primary beam. Mobile lead screens, in addition to personal protection, are useful to protect staff, for example the nurse or radiographer, during long cases.

The use of lead gloves during procedures is unusual as they are cumbersome and difficult to work in. The automatic brightness control will increase the exposure to go through two layers and one only protects the hand, so if they are going to be used a programme that sets the radiation factors rather than allowing adjustment may be appropriate. In practice, with careful collimation and attention to detail it should not be necessary for the operator's hand to be in the primary beam and only close to it for short periods.

The most important thing to remember is that all individuals should be fully trained and learn to be responsible for radiation safety. Involvement of a radiation expert is essential and is particularly useful in equipment specification, assessment and quality assurance, but also in the formulation of Local Rules.
7 Summary of good practice

When starting a case:

- Be aware of and follow all Local Rules and protocols
- Ensure that all exposures are justified and there is informed consent
- Check patient identity
- Position patient comfortably flat, with arms above head where possible
- Ensure all members of staff in room are wearing suitable. For operators this should be lead glasses, thyroid collar and wrap-around lead apron
- Check all staff are wearing radiation monitors correctly
- Use all available lead shielding appropriately sited
- Position table before screening
- Keep tube current as low as possible and kVp as high as possible-for cardiac studies 60-90kV is appropriate
- Keep X-ray tube at maximum and image intensifier/receptor at minimum distance from patient
- Check all staff are as far away as possible in their role
- Use dose reduction programmes when possible
- Perform acquisitions on full inspiration where possible
- Collimate closely to area of interest
- Prolonged procedures: reduce dose to the irradiated skin e.g. change beam angulation
- Minimise-fluoroscopy time, high dose rate time and no of acquisitions
- Remember software features, such as replay fluoro to minimise dose
- Don't over-use geometric magnification
- Remove grid for small patients or when image intensifier/detector cannot be placed close to patient
- Check and record screening time and DAP at the end of the case and review against the DRL.

8 Recommendations

- Good radiation practice should be encouraged.
- Dedicated interventional equipment with the correct specification should be used
- Equipment procurement should take account of all radiation dose reduction packages-should be automatically included not optional
- Radiation dose in the form of DAP should be displayed on monitors (available on latest equipment).
- Radiation awareness should be promoted by audit and regular feedback
- Local standards should be developed and improved.
- Local DRLs should be regularly reviewed.
- There should be adequate education and training-including practical training, annual updates and testing.
- Research should be continued with a view to developing international standards.
References


9. NRPB Guidance notes for the protection of persons against ionising radiations arising from medical and dental use (1988)


Further Reading

1. Educational presentations at www.icrp.org
2. NRPB Guidance Notes for the Protection of Persons against Ionising Radiations arising from Medical and Dental Use 1988
3. NRPB Patient Dose Reduction in Diagnostic Radiology 1:3 1990
4. NRPB Guidelines on Patient Dose to Promote the Optimisation of Protection for Diagnostic Medical Exposures 10:1 (1999)
5. ACC Expert Consensus Document Radiation Safety in the Practice of Cardiology JACC 31 No 4:892-913