Radiation Protection in Paediatric Radiology

Radiation Protection of Children in Interventional Radiology and Cardiology

L07
Educational objectives

• At the end of the programme, the participants should know these
  • What are specific considerations for paediatric patients in interventional radiology and cardiology?
  • How can dose be managed in paediatric patients?
1. Radiation dose to the patients can only be measured by a specialized person standing in the catheterization laboratory during the procedure.

2. Skin injuries are possible in interventional procedures.

3. Detector should be as close as possible to the patient.
Contents

- Intervenational procedures performed on children
- Review of epidemiology of radiation effects
- Typical doses to patients in paediatric interventional radiology and cardiology
- Requirement for optimisation and tailoring of radiological technique to small body sizes
- Measures to protect patients and staff in paediatric interventional radiology
Introduction

• Paediatric interventional radiology (IR) is a medical field that specializes in minimally invasive diagnostic or therapeutic procedures using imaging guidance, in children:
  • *IR treatments can solve problems faster and with smaller incisions than can other techniques*
  • *They can help treat medical problems which cannot be solved any other way*
Some interventional procedures in pediatric radiology

- Nephrostomy
- Fluid collection drainage or aspiration
- Biliary stent placement
- Gastrostomy or cecostomy
- Angiography
- Angioplasty or stent placement
- Embolization, thrombolysis or sclerotherapy
- Radiofrequency ablation
- Biopsy – generally carried out using ultrasound, fluorography or CT
Some interventional procedures in pediatric cardiology

- **Balloon dilatation / stenting**
  - vascular stenoses
    - aortic coarctation
    - valvular obstructive lesions
      - pulmonary stenosis
      - mitral stenosis
  - **Transcatheter closure**
    - atrial septal defects (ASD)
    - ventricular septal defect (VSD)
    - patent ductus arteriosus (PDA)
- **Electrophysiology**
  - ablation
Unique Considerations for Radiation Exposure in Children

- Compared to a 40-year old, a neonate is several times more likely to produce a cancer over the child's lifetime, when exposed to the same radiation dose.
  - Interventional procedures in children must be carefully justified.
  - Radiation doses used to examine young children must generally be smaller than those employed in adults.
Possible radiation effects

• Stochastic effects (induction of malignant or hereditary diseases)
  • *Measure: effective dose*

• Tissue reactions (deterministic effects) is skin injury following interventional procedures
  • *Measure: maximum skin dose or cumulative dose to interventional reference point*
Possible radiation effects

Arm of 7-year-old patient after cardiological ablation procedure. Injury to arm occurred due to added attenuation of beam by presence of arm and due to close proximity of arm to the source.

Justification and interventional procedures

- Intervventional procedures in children are now more in demand, more sophisticated and longer
- Should always be individually justified and planned
- Balance the risk against the therapeutic benefit
- It is important to ask the referring practitioner, the patient, and/or the family about previous procedures
- Determination that the procedure is necessary relies on the radiological practitioner involved, the natural history of the untreated disease, and the risks and benefits of other therapeutic options available
Optimisation and interventional procedures

- Procedures should be pre-planned to minimize improper or unneeded runs:
  - *the number and timing of acquisitions, contrast parameters, patient positioning, suspension of respiration, sedation…*

- The acquisition parameters should be selected to achieve lowest dose necessary to accomplish procedure, taking account:
  - *dose protocol*
  - *patient size*
  - *frame rate*
  - *magnification*
  - *length of run*
Optimisation and interventional procedures

- Image acquisition using cinefluorography, or during digital subtraction angiography (DSA), accounts for the largest radiation doses during many interventional procedures (dose rates involved can be up few of orders of magnitude higher than fluoroscopy).
- Exposure factors for cinefluorographic image acquisitions and quasi-cine runs are much higher than those for fluoroscopy.
- The acquisition mode should be carefully selected.
Optimisation and interventional procedures

• Children are not just small adults:
  • *imaging equipment needs to be specifically designed for use with children and the operators must be trained accordingly*

• With infants and small children the image intensifier will completely cover the patient: accuracy of collimation is of much greater importance than with adults

• After procedure the dose records should be noted and reviewed
Optimisation and interventional procedures

• Steps in optimisation depend on patient size, technical challenge and critical nature of the procedure
• Overall patient safety is the most important
• The goal is to minimize the dose to the patient while providing important and necessary medical care

1. Equipment

• Requires careful selection, maintenance and Quality Assurance
• “Child size” protocol with dose reduction options available
• Dose recording system
X-ray equipment for pediatric IR

- The generator should have enough power to allow short exposure times (3 milliseconds).

Fluoroscopic pulsing X-rays are produced during a small portion of the video frame time. The narrower the pulse width, the sharper the image. (→ “Shutter speed” in camera)
X-ray equipment for pediatric IR

- The generator should be of high frequency (i.e., can produce higher pulsed fluoroscopy) to improve the accuracy and reproducibility of exposures.

  - E.g. children have faster heart rate. Coronary angiography in children is often acquired at 25-30 frames/sec, instead of the usual 12.5 – 15 frames/sec for adult patients.
X-ray equipment for pediatric IR

- The generator must provide a large dynamic range of mA and mAs levels (to minimize the range of kVp and exposure time needed to compensate for differences in thickness)
- Automatic exposure control (AEC) devices should be used with caution in pediatrics
- Careful manual selection of exposure factors usually results in lower doses
- Tree focal spots should be available
- Also: lateral imaging plane, spatial and spectral beam profiling, and a well functioning system of entrance dose regulation
Image intensifier should have high conversion factor to reduce patient dose.
Beam filtration

- The introduction of additional filtration in the X-ray beam (commonly copper filters) reduces the number of low energy photons and, as a consequence, saves skin dose for the patients.
- Additional Cu filters can reduce the skin dose by more than 70%.
Anti-scatter grid

• The anti-scatter grid in pediatrics gives limited improvement in image quality and increases patient dose given the smaller irradiated volume (and mass) the scattered radiation is less

• Increase kerma air product (KAP) and skin dose typically by ≥ 2 times

• Does NOT improve image quality
Antiscatter grid

The anti-scatter grid in pediatrics gives limited improvement in image quality and increases patient dose and should be removed.
Wedge filter

Partially absorbent contoured filters are also available to control the bright spots produced by the lung tissue bordering the heart.
Importance of wedge filters

The wedge filter has not been used to obtain this cine series. Note the important difference in contrast.

The wedge filter has been used to obtain this cine series.
New modalities

- Electronic road mapping is a must as it greatly reduces the risk of dissection during catheterisation of complex, narrow or irregular vascular channels.
- Digital subtraction angiography (DSA) is another must as it permits a great reduction in the concentration of contrast medium used, thus reduces the risk of toxicity to the kidneys and spinal cord
Relevant dosimetric quantities

- For assessment of stochastic risk:
  - *Kerma-area product* \( (KAP, P_{KA}) \)
- For prevention of tissue reactions (deterministic effects):
  - *Maximum skin dose* \( (MSD) \)
  - *Cumulative dose* \( (CD) \) to Interventional Reference Point \( (IRP) \)
X-ray room dosimetric information
2. Procedure

- Communication between in room personnel
- Plan in advance: *plan number of runs, injection parameters, contrast, pump, digital subtraction angiography (DSA) frame rates and optimize patient position timing with anesthesia*
- Lower the number of exposures: use flouro save when possible
- Use last image hold, decreasing acquisitions/exposures as much as possible when that level of detail is acceptable
- **Step lightly**: tap on pedal and examine still image on monitor, minimize live fluoroscopic time
2. Procedure

- Use pulse fluoroscopy when possible
  - *Decrease from 7.5 pulses/s to 3 pulses/s whenever possible*
- Collimate tightly
  - *Decreasing the area of patient exposure directly decreases patient dose*
  - *Avoid dose to the eyes, thyroid and gonads whenever possible*
- Minimize overlap of fields in repeated acquisitions
- Decrease the dose rate setting to the lowest level that provides adequate image quality
- Minimize use of electronic magnification
Pulsed Fluoroscopy

- Pulsed fluoroscopy can be used as a method of reducing radiation dose, particularly when the pulse rate is reduced.
- ...but ... pulsed fluoroscopy does not mean that dose rate is lower in comparison with continuous fluoroscopy!!.
Dual-shape collimators incorporating both circular and elliptical shutters may be used to modify the field for cardiac contour collimation.
Optimisation and interventional procedures

2. Procedure

• Maximize distance between source and patient throughout the procedure.
• Minimize patient to detector distance
• Avoid radiosensitive areas (breast, eyes, thyroid, gonads) when possible
• Audible periodic fluoroscopy time alerts
• Image acquisition limited only to needed (frames per second, lower dose protocols, magnification, length of run)
3. After procedure

- Review dose
- Counsel if:
  - $\text{Skin dose greater than or equal to } 2 \text{ Gy}$, or
  - $\text{Cumulative dose of greater than or equal to } 3 \text{ Gy}$
- Follow up:
  - $\text{Notes to primary care physician about procedure, dose and possible short and long term effects}$
  - $\text{Counsel patient and primary care to call if erythema develops at beam entrance site}$
  - $\text{Establish follow up procedures including skin examination at } 30 \text{ days}$
4. Training

• All persons directing and conducting interventional procedures, including radiologists and technologists, should have education and training in their discipline, radiation protection physics, radiation biology, and specialist training in its paediatric aspects.

• Specific training in paediatric interventional radiology improves the use of safety measures.
### Typical dose levels in paediatric interventional procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number</th>
<th>Mean KAP per unit of body mass (Gy cm(^2) kg(^{-1}))</th>
<th>Effective Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD Occlusion</td>
<td>259</td>
<td>0.42</td>
<td>3.9</td>
</tr>
<tr>
<td>PDA Occlusion</td>
<td>165</td>
<td>0.35</td>
<td>3.2</td>
</tr>
<tr>
<td>Balloon Dilatation</td>
<td>122</td>
<td>0.48</td>
<td>4.4</td>
</tr>
<tr>
<td>Coil Embolisation</td>
<td>33</td>
<td>0.50</td>
<td>4.6</td>
</tr>
<tr>
<td>VSD Occlusion</td>
<td>32</td>
<td>1.3</td>
<td>12</td>
</tr>
<tr>
<td>Atrial Septostomy</td>
<td>25</td>
<td>0.39</td>
<td>3.6</td>
</tr>
<tr>
<td>PFO Occlusion</td>
<td>21</td>
<td>0.23</td>
<td>2.2</td>
</tr>
</tbody>
</table>

ASD, PDA, VSD, PFO are, respectively, atria septal defect, patent ductus, ventricular septal defect and patent foramen ovale., Onnash et al, Br. J. Radiol. 80 (2007) 177-85
Typical dose levels in paediatric interventional procedures

- Cumulative skin dose is well correlated with patient size and not with fluoroscopy time

\[ y = 2.2812x + 51.977 \]
\[ R^2 = 0.447 \]
\[ p < 0.001 \]
Typical dose levels in paediatric interventional procedures

Comparison of surface entrance doses of radiation
A: Amplatzer et al. (atrial septal defect closure)
B: Moore et al. (patent ductus coil occlusion)
C: Moore et al. (pulmonary valvuloplasty)
D: Wu et al. (pulmonary valvuloplasty)
E: Park et al. (arhythmia ablation)
F: Rosenthal et al. (arhythmia ablation)
Staff doses in interventional radiology and cardiology

- All team members should become aware of the radiation exposure issues with interventional procedures, and the means of controlling them
- Most staff dose, in practice, arises from scattered radiation:
  - Regime/protocol (in digital fluoroscopy, cine, digital cine like, or DSA runs, the scattered dose to staff can be several orders of magnitude larger than during fluoroscopy)
  - Size of the patient
  - Complexity of the procedure
  - Training and experience
- For a given set up, both patient and staff doses are dependent
Staff doses in interventional radiology and cardiology

- The dominant direction for scatter is from the patient back toward the X-ray tube.
- The operator should be on the image receptor side and step back during injections.

90° LAO 150 cm
90° LAO 100 cm
60° LAO 100 cm
30° RAO 100 cm
Reducing staff doses in interventional radiology and cardiology

- Only those necessary for conduct of the procedure should be in the room
- Move personnel away from table, preferably behind protective shields during acquisitions
- The operator should stand to the side of the image intensifier.
- The operator should use a power injector when possible and step back from the image intensifier and/or behind a mobile lead screen during contrast injections
- If manual injection is necessary, maximize the distance using a long catheter
- Doses in the room and from undercouch tubes can be greatly reduced by well configured and properly used table side drapes
Reducing staff doses in interventional radiology and cardiology

- Use movable overhead shields for face and neck protection. Position these prior to procedure.
- Well designed suspended shielding/viewing systems are helpful to operators who learn to become skilful in their use.
- Wear well fitted, appropriate weight, protective aprons
- Wear a thyroid collar and/or lead glasses with side shielding
- The operator and personnel should keep their hands out of beam if possible and not between tube and patient
A freely movable lead glass or acrylic shield suspended from the ceiling should be used. Its sterility may be maintained by using disposable plastic covers.
Reducing staff doses in interventional radiology and cardiology

• Radioprotective gloves may be worn where appropriate, but note they can be counterproductive, reduce flexibility/dexterity and/or interfere with the AEC

• Slight angulation of the beam off the hands, strict collimation and careful attention to finger positioning will help reduce operator exposure

• Occupational dose measurements should include at least one badge under the lead apron to assess whole body dose

• Additional monitors over the apron to evaluate thyroid, hand/arm and eye doses are advisable in some situations
Radiation protection measures

- **Image intensifier**
- **Patient**
- **X-ray tube**

**Lens dose**, optional
**Finger dose**, optional
**Second dosemeter**, outside and above the apron at the neck, optional
**Personal dose**, dosemeter behind the lead apron

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**Dose limits of occupational exposure (ICRP 60)**

- **Effective dose**: 20 mSv in a year averaged over a period of 5 years
- **Annual equivalent dose in the**
  - lens of the eye: 150 mSv
  - skin: 500 mSv
  - hands and feet: 500 mSv
General recommendation:

Be aware of the radiological protection of your patient and you will also be improving your own occupational protection
Let's image gently when we care for kids! The image gently Campaign is an initiative of the Alliance for Radiation Safety in Pediatric Imaging. The campaign goal is to change practice by increasing awareness of the opportunities to lower radiation dose in the imaging of children.

**Step Lightly**

Interventional radiology helps us save kids' lives!

- But, when we treat patients, radiation matters!
- Children are more sensitive to radiation.
- What we do now lasts their lifetimes

**Treat kids with care:**

- Step lightly on the fluoroscopy pedal.
- Stop and child-size the technique.
- Consider ultrasound or, when applicable, MRI guidance.
Summary

• Increased radiation risks for pediatric patients
• Trend of increasing number of pediatric interventional procedures
• Radiation doses can be high
• Radiological technique must be optimized and tailored to small body sizes
• Operators shall be trained, as...
Summary

...patients and staff share a lot...

- correct indications
- fluoroscopy time reduction
- frame rate reduction
- collimation/filtering
- distance from X-ray source / image receptor
- protective organ shielding e.g. gonad, thyroid
- lead apron and thyroid protection
- protective glasses and suspended screen
1. Radiation dose to the patients can only be measured by a specialized person standing in the catheterization laboratory during the procedure.

2. Skin injuries are possible in interventional procedures.

3. Detector should be as close as possible to the patient.
1. False - There are dose indices available on the monitor in modern machine such as DAP and cumulative air kerma at interventional reference point.

2. True – Peak skin doses in the range of few gray exceeding the threshold of 2 Gy are possible.

3. True - Detector should be as close as possible and X ray tube as far as possible form the patient. This improves image quality and reduces patient dose.
References

- National Cancer Institute and Society of Interventional Radiology (2005) Interventional fluoroscopy; reducing radiation risks for patients and staff. NIH publication no. 05-5286.
References