Abstract

Patient dosimetry is performed in radiology and interventional radiology to assess whether deterministic injuries may occur and to establish the risk of stochastic effects. A fundamental problem for patient dosimetry is that no single quantity can be used to accurately assess both the risk of stochastic effects and whether deterministic injuries will occur following a specific examination or procedure. In cardiology and interventional radiology, two different approaches to patient dosimetry are commonly used. Effective dose is a quantity which correlates reasonably well with the risk of stochastic effects. Effective dose may be deduced from the dose area product for the procedure if sufficient information about the procedure is known. Dose area product does not correlate with maximum skin dose, which may be used to predict whether deterministic injuries may occur. DAP meter readings may be used to act as a trigger level for the investigation of maximum skin entrance dose. Trigger levels for different procedures are proposed.
1. **Introduction**

There is increasing concern about the contribution of interventional radiology to the population dose from medical exposures\[1\] and the risk of radiation injuries. This concern arises in part because the frequency of these procedures is increasing\[2\] and because the procedures are becoming more complex\[3\]. The increase in frequency arises from the clear benefits, as in many instances the interventional procedure is performed on an out-patient setting and replaces a surgical technique which involves treatment as an in patient and a protracted hospital stay. The public and press demand more access to this area of medicine.

The two main objectives of radiation protection to the patient in interventional radiology are:-

1) minimise the risk of stochastic effects such as cancer induction or hereditary effects. As these risks are proportioned to the radiation dose to the radiosensitive organ, this may be achieved in practice by reducing patient doses.

2) to avoid where possible the risk of deterministic injuries occurring. Radiation induced skin injuries have been observed in patients who have had interventional procedures\[4,5,6,7\].

2. **Patient Dosimetry**

Patient dosimetry is important in interventional radiology and cardiology. The issues of concern are:

1) Deterministic effects with thresholds. In interventional procedures the most relevant effects are the skin injuries. To assess whether skin injuries could occur it is necessary to know the skin dose distribution, from which it is possible to deduce which areas may have received a dose over a threshold\[8\].

2) Stochastic effects, which correlate reasonably well with DAP measurements. DAP can be easily obtained during the procedure using an instrument attached to the x-ray tube or inferred from knowledge of technique factors\[9,10\].

There are a number of practical problems performing patient dosimetry in interventional radiology. Dose-area product is a good approach to assessing the risk of stochastic effects, but has limitations regarding the peak skin dose. In interventional radiology and cardiology the projection direction changes during the procedure and inevitably the area of the skin surface directly irradiated changes.

Monitors, generally used for assessing skin dose at a point, such as thermoluminescent dosimeters also have limitations. It is difficult for predict before an examination commences, where on the patient's skin the maximum dose will be. Small changes in projection direction can mean a large change in dosimeter reading as it moves on and out of the primary beam. In any case a dosimeter which provides an instantaneous reading is to be preferred.

There are techniques to determine the distribution retrospectively, after finishing the procedure (such as specialised radiographic or radiochromic films). Computer based techniques are used to show the dose distribution during the procedure (dose mapping by computer calculations).

3. **Trigger levels**

There is, in principle, poor correlation between maximum skin dose and DAP, mainly because of changing projection angle, distance and field size during interventional procedures. However, where area based methods to obtain dose distributions are not available the only possible approach is to use the DAP reading to select those patients, who may require follow-up for potential deterministic effects because the threshold may be been reached.
It is possible to eliminate those patients, which would not reach the threshold for deterministic effects in the worst case, if a fixed projection direction and field size is assumed. For example, if the total DAP is lower than 300 Gy cm\(^2\) and the cross section of the field on the skin of the patient is typically 150 cm\(^2\), the dose cannot exceed 2 Gy, even under the assumption that the projection was the same throughout the interventional radiology or cardiology procedure all the time and the same area of skin was irradiated. The relationship between field size on the patients skin surface and the trigger level is summarised in Table 1.

Patients who receive a DAP above 300 Gy cm\(^2\) for a 150 cm\(^2\) field do not necessarily exceed the threshold for deterministic effects, because projection was may not have been fixed on the same area of the skin and the dose may still be substantially below 2 Gy. These patients, however, should receive a more detailed assessment of skin entrance dose using a knowledge of the available exposure parameters. This information could be obtained by analysing the data in the DICOM header[11].

This approach provides a simple screening method for deterministic injuries and a pragmatic solution for selecting patients, who deserve a more detailed study of the potential to develop deterministic effects, for the purposes of follow-up.

**Table 1** Proposed Trigger Levels

<table>
<thead>
<tr>
<th>Field Size (^+(\text{cm}^2))</th>
<th>Trigger Level Gy cm(^2)</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>20</td>
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<tr>
<td>20</td>
<td>40</td>
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<td>50</td>
<td>100</td>
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<tr>
<td>150</td>
<td>300</td>
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<tr>
<td>200</td>
<td>400</td>
</tr>
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</table>

\(^+\) At patient's entrance surface

4. Discussion

The trigger levels given in table 1 are area dependant and can be used to identify which patients may be at risk of deterministic injuries. For this group of patient's it is recommended that the skin dose is investigated in greater detail.

However, some patients may have repeated procedures \(^{(12)}\). In these circumstances it is suggested that the trigger levels are adjusted to take into account this additional dose. It is therefore suggested that for patients who may have multiple procedures the trigger levels are a third of these given in table 1. Given that it is unlikely that the field remained static and was the same for each examination, there will be a reasonable safety margin.

References


