PATIENT DOSE CONSIDERATIONS IN INTERVENTIONAL CARDIOLOGY

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INTRODUCTION

Interventional cardiology procedures are classified as high-dose procedures, owing to increased risk for radiation skin injuries and stochastic effects, such as cancer [1]. European MED Directive 97/43 requires special consideration and dose evaluation for this kind of procedures [2].

Many international and national studies investigated radiation dose to patient during fluoroscopy guided cardiology procedures [1,3-9]. Dose received by a patient, in general, depends on the radiological equipment, examination protocol, the way it is implemented, the patient's body weight and nature of disease. Long-term fluoroscopy of certain parts of the body, a significant body mass, high-value dose intensity, continuous rather than pulsed fluoroscopy, small focus-skin distance and repeated procedure on the same patient, are among the factors that can lead to radiation skin injuries [6,7]. A particular challenge is the fact that the radiation damage of the skin is difficult to detect and connect to the previously conducted cardiologic procedures. Deterministic injuries are related to radiation-induced reproductive sterilization of cells. This is not expressed clinically until unsuccessful attempt of these cells to divide, which is subject to biological variation. Dose threshold exists for such injuries. However, the fact that such injuries do not have immediate manifestation is very often reason that many of them remain undetected [10].

The purpose of this work is to assess the level of radiation dose to patients in percutaneous coronary interventions (PCI) in a large cardiac centre and to investigate possibility for setting of a practical trigger value if dose quantities exceed certain levels in terms of dose descriptors available at display of interventional cardiology unit.
MATERIAL AND METHODS

Two dedicated interventional cardiology units in a large teaching cardiac centre (Clinical Centre of Serbia, Belgrade, Serbia) were included in the survey. Both rooms (D and F) were equipped with X-ray units of the identical model: Siemens Axiom Artis (Siemens, Erlangen, Germany) with the flat panel detector and integrated ionization chamber to measure air kerma-area product ($P_{KA}$) and air kerma in international reference point ($K_{IRP}$).

$P_{KA}$ is an integral indicator of the duration of the procedure, its complexity, fluoroscopy modalities used and the number of acquisition series. However, it does not provide information on possible radiation injury of the skin, in particular, in interventional cardiology where a number of different projections are typically used. Skin dose can be assessed using radiochromic films [3–5,9,11], however, this cannot be applied routinely. Thus, measurement of $K_{IRP}$ and other dose indices is aimed to provide a reasonably good assessment of the risks for tissue reactions, but it does not provide information on dose distribution to the patient's skin. In the absence of ideal dosimetry concept, both quantities, $P_{KA}$ and $K_{IRP}$, together with the total fluoroscopy time are corsets for the determination of dose levels in interventional cardiology, primarily as an indicator of possible radiation injuries.

Patient doses were assessed in terms of $P_{KA}$, $K_{IRP}$ and maximum-skin dose (MSD). $P_{KA}$ and $K_{IRP}$ were assessed using a built-in, in situ calibrated dosimeters, while MSD was estimated using radiochromic films, Gafchromic XR–RV2 (International Speciality Products, Wayne, USA). For each patient, a film of size 35 cm × 43 cm was placed on patient table, just under the patient.

Calibration of dosimeters in terms of $P_{KA}$ and $K_{IRP}$ was performed on site, using a procedure for field calibration of under couch installations described elsewhere [11]. A solid state dosemeter R-100 Barracuda (RTI Electronic, Molndal, Sweden) was used as a reference dosimeter for air kerma measurement, while the file size was measured using radiographic film.

Gafchromic films were calibrated at Secondary standard dosimetry laboratory in a beam quality representative for interventional procedures. Film pieces of 2 cm × 2 cm size were positioned in a way to minimise the contribution from scattered radiation, and exposed to known air kerma in the range of 0 – 6000 mGy. A reference ionisation chamber Magna A650 with Unidos T10002 electrometer (PTW, Freiburg, Germany) was used for air kerma measurement. Exposed film pieces were read 24 h after exposure in the reflection mode using HP Scanjet G3110 flatbed scanner. A TIF
format with 48–bit RGB resolution enabled the use of the red component for calibration and dose evaluation. Freeware ImageJ software was used for image analysis. The net mean pixel value \((NMPV)\) was calculated using the equation:

\[
NMPV = k \frac{MPV_{unexp}}{MPV_{exp}}
\]

(1)

where \(MPV_{unexp}\) is the mean pixel value obtained in unexposed film (background), \(MPV_{exp}\) is the mean pixel value obtained after radiation exposure and \(k\) is a constant term having the value \(10^4\) [4].

Dose levels were measured for total of 27 patients undergoing PCI in two cardiology rooms during September and October 2010.

RESULTS

Table 1 shows the data related to dosimetry considerations of 27 patients undergoing PCI.

MSD in three patients (11 %) was higher than 3 Gy, while in 5 patients (19 %) MSD was higher than 2 Gy. In 19 patients (70 %), MSD was less than 1 Gy.

Correlations between different dose descriptors are presented in Figures 1 – 3. In spite of assumption that \(K_{IRP}\) is merely a conservative estimator of \(MSD\) [7], in this study cases where \(MSD\) was significantly higher than \(K_{IRP}\) were observed, while mean \(K_{IRP} / MSD\) ratio in was 0.84. This could be explained by the variable geometric conditions in interventional cardiology that may bring the point in which X-ray beam enters the body closer to or further from focus than point in which \(K_{IRP}\) calibration was performed. Also, this calibration assumes scatter free condition, however, the forward and backward scatter contributions are significant, ranging to more than to 50 % (scatter factor 1.58) [3].

As presented in Figures 1 – 3, correlation between \(MSD\) and other dosimetry indices was reasonably good, but different for different cardiology units. Many similar studies failed to prove significant correlations between dose descriptors in interventional cardiology [3-5]. Therefore, before setting trigger level for skin effects in terms of other quantities available in dose records, there is a need to assess a local practice and establish correlations for each procedure in each particular unit.

Based on MSD threshold of 3 Gy [10], trigger levels in terms of \(P_{KA}\), \(K_{IRP}\) and fluoroscopy time are given in Table 1.
Table 1. Patient and technique related parameters and patient dose levels for 27 patients during PCI procedure in two cardiology rooms

<table>
<thead>
<tr>
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<th>Unit D (N = 13)</th>
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<th>Unit F (N = 14)</th>
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<tbody>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>Height (cm)</td>
<td>Fluoroscopy time (min)</td>
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<tr>
<td>Minimum</td>
<td>60</td>
<td>153</td>
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<tr>
<td>Maximum</td>
<td>100</td>
<td>183</td>
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<td>12</td>
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<tr>
<td>Trigger level</td>
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|                  |                  |                  |                  |
| Minimum          | 58              | 152              | 2.5               | 375              | 28           | 0.33      | 0.16     |
| Maximum          | 104             | 186              | 69                | 1033             | 354          | 5.1       | 6.7      |
| Mean             | 78              | 167              | 12                | 625              | 74           | 1.0       | 0.98     |
| SD               | 14              | 10               | 16                | 176              | 84           | 1.2       | 1.6      |
| Median           | 71              | 169              | 7.6               | 650              | 46           | 0.63      | 0.45     |
| Trigger level    | /              | /                | 32                | /                | 170          | 2.5       | 3.0      |

Figure 1. Correlation between maximum skin dose and cumulative air kerma at interventional reference point (IRP) for 27 PCI procedures in two cardiology rooms
Figure 2. Correlation between maximum skin dose and air kerma area product for 27 PCI procedures in two cardiology rooms

Figure 3. Correlation between maximum skin dose and fluoroscopy time for 27 PCI procedures in two cardiology rooms

CONCLUSION
Although utilisation of XR–RV2 radiochromic film has been proven as a good dosimetric method for mapping skin doses in patients during interventional cardiology procedures, it is not practical and cost-effective to be used routinely. In this study, correlation between alternative dose descriptors (MSD, $K_{IRP}$, $P_{KA}$ and fluoroscopy time) was reasonable good, indicating that quantities available on the display of X-ray unit can be used for prediction of MSD if this correlation is confirmed for each particular unit. As readily available, they can alert operating staff that skin dose has reach threshold for manifestation of harmful tissue reactions.
REFERENCES