Radiation doses in flat detector digital systems in Interventional Cardiology procedures

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Abstract: The purpose of the study was to investigate patient radiation doses in flat detector (FD) digital X-ray systems in Interventional Cardiology procedures in three of the busiest haemodynamic departments in Greece and compare the results with the corresponding reference levels (RLs). Material and method: 569 Coronary Angiography (CA) and 571 Percutaneous Transluminal Coronary Angioplasties (PTCA) were investigated since these two procedures are the most frequently performed in haemodynamic units. Patient data collected were: sex, age, weight, height, Dose Area Product (DAP), fluoroscopy time (T) and total number of frames (F). Results: Median values of DAP and F in CA were: 31.0 Gycm\textsuperscript{2} and 752 in Hospital A, 35.3 Gycm\textsuperscript{2} and 487 in Hospital B and 21.1 Gycm\textsuperscript{2} and 461 in Hospital C. Median values of DAP and F in PTCA were: 63.2 Gycm\textsuperscript{2} and 1274 in Hospital A, 90.3 Gycm\textsuperscript{2} and 974 in Hospital B and 35.6 Gycm\textsuperscript{2} and 582 in Hospital C. Concerning T, the timer in Hospital C malfunctioned, whereas in hospitals A and B examination time was 4.7 and 3.6 min for CA and 10.3 and 12.7 min for PTCA, respectively. The results reveal a noted variability between hospitals especially in PTCA. However, patient dose values are lower than RLs (45 and 85 Gycm\textsuperscript{2} in CA and PTCA respectively). Conclusions: Large variations between patient dose values and main technical parameters were revealed when using FD digital systems in Greece. Dose optimization can be greatly achieved through continuous staff education in radiation protection issues. Moreover, the standardization of IC procedures in digital flat panel systems will definitely decrease patient and staff doses.
1. Introduction

Digital imaging has greatly progressed during the last decade, introducing dynamic flat panel digital detectors (FD) that replaced conventional image intensifiers. They offer better quality and less noise in the image as well as sophisticated movements, large freedom and increased speed around the patient, characteristics much favoured by the system operator. Digital imaging provides the opportunity to store acquired images in a Picture Archiving and Communications System (PACS), thus eliminating the need for film storage making this new technology even more popular. However, the facility of creating higher number of cine frames as well as the easy deletion of unwanted images which are also very appealing features (since there is no need to change film as in conventional technology) make accurate estimation of patient dose impossible and the use of X-ray equipment risky.

Dynamic flat detectors have been applied in Interventional Radiology and Cardiology (IC), medical specialties widely known to generate high radiation dose procedures to patients as well as to the medical staff involved [1-5].

Few studies are found in recent literature regarding the use of FD in IC [6-9]. Most of these studies investigate the performance of the X-ray machines [7, 9]. Recognizing the need for continually monitoring the radiation dose during IC procedures, the European Concerted Action SENTINEL «Safety and Efficacy for New Techniques and Imaging using New Equipment to Support European Legislation (FP6 – 012909) [10]» included the investigation of patient and staff dose levels in this new technology X-ray systems. With this framework, measurements of patient doses were performed in three major hospitals in Greece using flat panel cardiac angiographic systems during Coronary Angiography (CA) and Percutaneous Transluminal Coronary Angioplasty (PTCA). The objective of the study was to explore the clinical and technical factors that influence the radiation dose imparted to the patient during IC procedures.

2. Materials and Methods

Three Athenian hospitals participated in the study (hospitals A, B and C). The main technical characteristics of the digital FD X-ray systems are presented in Table 1.
Table 1: Main technical characteristics of the flat-panel digital X-ray systems used in this study

<table>
<thead>
<tr>
<th>Technical characteristics</th>
<th>Hospital A</th>
<th>Hospital B</th>
<th>Hospital C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Philips Allura F9</td>
<td>Philips Allura F10</td>
<td>GE Inova 2000</td>
</tr>
<tr>
<td>Field of view (cm)</td>
<td>15; 20; 25</td>
<td>15; 20; 25</td>
<td>12; 15; 17; 20</td>
</tr>
<tr>
<td>Additional filtration</td>
<td>0.1; 0.2 Cu</td>
<td>0.1; 0.2 Cu</td>
<td>0.1; 0.2 Cu</td>
</tr>
<tr>
<td>Fluoroscopy modes</td>
<td>Low, Normal, High</td>
<td>Low, Normal, High</td>
<td>Low, Normal</td>
</tr>
<tr>
<td>Pulse modes (p/s)</td>
<td>12.5; 25</td>
<td>15; 30</td>
<td>15; 30</td>
</tr>
<tr>
<td>Cine modes (frames/sec)</td>
<td>12.5; 25</td>
<td>12.5; 25</td>
<td>7.5; 15; 30</td>
</tr>
<tr>
<td>Power (kW)</td>
<td>100</td>
<td>100</td>
<td>80 or 100</td>
</tr>
<tr>
<td>Matrix size</td>
<td>1024x1024</td>
<td>1024x1024</td>
<td>1024x1024</td>
</tr>
<tr>
<td>Installation</td>
<td>October 2002</td>
<td>2004</td>
<td>December 2003</td>
</tr>
</tbody>
</table>

Of the total of 1140 patients participating in the study, 315 were treated in hospital A, 588 in hospital B and 237 in hospital C. 569 Coronary Angiography (CA) and 571 Percutaneous Transluminal Coronary Angioplasties (PTCA) were investigated since these two procedures are the most frequently performed in haemodynamic units.

Patient dose was measured in terms of Dose Area Product (DAP), fluoroscopy time (T) and total number of images (F). DAP meters were calibrated following the National Protocol for Patient Dose Measurements in Diagnostic Radiology [11]. The reading uncertainty of the instruments, as quoted by the manufacturers, was ± 4% for tube potentials ranging from 50 kVp to 100 kVp. Patient data also included sex, age, weight and height.

3. Results and Discussion

Median values of DAP, T, F together with their corresponding range are presented in Table 2. The results reveal a large range of patient doses for the hospitals involved (max/min DAP value equals to 1.7 for CA and 2.5 for PTCA), although the X-ray systems present similar technical characteristics (Table 1).
Table 2: Median values and range of DAP (Gycm²), fluoroscopy time T (min) and total number of images (Frames) separately for CA and PTCA procedures for the hospitals investigated

<table>
<thead>
<tr>
<th></th>
<th>Hospital A</th>
<th>Hospital B</th>
<th>Hospital C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CA</td>
<td>PTCA</td>
<td>CA</td>
</tr>
<tr>
<td>Number of cases</td>
<td>148</td>
<td>167</td>
<td>317</td>
</tr>
<tr>
<td>DAP (Gy*cm²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>31.0</td>
<td>63.2</td>
<td>35.3</td>
</tr>
<tr>
<td>Range</td>
<td>6.1-117.5</td>
<td>10.2-513.4</td>
<td>1.4-221.9</td>
</tr>
<tr>
<td>T (min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>4.7</td>
<td>10.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Range</td>
<td>0.8-39.4</td>
<td>3.2-53.3</td>
<td>0.4-27.7</td>
</tr>
<tr>
<td>Frames</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>752</td>
<td>1274</td>
<td>487</td>
</tr>
<tr>
<td>Range</td>
<td>231-2206</td>
<td>398-5940</td>
<td>0-1303</td>
</tr>
</tbody>
</table>
This is due to the large number of factors influencing patient dose such as the way the operator performs the procedure and the severity of the case. Dose variability found mainly in PTCA can be explained by the pathology of the patient. Bernardi et al [12] found a statistically significant increase in T and F in complex PTCA procedures. Padovani et al [13] found an increase of about 50% in radiation dose for medium complex procedures and an increase of 100% for complex procedures.

In Table 3 the SENTINEL reference level values (RL) [14] for CA and PTCA are presented.

**Table 3: SENTINEL RLs for interventional cardiac procedures**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>CA</th>
<th>PTCA</th>
</tr>
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<tbody>
<tr>
<td>DAP (Gy cm²)</td>
<td>45</td>
<td>85</td>
</tr>
<tr>
<td>FT (min)</td>
<td>6.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Number of cine</td>
<td>700</td>
<td>1000</td>
</tr>
<tr>
<td>images (frames)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Patient dose in terms of median values of DAP, fluoroscopy time (T) and total number of images (F) of this study, are presented in Figures 1-3 together with SENTINEL RLs.

**Figure 1:** Median values of DAP for the 3 hospitals investigated, compared with SENTINEL reference levels
Figure 1 shows that the DAP value in PTCA for hospital B (90.3 Gycm²) is relatively higher than the reference level (85 Gycm²) probably because PTCA examination in this hospital often includes a preceding CA examination.

**Figure 2:** Median values of fluoroscopy time T (min) for hospitals A and B, compared with SENTINEL reference levels

![Fluoroscopy Time Chart](chart_cropped.png)

Figure 2 shows that hospitals A and B used fluoroscopic time well below the proposed limits.

**Figure 3:** Median values of total number of images (frames) for the 3 hospitals investigated, compared with SENTINEL reference levels

![Total Frames Chart](chart_cropped.png)

Figure 3 shows that staff in hospital A record higher number of frames in CA (752) and significantly higher in PTCA (1274) than the corresponding reference levels (700 and 1000 respectively), probably because hospital A is a teaching hospital and inexperienced doctors are involved. Efforts must be done in order to reduce the number of frames and keep the dose values “as low as reasonably achievable”.

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4. Conclusion

CA and PTCA are routinely performed in a number of hospitals and are considered as safe diagnostic and therapeutic IC procedures. However, as the technology evolves in terms of X-ray equipment, catheters and stents, these procedures are becoming even more complex and this has a great impact on patient and operator radiation dose. Large variations between patient dose values and main technical parameters were revealed when using FD digital systems in Greece.

Dose optimization can be greatly achieved through continuous staff education in radiation protection issues. Moreover, the standardization of IC procedures in digital flat panel systems will definitely decrease patient and staff doses.

Acknowledgments

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REFERENCES