QUALITY ASSURANCE OF THE IMAGING SUBSYSTEM G4 CyberKnife. EVALUATION OF THE FLAT PANEL IMAGING CHARACTERISTICS

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Introduction
A G4 CyberKnife (CK) system has been installed at Iatropolis Clinic, Athens Greece since May 2006. In CK the Target Locating System (TLS) i.e. the imaging subsystem and an imaging software is used to locate the target and then to guide the therapeutic beam to the target with sub-millimeter accuracy [1], [3]. The imaging subsystem consists of a pair of standard kilovoltage x-ray generators installed on the ceiling of the treatment room and two amorphous silicon flat panel digital detectors, called camera A and B respectively. In G4 CyberKnife®, the flat panel detectors are embedded in the floor, in orthogonal configuration. Images from both cameras are acquired for initial patient alignment and throughout the treatment. These images are fed into the image-guidance software, which uses an image registration algorithm to track the target, i.e to calculate translations and rotations of the target during the treatment delivery [2]. Consistency of the TLS is dependent on the quality of the radiographs recorded by the cameras. The aim of the project is to perform quality assurance analysis of the flat panel detectors in the imaging subsystem of the G4 CyberKnife using the QCkV-1 phantom.

Materials and Methods
The flat panel amorphous silicon detectors are situated at approximately 140cm from the isocenter (depending on the ceiling height) and at a 45° angle to the kV-beam central axes [2]. They consist of a 1024×1024 pixel matrix of 0.4 mm nominal pixel size. As a result of the horizontal installation, primary x-ray images suffer from a geometrical distortion of the projected object. The distortion is corrected by the image-guidance software based on the geometrical configuration of the TLS camera. Image quality of each flat panel detector in terms of spatial resolution, contrast-to-noise ratio, image noise and geometrical distortion was evaluated using the QCkV-1 phantom (Figure 1) (Standard Imaging Inc) [4] and the PIPSPro software (Standard Imaging Inc) [5].

Spatial resolution was measured in terms of the parameters f50, which are the frequencies at 50% maximum of the relative modulation transfer function (RMTF). Contrast resolution was measured in terms of the contrast-to-noise ratio (CNR).

Geometrical distortion was quantitatively evaluated by measuring the phantom dimensions on the corrected images of the QCkV-1 phantom (Figure 3b). Phantom dimensions (Length, Width) and the ratio (L/W) were measured on the corrected images and compared with the nominal values provided by the manufacturer (Standard Imaging Inc).

Flat panel imaging characteristics were also investigated as a function of the kV setting. Spatial resolution f50 and CNR as a function of kV setting are presented in Figure 8 and 9 respectively.

Results
Image characteristics were measured using the QCkV-1 phantom and the PIPSPro software. Baseline values for spatial resolution, CNR and noise were established, averaging the initial ten measurements of each parameter, which correspond into two week time scale (Table 1).

Introduction of results:

TABLE 1

<table>
<thead>
<tr>
<th>MONTH</th>
<th>CAMERA A</th>
<th>CAMERA B</th>
</tr>
</thead>
<tbody>
<tr>
<td>f50</td>
<td>1.91±0.0062</td>
<td>1.90±0.0047</td>
</tr>
<tr>
<td>f40</td>
<td>1.67±0.0043</td>
<td>1.63±0.0048</td>
</tr>
<tr>
<td>f30</td>
<td>1.66±0.0033</td>
<td>1.44±0.0027</td>
</tr>
<tr>
<td>CNR</td>
<td>85.5±2.617</td>
<td>85.6±2.137</td>
</tr>
<tr>
<td>Noise</td>
<td>0.80±0.0165</td>
<td>0.78±0.0107</td>
</tr>
</tbody>
</table>

Discussion and Conclusions
Quality assurance analysis of the flat panel detectors in the imaging subsystem of a G4 CK system using the QCkV-1 Phantom and the PIPSPro software has been performed. Image characteristics such as Spatial Resolution f50, Contrast-to-Noise Ratio, Image Noise and Geometrical Distortion were investigated. Baseline values of the measured parameters are presented in Table 1. Spatial resolution f50 was measured 1.462±0.0062lp/mm and 1.448±0.0027lp/mm for Camera A and Camera B respectively. These values are in very good agreement with values reported in the literature [3].

Time dependence performance of the above parameters was found in acceptable range, i.e. variation within ±2SD with respect to the baseline values. Geometrical distortion was quantitatively evaluated using the PIPSPro software. Dimensions of the corrected QCkV-1 images revealed was found in very good agreement (within ±1.5%) with the nominal dimensions of the QCkV-1 phantom. Spatial resolution f50 and CNR were found to be independent on the kV variation within the range of CK clinical practice (100 –125kV). However, considerable variation has been revealed in the less kV range (70 - 90kV).

Flat panel imaging characteristics were also investigated as a function of the kV setting. Spatial resolution f50 and CNR as a function of kV setting were presented in Figure 8 and 9 respectively.

Acknowledgements
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References
4. QCkV-1 Phantom (standard model), Standard Imaging Inc
5. PIPSPro Software User Manual, Standard Imaging Inc

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