Patient-specific organ doses estimation in interventional TAE using Monte Carlo and K-Means medical image segmentation

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Purpose

The purpose of this study is to evaluate organ doses using measurement-based Monte Carlo simulation with an adaptive organ segmentation for individual patients undergoing interventional transcatheter arterial embolization.

Materials & Methods

The development of a Patient-specific interventional transcatheter arterial embolization procedures dosimetry model for organ dose calculations generally involves three parts. The first part using GAFCHROMIC® XR-RV3 dosimetry film to record and measure patient skin exposure during interventional transcatheter arterial embolization procedures. The measured data is stored for use in the second part measurement-based Monte Carlo simulates photon transport through the voxelized patient phantoms. The third part patient organ dose calculation, apply threshold for the bone segmentation. K-means clustering algorithm for soft tissue 3-D anatomical medical images. Each iteration consists of two steps: estimate mean intensity at each location for each type, and estimate tissue types by maximizing the a posteriori probability.

Results

The dose-response curve fitted using the saturation growth-rate model was very well (R²=0.999), shown in Fig 1. Film response variation between 65 and 95 kVp was 2.7%. An individual dosing system was established for an 67-year old male patient whose height was 162 cm, weight was 64 kg. At the end of the intervention, the fluoroscopy time, total number of acquired images were recorded(table 1). The dose area product value measured by the built-in transition chamber was 168 Gy-cm², the cumulative dose at the IEC reference point was 1383 mGy. The peak skin dose (PSD) for this case was 1140 mGy. Figure 2 (a) is the patient skin dose distribution (b) shows the dose distributions on the coronal CT image (c, d) dose distributions on the axial CT images at the level of the liver and kidneys. The organ dose (OD) for i organ was the average dose of the regions of interest as below equation:

$$\text{OD}_i = \frac{\sum D \times \text{ROI}_i}{\sum \text{ROI}_i}$$

Where D is the 3D dose matrix, and ROIi is the cluster region for i organ. Figure 3(a) is the isodose curves on the axial CT images (b, c, d, e, f) were bone, liver, right kidney, left kidney, and pancreas organ segmentation result respectively. (g, h) shows three-dimensional volume of the segmented liver and kidney. The organ doses were 184 mGy for bone, 126 mGy for liver, 387 mGy for R-kidney, 30 mGy for L-kidney, 17 mGy for spleen, and 42 mGy for pancreas.

Table 1. Angiographic data for Fluoroscopy and DSA

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<tr>
<th>Parameters</th>
<th>Fluoroscopy</th>
<th>DSA</th>
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<tr>
<td>kV</td>
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<td>73</td>
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<td>Cu filtration</td>
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<td>Fluoroscopy times(min)</td>
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<td>Frames</td>
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<td>43</td>
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<tr>
<td>Ref (mGy)</td>
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<td>152</td>
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</table>

Fig 1. Dose-response curves

Fig 2 (a) Patient skin dose distribution (b) dose distribution on the coronal CT image, dose distributions on the axial CT images at the level of the liver (4c) and kidneys (4d).

Conclusion

K-means clustering is used because it is simple and has relatively low computational complexity. In addition, it is suitable for biomedical mage segmentation as the number of clusters (K) is usually known for images of particular regions of human anatomy. We have successfully used a semi automated image process to evaluate organ doses for individual patients undergoing interventional transcatheter arterial embolization.

Fig 3 (a) Axial CT images with isodose curves (b, c, d, e, f) bone, liver, right kidney, left kidney, and pancreas organ segmentation result respectively. (g, h) shows three-dimensional volume of the segmented liver and kidney.