Analysis of Cumulative Dose to Implanted Pacemaker According to Various IMRT Delivery Methods: Optimal Dose Delivery Versus Dose Reduction Strategy

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Introduction

Cancer patients with implanted cardiac pacemaker occasionally require radiotherapy. Pacemaker may be damaged or malfunction during radiotherapy due to ionizing radiation or electromagnetic interference. Although radiotherapy should be planned to keep the dose to pacemaker as low as possible not to malfunction ideally, current radiation treatment planning (RTP) system does not accurately calculate deposited dose to adjacent field border or area beyond irradiated fields. In terms of beam delivery techniques using multiple intensity modulated fields, dosimetric effect of scattered radiation in high energy photon beams is required to be detailed analyzed based on measurement data.

The aim of this study is to evaluate dose discrepancies of pacemaker in a RTP system as compared to measured doses. We also designed dose reduction strategy limited value of 2 Gy for radiation treatment patients with cardiac implanted pacemaker [1].

Materials and Methods

To evaluate cumulative doses to a implanted pacemaker (5 mm distance from irradiated field border in inferior direction) according to delivery methods, Step-and-Shoot (SS) with intensity levels of 10, 20, and 30 and Sliding Window (SW) were adopted in a patient with tongue cancer. Intensity modulated radiation therapy (IMRT) plans for a gross tumor volume (GTV) prescribed with 66 Gy per 30 fractions were simulated in a planning system (Eclipse, ver. 7.3, VMS, Palo Alto, USA) and a treatment unit (21EX, VMS, Palo Alto, USA). Dose volume histograms (DVHs) of implanted pacemaker to dose conformity of GTV were evaluated. Planned doses were verified with and without 2 mm-lead shielder in in-vivo dosimetry on skin of the patient’s chest, (c) dose verification on a humanoid phantom using mosfet.

Fig. 1. Evaluation of the delivered doses on the pacemaker. Calculation doses of a planning system in (a) a coronal, (b) an axial view, and (c) in-vivo dosimetry on skin of the patient’s chest, (d) dose verification on a humanoid phantom using mosfet.
Table 1. Comparison of measured fractional doses using mosfet in different IMRT delivery techniques (SS: step-and-shoot, SW: sliding window)

<table>
<thead>
<tr>
<th>Measurement position</th>
<th>Beam delivery technique</th>
<th>SS RTP</th>
<th>Mosfet RTP</th>
<th>SW</th>
<th>Mosfet SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanoid Phantom</td>
<td>Without lead shield</td>
<td>Upper</td>
<td>2.60</td>
<td>5.63</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center</td>
<td>0.60</td>
<td>4.81</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>0.00</td>
<td>3.77</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>With lead shield</td>
<td>Upper</td>
<td>3.84</td>
<td>-</td>
<td>4.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center</td>
<td>2.60</td>
<td>-</td>
<td>2.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>1.09</td>
<td>-</td>
<td>1.95</td>
</tr>
<tr>
<td>In-Vivo</td>
<td>Without lead shield</td>
<td>Upper</td>
<td>3.87</td>
<td>12.91</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center</td>
<td>2.11</td>
<td>9.23</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>0.11</td>
<td>7.00</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>With lead shield</td>
<td>Upper</td>
<td>-</td>
<td>5.62</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center</td>
<td>-</td>
<td>3.51</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>-</td>
<td>1.50</td>
<td>-</td>
</tr>
</tbody>
</table>

In-vivo and measured doses on pacemaker position showed critical dose discrepancies reaching up to 4 times as compared to planned doses in RTP. The current SS technique could deliver lower scattered doses than recommendation criteria, but use of 2-mm lead shielder contributed to reduce scattered doses by 60%. The tertiary lead shielder can be useful to prevent malfunction or electrical damage of implanted pacemakers during radiotherapy. It is required to estimate more accurate scattered doses of the patient or medical device in RTP to design proper dose reduction strategy.

Reference