The Impact of X-RAY Energy on Radiotherapy Plan Quality and Acceptability

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ABSTRACT

Radiotherapy is still burgeoning in low- and middle-income countries (LMICs) and faces challenges such as understaffing and limited equipment. The collaboration with institutions in nations with a longer history of radiotherapy is a solution that is often limited by the disparities between the treatment planning systems or treatment machines. The purpose of this research is to compare accepted treatment plans with alternative plans obtained by modifying photon energy, and possibly, establish a threshold of acceptability.

Radiotherapy treatment plans were generated using 4-field box (cervix), and tangents/supraclavicular field (chest wall) using the Radiation Planning Assistant (RPA), an online automated contouring and planning tool. Plans were generated for 15 patients per treatment site (30 total). The impact of selecting different radiation energy was evaluated for 6, 10, 15, 18MV or a mix of 6 and 18MV. Plans were normalized consistently, and the variation in hotspots and doses to organs at risk compared.

For cervix plans, all targets are fully covered by the prescription line for all the energies. For chest wall (CW) plans, all supraclavicular (SCV) targets met the acceptable dose objectives for all the energies; and CW planning target coverage was around 85% for most cases. The difference is observed in the dose to the organs at risk (OAR) and the hotspot.

Cervix plans for 18MV are optimum with lower dose to organs at risks. Mixed energy (6 and 18MV) chest wall plans are optimum with lower dose to the heart and lungs. If the optimum energy is not available, some alternative energies could be used among the ones studied after review of the dose to organs at risks with additional techniques.

Keywords: Radiotherapy, photon energy, cervical cancer, chest wall.

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INTRODUCTION

In 2012, 14.1 million new cases of cancer were reported worldwide, and this number is projected to reach 24.6 million by 2030.1 About 8.2 million cancer death were recorded globally in 2012, with a projection of 13 million deaths by 2030, most of them in low- and middle-income countries (LMICs).[1,2]
Radiotherapy coverage is insufficient or even non-existent in many (LMICs).[3] Less than ten percent of the population in low-income countries have access to radiotherapy service, while in high-income countries, about half of all cancer cases treatment involve radiotherapy.[4] The continuous improvement of radiotherapy equipment and systems requires highly trained workers for their operation and maintenance. In developing countries that are still in the early stages of implementing radiotherapy, there is a severe lack of adequately trained personnel, especially when it comes to treatment planning.[5,6] Solutions to the shortage of planning personnel include automated and/or remote planning. Automated software planning generates the treatment plan based on patient's data.[5,6,7,8] In remote planning, a dosimetrist receives the patient's data and generates a plan using a treatment planning system (TPS). Both solutions have limitations that could be detrimental to the patient in some cases. There is a wide range of treatment machines that differ in multi-leaf collimator (MLC), and photon energy. The machines in these centers often have different energy from the ones available to the dosimetrist or the automated planning system. The purpose of this research is to compare accepted treatment plans designed according to the standard for the disease site with alternative treatment plans in which photon energies differ.

METHODS AND MATERIALS

The main equipment for this research include the Radiation Planning Assistant (RPA) and research Eclipse 15.1. The RPA generates the treatment plans, and Eclipse is a treatment planning system utilized for plans verification and data collection.

The process starts with a Computer Tomography (CT) image set upload and a service request submission form that includes the patient information and disease site. After the service request approval, and validation of reviewed CT data, the RPA proceeds to generate the treatment plan. The completed plan generated by the RPA is downloaded and imported to Eclipse for review and data collection.

A total of 30 cases were planned including 15 patients per disease site. Cervix plans were generated with a 4 field box technique for a prescription of 45Gy in 28 fractions to the planning target volume (PTV). The field and field was added after importing into eclipse, using a special script that is intended to be integrated into the RPA. Cervix plans were generated with energies 6, 10, 15 and 18 MV for each case which gives a total of 60 plans. No mixed energy plan was generated for cervix. chest wall plans were generated with field and field integrated in the RPA for a prescription of 50Gy in 25 fractions. Energies used are 6, 10, 15, 18MV, and mix (6 and 18MV) which gives a total of 75 plans. The planning targets are SCV nodes and CW. CW is designed by the RPA to delineate the tangent fields' border and does not represent the true chest wall as it extends into muscle and rib cage. The evaluation of its coverage is for comparison purposes. All 30 cases are downloaded from the RPA to Eclipse. Plan data including organs at risks dose and target coverage were collected and compared.

RESULTS

For cervical cancer cases, the results show that all the energies used provide good coverage (100% of prescription dose). As the energy increases, the dose to the OAR and the size of the hotspot decreases (Figure1).

The average maximum dose (Max<45Gy) to the spinal cord changes as follow: 43.5Gy (33.5-48), 44.75Gy (39.5-49), 44.76Gy (40-48), and 45.05Gy (40.8-48.4) for 18, 6,15, and 10MV respectively.

The SCV target of the chest wall plan has a coverage greater than 95% by the 45Gy isodose line for all the energies (Chart1). The CW planning target coverage by the 45Gy line is lower than 85% for at least 50% of the cases for all the plans. For energies below 10MV, less than half of the plans have both targets covered by 40% or more of the 105% hotspot. For the energies above 10MV, at least 50% of the cases have both targets covered by 40% or more of the 105% hotspot. The mean dose to the heart is below the acceptable limit of 6Gy for more than 90% of the cases for all the energies. Only one case displays a mean dose greater than 8Gy for every energy. For every case, the volume of lung receiving 17Gy (V17) is lower than the acceptable limit of 40%. The maximum dose for the composite plan is lower than 116%, defined as the acceptable limit,[8] for almost all the plans using energies other than 18MV.

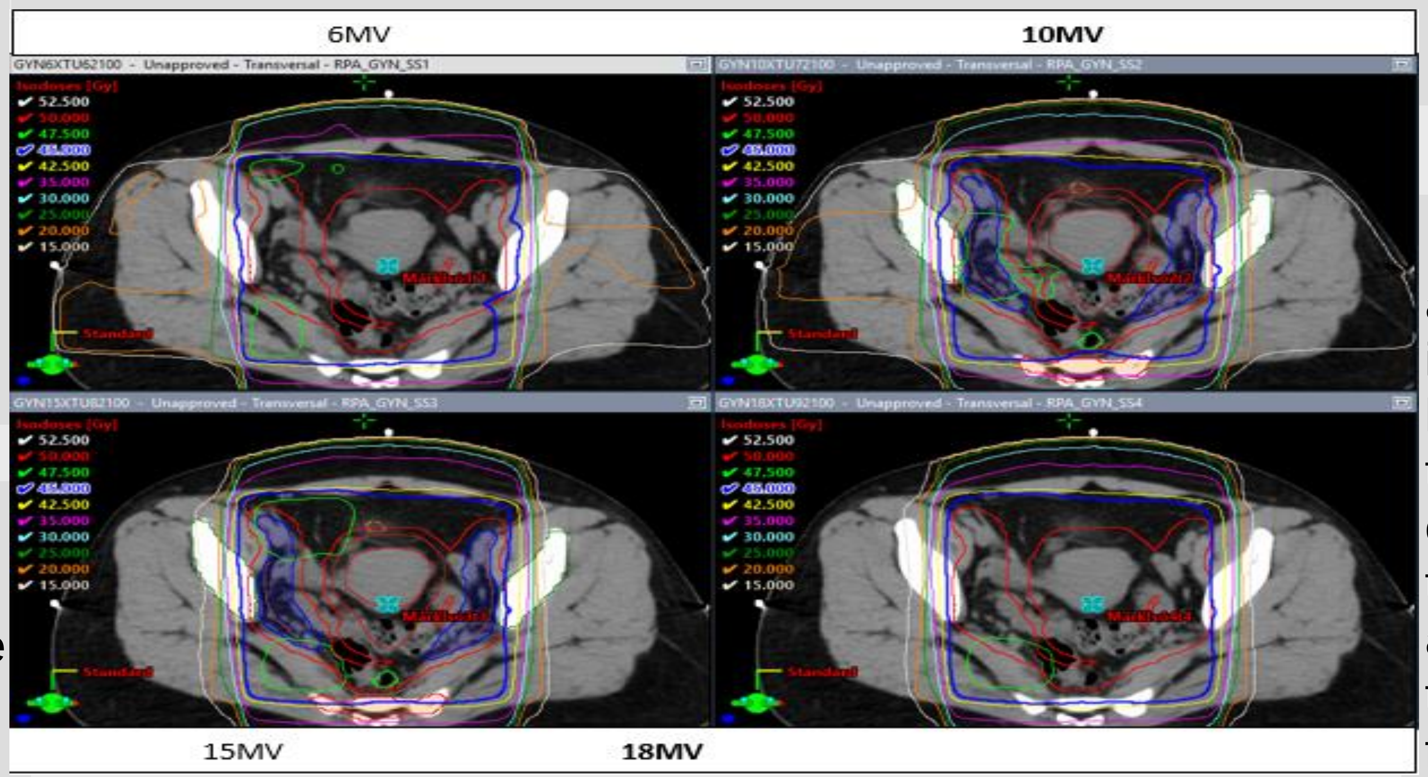

Figure 1. Cervix Isodose distribution

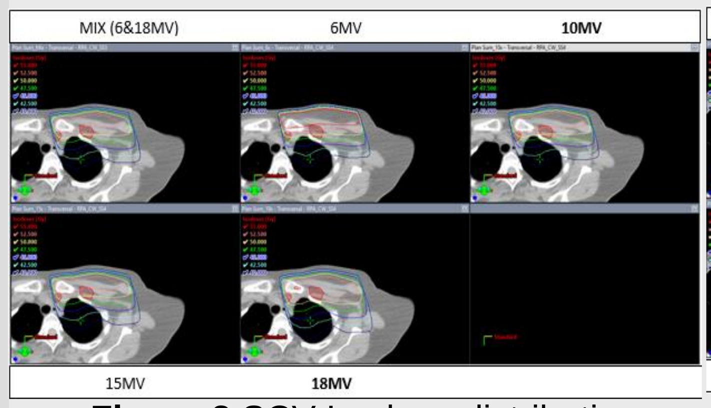

Figure 2. SCV Isodose distribution

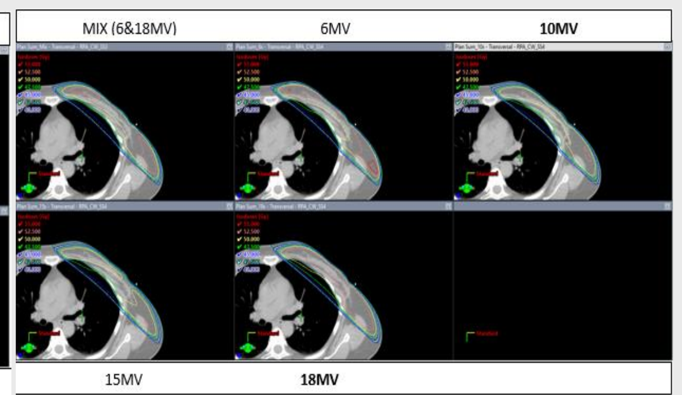

Figure 3. CW Isodose distribution

	6MV	10MV	15MV	18MV	MIX (6&18MV)
CERVIX	100%	100%	100%	100%	N/A
SCV	99.8%	99.2%	98.4%	98.2%	99.4%
CW	86.8%	83.3%	81.7%	82.4%	85.3%

Table1: COVERAGE 45Gy line

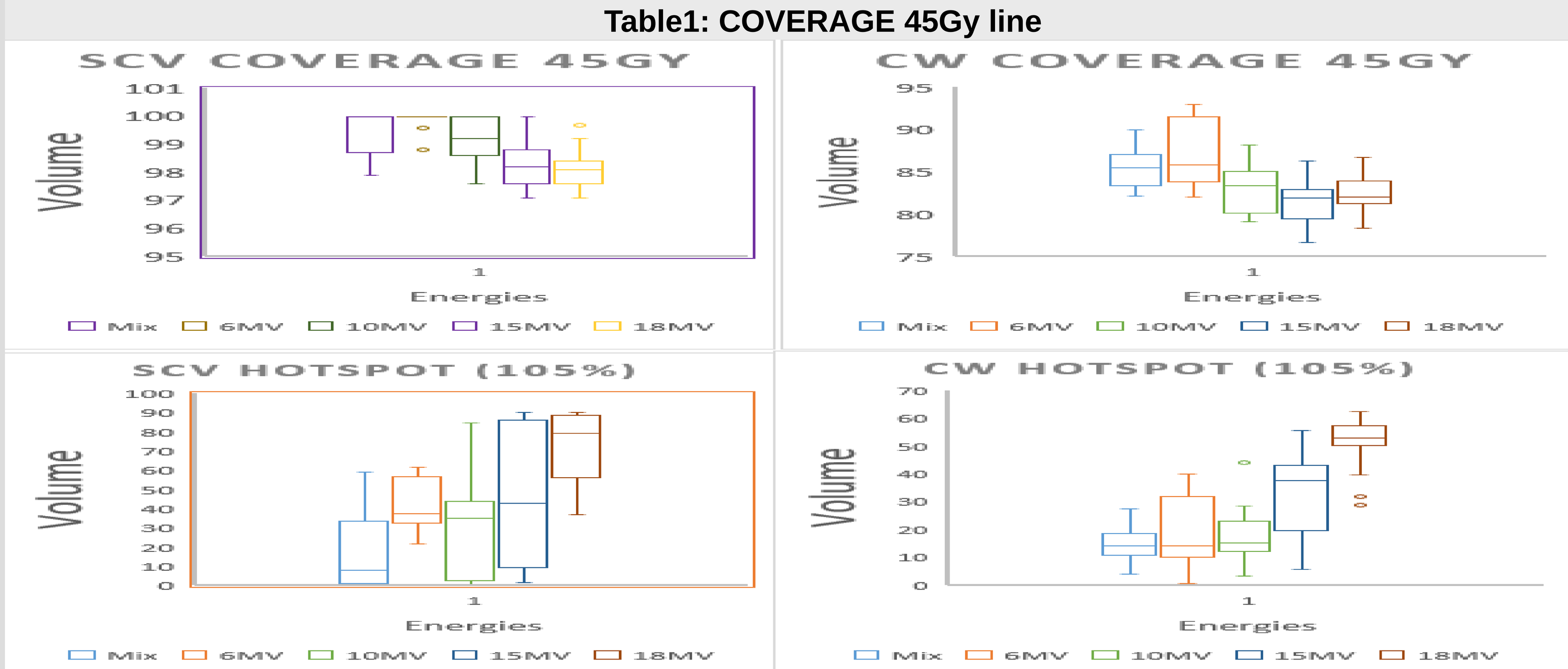

Chart 1. SCV and CW coverage and 105% Hotspot by energy

DISCUSSION

In this work, we have demonstrated that acceptable cervical cancer treatment plans can be achieved using 10 or 15MV. For most patients, with these energies, we have a higher dose to the OAR, but still within the acceptable range. The plans with 6MV energies were too hot for use. These results mean that clinics with limited equipment can still be able to treat certain patients even if their linear accelerator only has 10 or 15MV photon energy.

For chest wall cases, plans generated with the RPA provided adequate coverage of the SCV field. The coverage of the CW planning target is used for comparison only. In fact, the RPA CW region of interest (ROI) is simply a planning structure and not the true chest wall volume. The current RPA structure is used to define the tangential field borders only therefore it extends into the muscle and ribcage. Laterally, our contour is overextended past the breast/CW tissue. Considering the plan with the mixed energy as an ideal plan, we observed that the plan generated with 10MV appears to have some similarities in terms of coverage, dose to OARs and high dose for the tangent fields. Some patients, probably due to small separation, also display acceptable plans with the 6MV energy. Plans using 15 and 18MV offered less coverage and highest doses.

CONCLUSIONS

We generated treatment plans using an automated planning system to evaluate the impact of energy change on target coverage, hotspot and OAR. For cervix, besides18MV that is the energy of choice, 10MV and 15MV offer similar coverage with acceptable dose to the OAR. The 6MV energy produce plans that are too hot to be used. Further optimization of these plans will be possible once the field and field script is improved. For chest wall, the plans generated with the mixed energy gave the best ratio of coverage and dose to OAR as well as high dose. For some cases, 6MV or 10MV also generated clinically acceptable plans. Due to extended area covered by the CW planning target by the RPA, its coverage was only used for comparison between plans.

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