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Monte Carlo Based Algorithms Are More Accurate for Dose Calculations in Radiotherapy

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Abstract Monte Carlo (MC) is considered as gold standard for dose calculations in radiotherapy. MC dose calculations often require sophisticated computing services with long processing time and this has been an issue for the busy cancer centers. Hence, majority of the treatment planning system include faster dose calculation engines for the daily clinical routine. Due to advancement in technology and computing power, it is now possible to implement MC based dose calculation algorithms in the clinical environment. This report summarizes the major findings of various researchers who have investigated Acuros XB algorithm, which is the MC based dose calculation algorithm commercially available for dose calculations in radiotherapy.

Keywords: *dose calculation, monte carlo*

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1. Introduction

Accuracy of dose calculations in radiotherapy is crucial to prevent mistreatment of patients undergoing radiotherapy. The estimation of dose deposited in matter is a complex process which involves the interaction of radiation beam with the matter. [1] In radiation therapy, there are various vendors, which supply treatment planning system (TP), and different TPS are more likely to have different dose calculation engines. This is mainly due to the difference in the radiation beam modeling approach among different TPS. Hence, it is expected that the dose calculations of one TPS may not be similar to that of another TPS. This could create confusion for the clinicians if they have to choose one TPS over the another.

Monte Carlo (MC) is considered as gold standard for dose calculations in radiotherapy. [1] MC dose calculations often require sophisticated computing services with long processing time and this may be an issue for the busy cancer centers. Hence, majority of the treatment planning system include faster dose calculation engines for the daily clinical routine. Due to advancement in technology and computing power, it is now possible to implement MC based dose calculation algorithms in the clinical environment. This report summarizes the major clinical findings of various researchers who have investigated Acuros XB algorithm, which is the MC-based dose calculation algorithm commercially available for dose calculations in radiotherapy.

2. Methods

Google Scholar and PubMed were used to conduct the literature search of this article. Literature search was carried out using terms "Acuros XB" and "Dose Calculation".

3. Results and Discussion

Several researchers [2-7] have investigated the accuracy of one of the most recent dose calculation engines called Acuros XB, which is considered to be MC based engine. As many centers continue to explore the accuracy of Acuros XB, current literature shows the promising results of Acuros XB as it is validated against the measurements and MC simulations [2-7]. The accuracy of Acuros XB was reported to be within 5% [2] when compared to the MC calculations. Other research groups also reported better results, with accuracy up to 4.4% [3], 3% [4], 2% [5], and 2.8% [6]. It was also reported that Acuros XB calculated results showed relatively high level of agreement in 3D gamma analysis and dose volume histogram (DVH) comparison when compared to the MC simulation results. [7] These results suggest high level accuracy of Acuros XB for dose calculations in simple and complex situations.

A good number of studies have also investigated the clinical use of Acuros XB. For example, Kroon *et al*. [8] evaluated the Acuros XB for lung cancer patients and found that Acuros XB calculations lower near-minimum PTV dose and mean PTV dose than the plans calculated by analytical anisotropic algorithm (AAA). Similar finding was reported by Kathirvel *et al*. [9] with Acuros XB producing slightly lower mean PTV dose against AAA for lung cancer. Liu *and colleagues* [10] reported lower plan conformation number and higher target dose heterogeneity in the Acuros XB plans than in the AAA plans. Fogliata *et al*. [11] reported that the AXB predicted lower mean PTV dose in the soft tissue when compared to the AAA for both the 6 MV and 15 MV photon beams. While the target doses from Acuros XB are more favorable than AAA, clinicians must pay special attention to the reduced PTV coverage from Acuros XB calculations in the case of lung cancer as demonstrated by Rana and colleagues [6,12].

Difference in dose calculations can be dependent on the materials assignment in the Acuros XB and the uncertainty in the CT calibration curve. Difference in dosimetric results of various algorithms may also influence the treatment outcomes of the patients undergoing radiotherapy. Report shows that 5% to 10% lower dose differences may result in 10% to 20% changes in tumor control probability (TCP) or 20% to 30% changes in normal tissue complication probability (NTCP) [7,13]. Hence, it is imperative to perform dose calculations in treatment plans using most accurate dose calculation algorithms. Furthermore, most of the clinical studies on the dose calculation algorithms are done based on DVH results. Treatment plan optimizations are also done using DVH parameters. It is possible to achieve more accurate prediction of TCP and NTCP if treatment plans are evaluated using radiobiological parameters [14].

Despite the promising results of Acuros XB, clinicians may not be able to implement Acuros XB in their clinics immediately due to financial/budget issues. Other commonly used dose calculations algorithms are collapsed cone convolution superposition (CCCS), AAA, and pencil beam convolution (PBC). [1,5,15,16] The literature suggests that CCCS is more accurate than both the AAA and PBC when dose calculations are performed in inhomogeneous media. [1] The influence of dose calculation algorithms will be noticeable for the lung cancer treatment plans, which involve the low-density tissue. The combination of small field size and low-density tissue could cause charge particle disequilibrium, and this must be accounted when heterogeneity corrections are applied by the dose calculation algorithms. However, due to the difference in the beam modeling within dose calculation algorithms, there is going to be discrepancy in their dosimetric results. For example, tissue heterogeneity corrections in PBC are done only in the beam direction, but not in the lateral directions [1].

In photon radiotherapy, the most commonly used beam energy is 6 MV. However, other higher energies such 10 MV and 15 MV are also used for the treatment. Dosimetric results can be dependent on the photon beam energy. [17,18] Higher energy will produce the beam hardening effect, and dose calculation algorithms must be able to account for the beam hardening as well as beam attenuation and later scatter in the final dose calculations.

4. Conclusion

Literature review shows that results of Acuros XB are very promising, and it could be used as an alternative dose calculation engine for calculations in radiotherapy. Further studies on radiobiological impact of Acuros XB would provide more confidence on its clinical use in many cancer centers.

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