Effects of dose calculation algorithms on the estimate NTCP for thoracic cancer

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Abstract. The study aims to investigate the effect of dose calculation algorithms on the estimate normal tissue complication probability (NTCP) of thoracic cancer. Dose distributions of treatment plans are calculated by using Collapsed Cone (CC) and Pencil Beam (PB) algorithms from Oncentra Masterplan treatment planning system. Four treatment plans of thoracic cancers are created and dose volume histograms (DVHs) from each planning were evaluated based on criteria of acceptance level. The DVH data of the treatment planning were exported to Biosuite Software to compute the NTCP values. The NTCP were calculated accounting for the CC and PB algorithm using the Lyman-Kutcher-Burman (LKB) and Relative Seriality (RS) model. The NTCP values of the LKB model are found to have slightly higher values compare to RS model for all treatment planning using both algorithms. This study also demonstrates that the dose calculation algorithms of CC and PB did not significantly influence the computed NTCP value in the present treatment planning of thoracic cancer.

1. Introduction
Radiotherapy is delivered by taking into consideration the optimal dose to the tumour and tolerance dose to the healthy tissue. Previous studies have demonstrated the influence of different dose calculation algorithms on the dose distribution and dose volume histogram (DVH) for radiotherapy treatment planning [1]. Different dose calculation algorithms might possess some uncertainties that could cause error to the dose distribution and hence influence the treatment planning evaluation [2]. This is a concern not only when evaluation of radiotherapy treatment planning based on physical dose that might be affected by the different dose calculation algorithms but also the biological outcome. Radiobiological analysis of treatment planning is quantified by calculating the tumour control probability (TCP) and normal tissue complication probability (NTCP). NTCP model uses a mathematical expression to describe the relationship between the prescribed radiation dose and the biological effects in normal tissue [2]. The knowledge of the biological outcome due to the application of different dose calculation algorithm might assist in optimizing the process of treatment planning and improve overall radiotherapy treatment [3]. In this study, we investigate the influence of dose calculation algorithms; collapsed cone (CC) and pencil beam (PB) on the NTCP of the organ at risk (OAR) for thoracic cancer.

2. Materials and Methods
Two clinical 3D conformal radiotherapy (3DCRT) treatment plans of thoracic cancer were considered. Both treatment plans used 6 MV photon beam with total dose of 30 Gy and 15 fraction. OAR for thorax are spinal cord, right lung and left lung. The dose distribution of planning target volume (PTV) and OAR were calculated as displayed in DVH. The first 3DCRT plans consisted of 3 beam plans and the second plan was with 5 conformal fields plan. The treatment plans were done with the CC algorithm of the Oncentra Masterplan and later repeated with PB algorithm.

The DVH data for both planning of CC and PB algorithm were exported to Biosuite software for radiobiological analysis \( [4] \). The NTCP values were computed based on The Lyman-Kutcher-Burman (LKB) and Relative seriality (RS). The LKB model as shown in equation (1) is also known as the normal or probit model that used to calculate the probability of complication of a partially uniformly irradiated critical organ. The parameters needed for the model are \( TD_{50} \), \( m \) and \( \alpha/\beta \) \( [5] \).

\[
NTCP_{LKB} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{x^2}{2}} \, dx
\]

\[
t = \frac{D - TD_{50}(v)}{mTD_{50}(v)}
\]

\[
TD_{50}(v) = TD_{50}(1) \cdot v^{-n}
\]

\( TD_{50} \) defined as the dose which uniformly delivered over the whole organ that will produce a 50% chance of complications while \( v \) is the fraction of the organ irradiated uniformly. The three parameter \((TD_{50}, m \) and \( n)\) is referred to the publication by Burman et al. \( [5] \).

The RS model as shown in the equation (2) calculated the probability of damage of normal tissue based on binomial statistics. The parameters used is \( D_{50} \), \( \gamma \) (gamma is maximum relative slope of the dose-response curve), \( s \) (seriality) and \( \alpha/\beta \). \( D_{50} \) is the dose which uniformly delivered over the whole organ that will produce a 50% chance of complications \( [6] \).

\[
NTCP(D_j) = 2^{-\gamma \left(1 - \frac{D_j}{D_{50}}\right)}
\]

3. Results and Discussion

Dose calculation algorithms implemented for radiotherapy treatment planning predict dose distribution and dose volume histogram. Different dose calculation algorithms will provide different dose outcome for the same treatment which could affects the calculation of NTCP values. PB and CC were used to calculate dose and estimated the NTCP values for 3D conformal radiotherapy planning of thoracic cancer. Table 1 present the total dose received by the critical structures, gross tumour volume (GTV) and planning tumour volume (PTV) for 3 and 5 beam treatment fields calculated using CC and PB planning for thorax. In the 3 beams field planning, the total dose received by right lung at 37% of volume is 3.2% and 3.0% for collapsed coned and pencil beam respectively. For left lung, the total dose received is 2.6% for collapsed cone and 2.7% for pencil beam with the same volume as the right one. Meanwhile for spinal cord, the dose indicates 31.4% and 32% with the volume at 0.03% for both algorithms. The GTV covers 95.1% for collapsed coned and 95.9% for pencil beam. However, PTV only covers 94.4% by using collapsed coned and 93.2% by using pencil beam. Both GTV and PTV are evaluated at 100% of volume.

In the 5 field beams planning, the total dose for right lung shows higher value than 3 beams which is 6.7% for collapsed coned and 5.2% for pencil beam. Left lung also show greater dose which is 6.2% and 5.5% for both algorithms respectively. The dose on spinal cord is somehow lower than 3 field beams which are 20.6% for both algorithms. Slightly different dose were obtained for GTV which 93.7% and 93.3% for CC and PB respectively. The PTV values for 5 field beams are lower than 3 field beams which are 85.7% and 85.3% respectively for both algorithms.
Table 2 presents the NTCP value computed from LKB and RS models for treatment planning based on CC and PB algorithms. For CC planning, the right lung shows a NTCP value of 100% on LKB model and 98% on RS model for 3 field beams. Meanwhile, 5 field beams show 100% of NTCP value on both models. Besides, the left lung indicates 98% value on LKB model and 95% for RS model. For 5 field beams, it shows 100% value for both models. LKB model does not provide a parameter for spinal cord but for RS model, spinal cord shows 90% value for 3 field beams and 98% value for 5 field beams. For pencil beam, the right lung shows 100% NTCP value for both models. Left lung shows 98% value of RS model and 100% of LKB model. Meanwhile, spinal cord shows 95% for 3 field beam and 98% for 5 field beams.

Table 1. Total dose (%) of the critical structures, GTV and PTV for 3 and 5 treatment fields by using collapsed coned (CC) and pencil beam (PB) for thorax cancer

|                     | 3 field beams | 5 field beams |
|---------------------|---------------|---------------|
|                     | Collapsed     | Pencil Beam   | Collapsed   | Pencil Beam |
|                     | Coned         |               | Coned       |               |
| Right Lung (V37)    | 3.2           | 3.0           | 6.7         | 5.2           |
| Left Lung (V37)     | 2.6           | 2.7           | 6.2         | 5.5           |
| Spinal Cord (V0.03) | 31.4          | 32            | 20.6        | 20.6          |
| GTV(V100)           | 95.1          | 95.9          | 93.7        | 93.3          |
| PTV(V100)           | 94.4          | 93.2          | 85.7        | 85.3          |

Table 2. NTCP calculation for collapsed coned (CC) and pencil beam (PB) for 3 field beams and 5 field beams planning

|                     | 3 field beams | 5 field beams |
|---------------------|---------------|---------------|
|                     | NTCP-LKB (%)  | NTCP-RS (%)   | NTCP-LKB (%) | NTCP-RS (%)   |
| Collapsed Coned     |               |               |             |
| Right Lung Pneumonitis | 100          | 98            | 100         | 100           |
| Left Lung Pneumonitis | 98           | 95            | 100         | 100           |
| Spinal Cord Myelitis | -             | 90            | -           | 98            |
| Pencil Beam         |               |               |             |
| Right lung Pneumonitis | 100          | 100           | 100         | 100           |
| Left lung Pneumonitis | 100          | 98            | 100         | 100           |
| Spinal cord Myelitis | -             | 95            | -           | 98            |

4. Conclusions
The dose distribution of the critical structures, GTV and PTV for 3 and 5 beam treatment fields computed using collapsed coned and pencil beam algorithms for thorax treatment planning demonstrate minimal differences which did not influence the NTCP values significantly. LKB model computed slightly higher NTCP values compared to RS model for all treatment planning using both algorithms. The results from this study might provide an indication on the possible error which is
found to be negligible when applying different dose calculation algorithms in estimating the NTCP values for treatment planning evaluation. Future study will include more advanced dose calculation algorithms to other tumour sites and organ at risk.

5. References
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Acknowledgements
This work was funded by Universiti Sains Malaysia Research University Grant (RUI: 1001/PPSK/8012212). We also would like to spread our gratitude toward Hospital Universiti Sains Malaysia for providing necessary facilities for us to conduct this research.