Validation of in-house treatment planning system software for cobalt-60 teletherapy unit at two radiotherapy installations

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Abstract. DSSuperDose v.1.0 is an in-house treatment planning system (TPS) developed by Medical Physics and Biophysics Laboratory (LFMB) Universitas Indonesia as a treatment planning software for Cobalt-60 teletherapy unit. The main objective of this study was the validation of in-house TPS calculation as an essential part in quality assurance (QA) of radiotherapy. Validation of an in-house TPS was performed with two Cobalt-60 teletherapy units by comparison between in-house TPS and ISIS TPS and by measurements of absorbed dose. Mean dose deviations between in-house TPS and measurement were (1.97 ± 2.42)% for open field, (1.32 ± 1.30)% for tray field, and (2.91 ± 2.36)% for wedge field treatments. In-house TPS provide optimal planning for open and tray beam conditions with depth fewer than 10 cm (≤ 10 cm) and field sizes up to 20×20 cm², while for wedge beam conditions with field sizes fewer than the physical size of the wedge. Comparison of in-house TPS and ISIS TPS demonstrated a good match of 96%. From the results, it is concluded that DSSuperDose v.1.0 is adequately accurate for treatment planning of radiotherapy.

1. Introduction

Radiation therapy (both internal and external radiation) is a complex and potentially a high risk procedure. It is very important that radiation therapy is accurately planned and properly delivered to the patients. In external beam radiation therapy, either treatment time of teletherapy unit or monitor unit (MU) of linear accelerator becomes the important parameter in ensuring the accuracy of prescribed dose to patients [1]. Efforts to reduce errors and uncertainties of the calculation in treatment planning allow important role in achieving the optimal therapy. Improving the accuracy of the calculation, computational tools should be applied in the treatment planning process. Such as in-house treatment planning system (TPS) was developed in beginning of 2015 by Medical Physics and Biophysics Laboratory (LFMB) Universitas Indonesia as the treatment planning software for cobalt-60 teletherapy unit.

Quality assurance (QA) in treatment planning process of the radiation therapy is essential for minimizing the possibility of accidental exposure. The accuracy of either treatment time or MU calculation is one of important parameter in QA TPS [2]. Validation of MU calculation as part of the
commissioning process is one way to identify errors on TPS algorithms, before it should be used clinically [3]. This validation is done by comparison of dose calculation and measurement. Some researchers have described several criteria of dose deviation or acceptable tolerances [2-4]. Another verification methods can also be reached to strengthen confidence in the accuracy of an in-house TPS. Verification calculations are traditionally performed by applying empirical algorithms in a manual calculation procedure [2, 5]. Moreover, comparison of in-house TPS with independent MU calculation software can also be an alternative that is sufficient to identify significant errors and uncertainties in clinical dosimetry [6, 7]. Another method is by comparing the in-house TPS with others commercial software that has been implemented clinically, this method could be a way to identify systematic errors of the algorithm implemented in the TPS [3].

The main objective of this study was to validate in-house TPS of LFMB UI as an essential part in QA of computerized planning systems for radiotherapy. This study was conducted to identify errors on in-house TPS algorithm for the calculation of treatment time for varied beam conditions. Finally, the results of this study can be a used to evaluate the accuracy of the algorithm, before it should be implemented clinically in the patient therapy planning.

2. Materials and methods

In-house TPS was tested to two well-establish radiotherapy department where were Cipto Mangunkusumo National Center Hospital and Persahabatan Center Hospital. Both teletherapy units were FCC 8000 type Cobalt-60 teletherapy of Shandong Xinhua Medical Co. Ltd, China which source activity of each teletherapy unit were 231.25 TBq at October 7th, 2005 and 319.7 TBq at Mart, 2007.

2.1. Treatment time calculation of DSSuperDose v.1.0

DSSuperDose v.1.0 is in-house TPS developed by Medical Physics and Biophysics Laboratory (LFMB) Universitas Indonesia as a treatment planning software for Cobalt-60 teletherapy unit. The semi-empirical method was implemented in the Java™ algorithm. The general formula used to calculate each technique of treatment were allowed in equation (1), is used in fixed SSD (Source to Surface Distance) technique, and equation (2), is used for fixed SAD (Source to Axis Distance) technique [2]. However, several correction factor such inhomogeneities and off-axis correction weren’t considered in DSSuperDose v.1.0. The general flow chart of DSSuperDose calculation was displayed by figure 1.

\[
\text{time} = \frac{\text{PrescribedDose}}{D(d_{ref} , A_{ref}) \times RDF(d_{ref} , A) \times \frac{\text{PDD}(d, A)}{100} \times \text{WF} \times \text{TF}}
\]  

(1)

\[
\text{time} = \frac{\text{PrescribedDose}}{D(d_{ref} , A_{ref}) \times RDF(d_{ref} , A) \times \text{TMR}(d, A) \times \text{ISF} \times \text{WF} \times \text{TF}}
\]  

(2)

Data of dosimetry quantities was imported into SQL database system of in-house TPS, to be used for basic beam data of treatment time calculation. Data of percentage depth dose (PDD) and tissue-maximum ratio (TMR) were implemented based on table data of Cobalt-60 beams in British Journal of Radiology Supplement 25 [8], while data of dose rate, relative dose factor (RDF), wedge factor (WF), and tray factor (TF) were implemented by calibration certificate of each teletherapy unit. Linear interpolation was used to calculate numbers of \( \text{PDD}(d,A), \text{TMR}(d,A) \) and \( \text{RDF}(A) \), while equivalent square field (\( A_{eq} \)) was determined by 4 Area/Periphery (Day’s rule) [2,8]. Calculation of dose rate decay of cobalt-60 source was determined by exponential extrapolation of radioactive decay which half-time (\( t_{1/2} \)) of cobalt-60 decay is 5.27 years or 1919.9 days [2,8].

2.2. Treatment planning
Test plans were created by both DSSuperDose v.1.0 and ISIS TPS to determine quantities of treatment time in delivering prescribed dose of 50 cGy or 100 cGy for each teletherapy units. Results were acquired for 471 treatment plans of patient-related data including varied treatment techniques, both fixed SSD and fixed SAD technique, for varied beam conditions.

2.3. Measurement of absorbed dose
Absorbed dose were measured at the central beam axis which SSD technique was implemented. Treatment times for each measurement were taken by calculation of DSSuperDose v.1.0 which were acquired for 119 treatments including varied beam conditions as open field, tray field, and wedge field with varied of field sizes and depths. Absorbed dose was calculated based on IAEA TRS 398 [9]. Dose deviations were evaluated with respect to beam conditions, as follow [2]:

\[
\delta(\%) = \frac{D_{\text{planned}} - D_{\text{measured}}}{D_{\text{measured}}} \times 100\%
\]  

Measurements were performed with 0.6 cc ionization chamber in a homogeneous condition. At Cipto Mangunkusumo National Center Hospital, type chamber (PTW Farmer® type N30013) which was connected to PTW Unidos electrometer with the calibration factor of the detector is \((53.99 \pm 0.67)\) cGy/nC was used in a scanning water phantom (IBA Blue Phantom). While, in Persahabatan Hospital measurements were carried out in the water phantom with a calibrated ionization chamber (TM type 30013) connected to PTW Unidos electrometer T 10001 with the calibration factor of the detector is \(53.25\) cGy/nC.

3. Results and discussions

3.1. Comparison with ISIS TPS
Analysis of linear regression was used to the comparison between in-house TPS and ISIS TPS calculation, summarize in table 1. A linear fit produced a slope that indicated a ratio of treatment time calculated by both TPS, and a correlation coefficient that demonstrated a match level between both datasets [10]. In general, good agreement was acquired between calculations performed by in-house TPS and ISIS TPS, with the level of data variability achieved 96% that was represented by the coefficient of linear regression (\(R^2\)) up to 0.96.

3.2. Measurement of absorbed dose
First, we evaluated output calibration of each cobalt-60 teletherapy unit for several date of treatment. It showed dose rate deviation between in-house calculation and measurement inside the acceptance tolerance of \(\pm 2\%\) [2]. In other words, it indicated good performance about exponential extrapolation of Cobalt-60 decay in in-house TPS.

For open field, dose deviation of cobalt-60 teletherapy unit A and B were shown in left side of figure 2 and figure 3. In general, limit tolerance of \(\pm 2\%\) dose deviation for the open field was achieved. However, high dose deviations were found for small field size and deep depth, such field of \(3\times3\) cm\(^2\) and depth of 15 cm. This results were affected by limitation of RDF as a basic beam data of in-house TPS. Data of RDF for cobalt-60 teletherapy unit A were limited only from field size of \(4\times4\) up to \(25\times25\) cm\(^2\). RDF data for field size of \(3\times3\) cm\(^2\) and \(30\times30\) cm\(^2\) was determined by extrapolation and gained uncertainties. Then, an effect of the penumbra in small field size and deep depth should be considered [11]. The same indication was found for results of Cobalt-60 teletherapy unit B.

For treatment with beam modifiers such tray and wedge field, results were displayed by right side of figure 2. For tray field, it showed same indication with open field. In addition, deviations of tray factor (TF) both of tray with hole and tray without hole provided additional errors of dose deviations. For wedge field, it was acquired that acceptable tolerance of \(\pm 3\%\) for wedge field was reached for several data. Dose deviations increased for field sizes larger than the physical size of wedge (\(10\times15\))
and high wedge angle. Deviations of wedge factor (WF) for each wedge angle provided additional errors. Cozzi et al. have reported that wedge factor depends on field size [12]. It confirmed

**Figure 1.** Flow chart of DSSuperDose v.1.0.

**Table 1.** Comparison between DSSuperDose and ISIS TPS of each Cobalt-60 teletherapy unit. A linear fit produced a linear equation $Y = a X \pm b$, with treatment times calculated by DSSuperDose at Y-axis, treatment times calculated by ISIS TPS at X-axis, $a$ is the curve slope and $b$ is the intercept, while $R^2$ is the coefficient of linear regression.

| Beam conditions          | Cobalt-60 Teletherapy Unit A | Cobalt-60 Teletherapy Unit B |
|--------------------------|------------------------------|------------------------------|
| Fixed SSD - Open field   | $Y = 0.2295 + 0.8859 X; R^2 = 0.9758$ | $Y = 0.1074 + 0.9956X; R^2 = 0.9901$ |
| Fixed SSD - Tray field   | $Y = 0.1460 + 0.9357 X; R^2 = 0.9607$ | $Y = 0.1084 + 0.9719 X; R^2 = 0.9894$ |
| Fixed SAD - Open field   | -                            | $Y = 0.1556 + 0.9545 X; R^2 = 0.9721$ |
| Fixed SAD - Tray field   | -                            | $Y = 0.2363 + 0.8859 X; R^2 = 0.9597$ |
that dose deviation would increase for a beam with field size larger than the physical size of wedge as an effect of scattered dose. Then, the discrepancy of PDD should be considered. The use of open field PDD data to represent wedge field PDD data was not recommended because the beam hardening to be expected with wedges in a cobalt beam depends upon the spectrum of scattered beam, especially photon beam, as well as upon the wedge construction [8].

In general, discrepancies between PDD of in-house TPS and table data of each machine commissioning would provide errors. Although many research showed that discrepancy of PDD for others machine was only 1% up to 2% [8]. However, discrepancies of PDD for another machine were affected by characteristics of beam output which was affected by the construction of Cobalt-60 teletherapy unit, such source size and collimator type. Large source size would provide large effect of penumbra [13]. We found discrepancies between PDD of in-house TPS and table data of each machine commissioning were up to 3.61%, high discrepancy was found for deep depth, such depth of 15 cm, and field size of 25x25 cm².

Summary of dose deviation was shown in table 2. Confidence level (CL) 95% was taken to improve the data confidence. Results were acquired 80% of data for open field, 91% of data for tray field, and 65% of data for wedge field which achieved the limit tolerance for each beam condition. In addition, evaluation of equivalent square field showed discrepancies of dose deviation between a rectangular field with an equivalent square field that occurred fewer than 1%. It was confirmed that...
Day and Sterling have reported that equivalent square demonstrated same dosimetry characteristics with own rectangular field [14].

Table 2. Summary of dose deviation with respect to varied beam conditions.

| Beam conditions | number of fields | Min. | Max. | Mean | SD | CL |
|-----------------|------------------|------|------|------|----|----|
| Open field      | 54               | 0.06 | 11.84| 1.97 | 2.42 | 1.97 ± 3.63 |
| Tray field      | 22               | 0.02 | 5.61 | 1.32 | 1.30 | 1.32 ± 1.94 |
| Wedge field     | 43               | 0.05 | 9.95 | 2.91 | 2.36 | 2.91 ± 3.53 |
| Overall         | 119              | 0.02 | 11.84| 2.19 | 2.29 | 2.19 ± 3.44 |

4. Conclusion
In this study, we have done the validation of DSSuperDose v.1.0. In-house TPS gives optimal planning for open and tray beam conditions with depth fewer than 10 cm (≤ 10 cm) and field size up to 20x20 cm², while for wedge beam conditions with field size fewer than the physical size of the wedge. Comparison of in-house TPS and ISIS TPS demonstrated a good match of 96%. From the results, it is concluded that DSSuperDose v.1.0 is adequately accurate for treatment planning of radiotherapy. The accuracy of in-house TPS was affected by basic beam data.

5. References
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Acknowledgements
This study was funded by Hibah PUPT 2015 with contract number 0540/UN2.R12/HKP.05.00/2015. We also gave thanks to the head and medical physicist of Department of Radiotherapy Cipto Mangunkusumo Hospital and Persahabatan Hospital who contributed in measurement procedures.