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Evaluation of dose calculation accuracy of a commercial radiotherapy treatment planning system for adjacent radiation fields

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Abstract

Background: Adjacent radiation fields are applied in some radiotherapeutic cases. When using these radiation fields, considerable dose errors across the junction of radiation fields are possible. Therefore, it is necessary to evaluate the accuracy of the dose calculated by treatment planning system (TPS) when using the adjacent radiation fields. The present study aimed to quantify the dose calculation accuracy of ISOgray TPS for the photon-photon adjacent fields.
Materials and methods: To assess the accuracy of dose calculations, the dose profiles were first measured by a Semiflex ionization chamber at 1, 1·5, 5 and 10 cm depths for different field sizes (6×6, 10×10 and 20×20 cm^2), source to surface distances (SSDs) (90, 100 and 110 cm) and beam angles (0º, 15º, 30º and 45º). In the second step, the data at corresponding depths were extracted from the ISOgray TPS. Finally, the dosimetric performance of TPS was evaluated using a gamma index analysis.
Results: The overall dose calculation accuracy of ISOgray TPS was within the acceptable range for the build-up region (with acceptance criteria of dose difference (DD) = 15% and distance to agreement (DTA) = 3 mm) and the depths after the build-up region (with acceptance criteria of DD = 5% and DTA = 3 mm). Moreover, the overall accuracy of dose calculations was not affected by the field size and the SSD. It was also shown that the accuracy of dose calculations was similar for the adjacent radiation fields with beam angles of 0º, 15 º and 30 º, while a considerable decrease in the pass rate values is obtained for the adjacent radiation field with 45 º beam angle. A more detailed analysis of the findings revealed that the accuracy of dose calculations in the match line regions of the adjacent radiation fields for 1 cm beam profiles was within the acceptable range; however, it declined for other depths.
Conclusions: The findings showed that the overall dose calculation accuracy of ISOgray TPS was acceptable for evaluated adjacent radiation fields. However, the accuracy of dose calculations in the match line regions of the adjacent radiation fields for the depth after build-up was not within the acceptable range.

Introduction

Cancer or malignant tumor is a prominent cause of death and an important impediment to extending life expectancy in the world.[1,2] Overall, cancer incidence and mortality are increasing at an alarming rate worldwide. In 2040, an estimated 28·4 million new malignant tumor cases would be diagnosed worldwide, up 47 percent over the 19·3 million cases diagnosed in 2020·[3] There are different therapeutic modalities for cancer treatment such as surgery, radiotherapy, chemotherapy, ultrasound with high intensity, hormone therapy, immunotherapy and so on.[4–7] Radiotherapy is an effective therapeutic option for treating various tumors that is applied in almost half of all patients with localized cancer.[8–11]

The radiotherapy process is complex and consists of a series of steps that begins with patient diagnosis and tumor staging and culminates in treating a determined target volume/tumor with established radiation energy, treatment technique and other beam parameters. The accuracy in each of the radiotherapeutic steps has an important and critical effect on the treatment outcome. To achieve such accuracy, the discrepancies in all these steps must be minimized as much as feasible.[12–14] Treatment planning system (TPS) is a substantial component of the cancer radiotherapy process; hence, its accuracy is necessary for treatment success.[15] In other words, uncertainties or mistakes in this stage of the radiotherapeutic treatment can lead to a lower therapeutic efficacy associated with considerable adverse consequences.[12,13] Several guidelines and protocols for the quality assurance (QA) of radiotherapy TPSs have been published in recent years.[16–20]

Some studies have evaluated the dose calculation accuracy of radiotherapy TPSs.[21–30] Bahreyni Toosi et al.[29] assessed the dose calculation accuracy of ISOgray TPS in craniospinal radiotherapy. The obtained findings showed that the discrepancies between the dose values determined by TLD chips and TPS for the regions inside the treatment field were less than

4% for 90% of the evaluated points in both electron and photon beams. Nevertheless, the differences between the dose measurements and the dose calculations ranged from 10 to 40% for the regions outside the treatment field.[29] Moncion et al.[31] evaluated the dose calculation accuracy of different TPSs in the near-surface region for patients receiving whole breast irradiation. Of note, the dose values were measured with radiochromic film placed at 5 mm and 10 mm depth and three locations per depth within the phantom. The findings indicate that there were no significant differences between the mean of calculated and measured dose values for all TPSs.[31] Howell et al.[32] investigated the dose calculation accuracy of Eclipse TPS for locations outside the treatment field. They reported that the TPS underestimated out-of-field dose values by an average of 40% as compared with measured doses.[32]

Adjacent radiation fields are used in some radiotherapeutic cases such as irradiation of the entire muscle compartment for treating soft-tissue sarcoma, mantle and inverted-Y irradiation fields used for treating Hodgkin's disease, craniospinal irradiation fields for treating medulloblastoma and head and neck tumors. Among the reasons for using the adjacent radiation fields in radiotherapy are 1) larger treatment volume than the maximum radiation field size and 2) the anatomy of the patient (the normal tissue constraints and patient's contour may necessitate more than one beam configuration). However, when using the adjacent radiation fields, there is a possibility of large dose errors across the junction of radiation fields, thereby leading to severe adverse effects (if it is overdosed) or/and tumor recurrence (if it is underdosed).[33] The problems related to the adjacent radiation fields have also been extensively studied.[34–38] In view of the above, it is necessary to evaluate the accuracy of the dose calculated by the TPS when using the adjacent radiation fields.

To the best of our knowledge, there is no study conducted on assessing the dose calculation accuracy of TPS in the adjacent radiation fields. Hence, in this study, we evaluated the dose calculation accuracy of ISOgray TPS for the adjacent radiation fields. The effects of different parameters (including field size, source to surface distances (SSDs) and beam angle) on the accuracy of dose calculations in the adjacent radiation fields were also investigated.

Materials and Methods

Phantom irradiation and dose measurements

A MP3-M water phantom (PTW, Freiburg, Germany) with a dimension of $50 \times 50 \times 50\ \mathrm{cm}^3$ was used in the present project. This phantom was irradiated with 6 MV X-rays emitted from Siemens Primus linear accelerator (Siemens AG, Erlangen, Germany) installed in Yasrebi Radiation Oncology Center (Kashan, Iran).

The dose measurements were performed by a Semiflex ionization chamber with $0{\cdot}125\ \mathrm{cm}^3$ volume (TM31010, PTW-Freiburg, Germany) in the irradiated phantom for photon–photon adjacent fields with field sizes of 6×6, 10×10 and 20×20 cm2, SSDs of 90, 100 and 110 cm and beam angles of 0º, 15º, 30º and 45º. It is noteworthy that the selection of these beam parameters was based on our clinical experience in the radiotherapy center as well as previous studies[18,20,39–43]; however, due to the limitation in financial support, we could not evaluate more field sizes, SSDs and beam angles. In this study, the adjacent radiation fields were created by Half-Beam technique. For instance, in order to create a $10 \times 10\ \mathrm{cm}^2$ adjacent radiation field, we first created a $10 \times 5\ \mathrm{cm}^2$ field size (named Half Beam-A) by the collimators (Figure 1-a), and the dose profiles were then measured at different depths. In the second step, another $10 \times 5\ \mathrm{cm}^2$ field size was created (named Half Beam-B) (Figure 1-b), and similar to the first step, the dose profiles were measured at the corresponding depths. Finally, the combination of the two radiation fields along their central axes created a $10 \times 10\ \mathrm{cm}^2$ adjacent radiation field (Figure 1-c) as well as the dose profiles for this adjacent radiation field were obtained through the sum of the dose measurements obtained from the Half Beam-A and the Half Beam-B. Moreover, for evaluating the impact of each of the mentioned beam parameters (including field size, SSD and beam angle) on the accuracy of dose calculations, that variable was changed and the other parameters were constant (see Table 1). Accordingly, the ten tests coded with A, B, C, D, E, F, G, H, I and J were evaluated. In all tests, the dose profiles were measured at 1, 1·5, 5 and 10 cm depths (more details are shown in Figure 1).

Treatment planning system and dose calculations

ISOgray version 4·2·3 (Dosisoft, Cachan, France) TPS was applied for dose calculations in different points of the adjacent radiation fields. It is noteworthy that the different dose calculation points corresponded to those of the dose measurement points.

To assess the dose calculation accuracy of ISOgray TPS in the adjacent radiation fields, a water phantom with a dimension of $50 \times 50 \times 50\ \mathrm{cm}^3$ ($x \times y \times z$) was first simulated using the TPS. In the second step, the photon–photon adjacent fields with different field sizes (6×6, 10×10 and $20 \times 20\ \mathrm{cm}^2$), SSDs (90, 100 and 110 cm) and beam angles (0º, 15º, 30º and 45º) were planned. Then, the dose profiles were obtained for each test (corresponding to the measured dose profiles as described in Section 2.1.)

Analysis of results

In this study, gamma index method is used to compare the dose distributions measured by the ionizing chamber and calculated by the TPS. This method is first introduced by Low et al.[44] that uses dose difference and physical distance normalized by the acceptance criteria for the dose difference (DD) and the distance to agreement (DTA).[45] Some studies have applied the gamma index method to quantitatively compare measured and calculated dose distributions.[44,46–54] According to this method, the difference between the measured and the calculated dose distributions is obtained using Eq. 1:

$$\gamma(r_m) = \min\{\Gamma(r_m, r_c)\}\forall\{r_c\} \tag{1}$$

where

$$\Gamma(r_m, r_c) = \sqrt{\frac{r^2(r_m, r_c)}{\Delta d_m^2} + \frac{\delta^2(r_m, r_c)}{\Delta D_m^2}} \tag{2}$$

where $r(r_m, r_c)$ is the distance between the measured point to the calculated point ($|r_c - r_m|$) and $\delta(r_m, r_c)$ indicates the difference between the measured and calculated doses ($D_m(r_m) - D_c(r_c)$). Moreover, ΔD_m and Δd_m represent the "DD" and the "DTA" criteria.

The pass and fail criteria for the gamma index analysis are finally as follows: for $\gamma(r_m) \leq 1$, the doses calculated by the TPS are passed and for $\gamma(r_m) > 1$, the doses calculated by the TPS are failed.

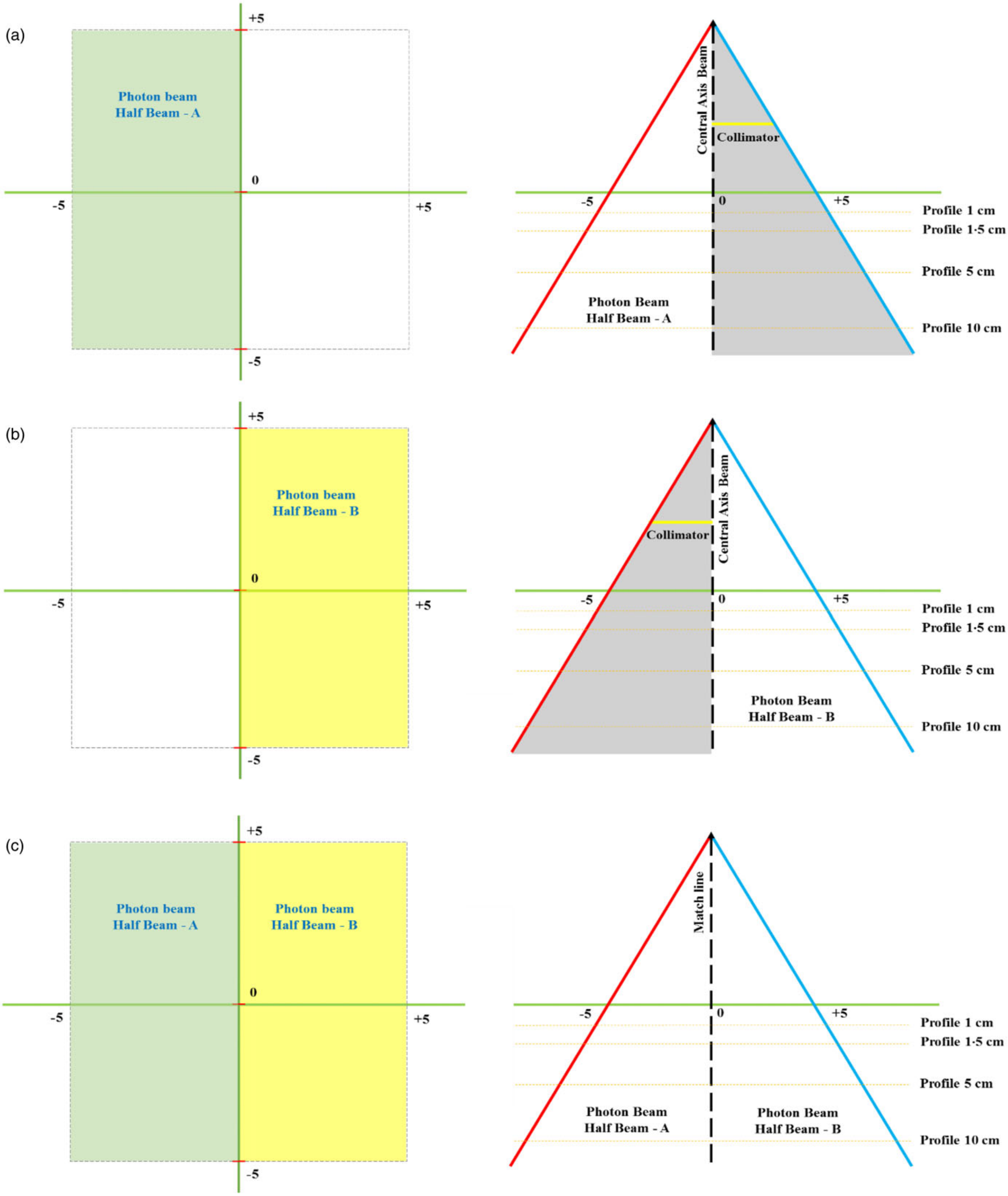

Figure 1. Schematic view of photon–photon adjacent radiation (10 cm × 10 cm) along with the dose profiles in different depths. Half Beam-A field (10 cm × 5 cm) (a), Half Beam-B field (10 cm × 5 cm) (b) and adjacent radiation field (10 cm × 10 cm) (c).

In the present research, the acceptance criterion for the DTA parameter applied in the gamma index formula was 3 mm for all evaluated tests. However, the acceptance criterion for the DD parameter was different for the evaluated tests, and its value was chosen based on the type of test geometry and the evaluated region. Of note, these DD values were extracted based on previous studies

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Table 1. The tests applied to assess the dosimetric performance of ISOgray treatment planning system for photon–photon adjacent fields.

Test Name	Field size (cm^2)	SSD (cm)	Match line angle (°)
A	6 × 6	100	0
B	10 × 10	100	0
C	20 × 20	100	0
D	10 × 10	90	0
E	10 × 10	100	0
F	10 × 10	110	0
G	10 × 10	100	0
H	10 × 10	100	15
I	10 × 10	100	30
J	10 × 10	100	45

Table 2. The 'dose difference (DD)' criterion applied in the gamma index formula for comparison between the measured and calculated doses. It is noteworthy that the 'distance to agreement (DTA)' criterion for all dose profiles was 3 mm.

		DD (%)				
	Depth (cm)	3	4	5	10	15
Dose profile	1	–	–	✓	✓	✓
	1·5	✓	✓	✓	–	–
	5	✓	✓	✓	–	–
	10	✓	✓	✓	–	–

and guidelines regarding the quality assurance of radiotherapy TPSs.[18,20,55,56] Considering that the geometry evaluated in the present study (adjacent radiation fields) is a more complex geometry, the DD parameter was considered 15% for the 1 cm beam profile (build-up region) and 5% for the other depths (1·5, 5 and 10 cm beam profiles). However, in this study, we also analyzed the results based on stricter values of the DD parameter (DD = 10 and 5% for the build-up region and DD = 4 and 3% for the other depths), as listed in Table 2.

Results and Discussion

The differences between the dose distributions measured by the ionizing chamber and calculated by the ISOgray TPS for the adjacent radiation fields with different field sizes, SSDs and beam angles were quantitatively evaluated using the gamma index method, and the obtained results were presented in the form of the gamma pass rate (the percentage of evaluated points with $\gamma(r_m) \leq 1$(. These results are listed in Tables 3-5. For better understanding, the findings are also illustrated as graphs (in Supplementary Figures 1–40).

Considering the purpose of the current project, we also specifically assessed the accuracy of dose calculations in the match lines (an area with a width of 2 cm, ± 1 cm from the central beam axis) of adjacent radiation fields, and the results are presented in Table 6.

In the current study, the gamma pass rate ≥ 90% was considered acceptable.

Table 3. The pass rate values of the gamma index analysis for different dose profiles in the field sizes of 6 × 6 (test A), 10 × 10 (test B) and 20 × 20 (test C) cm^2. The 'distance to agreement (DTA)' criterion for all dose profiles was 3 mm.

			Pass rate (%)		
	Depth (cm)	DD (%)	Test A	Test B	Test C
Dose profile	1	5	96·0	100	98·6
		10	100	100	100
		15	100	100	100
	1·5	3	69·0	83·0	95·0
		4	89·0	90·0	96·4
		5	98·0	94·0	97·1
	5	3	74·0	85·0	96·9
		4	87·0	93·0	97·5
		5	100	98·0	97·5
	10	3	75·0	84·0	97·5
		4	86·0	89·0	97·5
		5	99·0	94·0	98·8

Table 4. The pass rate values of the gamma index analysis for different dose profiles in the source to surface distances of 90 (test D), 100 (test E) and 110 (test F) cm. The 'distance to agreement (DTA)' criterion for all dose profiles was 3 mm.

			Pass rate (%)		
	Depth (cm)	DD (%)	Test D	Test E	Test F
Dose profile	1	5	100	100	97·0
		10	100	100	100
		15	100	100	100
	1·5	3	94·9	83·0	91·0
		4	97·0	90·0	94·0
		5	98·0	94·0	97·0
	5	3	80·0	85·0	86·0
		4	95·0	93·0	95·0
		5	98·0	98·0	96·0
	10	3	59·6	84·0	56·0
		4	88·9	89·0	86·0
		5	98·0	94·0	97·0

Evaluating the dose calculation accuracy of ISOgray TPS: effect of field size

The effect of field size on the accuracy of dose calculations is presented in Table 3 (tests A, B and C) and Supplementary Figures 1-12.

As seen in Table 3, for the 1 cm beam profile (build-up region) with DD = 5% and DTA = 3 mm, the pass rate values of the gamma index analysis for the field sizes of 6 × 6, 10 × 10 and 20 × 20 cm^2 were 96%, 100% and 98·6%, respectively. When the acceptance criterion for the DD parameter was increased (DD = 10% or 15%, DTA = 3 mm), the pass rate values for the corresponding field sizes increased to 100%. As a result, it can be

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Table 5. The pass rate values of the gamma index analysis for different dose profiles in the beam angles of 0º (test G), 15º (test H), 30º (test I) and 45º (test J). The 'distance to agreement (DTA)' criterion for all dose profiles was 3 mm.

	Depth (cm)	DD (%)	Pass rate (%) Test G	Test H	Test I	Test J
Dose profile	1	5	100	100	99·1	92·7
		10	100	100	100	99·1
		15	100	100	100	100
	1·5	3	83·0	64·3	93·6	85·0
		4	90·0	97·1	97·3	88·8
		5	94·0	99·3	99·1	89·7
	5	3	85·0	75·5	91·0	85·6
		4	93·0	95·0	92·0	87·5
		5	98·0	96·4	96·0	90·4
	10	3	84·0	93·0	92·0	65·0
		4	89·0	93·0	95·0	82·5
		5	94·0	95·0	96·0	85·5

mentioned that the dose calculation accuracy of TPS is almost the same for the three field sizes (the differences between pass rate values were less than 5%). In the other words, the dose calculation accuracy of the TPS for the build-up region (1 cm beam profile) does not change under the various evaluated field sizes. The results for other depths (beam profiles of 1·5, 5 and 10 cm) with different values of the DD parameter are given in Table 3. The results revealed that the accuracy of dose calculations for the depths after the build-up region decreases and the pass rate values ranged from 69·0% to 97·5% for DD = 3%, from 75·0% to 97·5% for DD = 4% and from 94·0% to 100% for DD = 5%. This decrease in the accuracy of dose calculations can be due to the decrease in the acceptance criterion of the DD parameter. However, the overall dose calculation accuracy of the TPS was acceptable for these depths (after the build-up region) with acceptance criteria of DD = 5% and DTA = 3 mm. It can be mentioned that with increasing the field size, the pass rate value of the gamma index analysis in most cases increases. Furthermore, for the DD parameter equal to 3% or 4%, the dose calculation accuracy of the TPS is affected by the field size (in most cases), while the accuracy of dose calculations was independent of the field size for DD = 5%.

In a study by Farhood et al.,[25] the dose calculation accuracy of TiGRT and Prowess Panther TPSs in the build-up region for different field sizes (8×10, 10×10 and 15×10 cm^2) was investigated. Their results showed the dose calculation accuracy of the Prowess Panther TPS with collapsed cone convolution superposition algorithm was within the tolerance limit, while it was not within the tolerance limit for the TiGRT TPS and Prowess Panther TPS with fast photon effective algorithm. Furthermore, they showed that there was not a constant trend of increasing or decreasing with the variation of field size.[25] Fogliata et al.[57] investigated the dosimetric performance of Eclipse TPS with Acuros XB algorithm at Dmax (depth of maximum dose), 5, 10, 20 and 30 cm depths over various open field sizes (ranging from 3×3 cm^2 to 40×40 cm^2). Their gamma evaluations (with acceptance criteria of DD = 1% and DTA = 1 mm) indicated that the Acuros XB algorithm could accurately reproduce measured data for the 'in field' regions and only small deviations were found for all the investigated quantities. Moreover, the pass rate values of the gamma index analysis did not show any trend of increasing or decreasing over the field size.[57]

Evaluating the dose calculation accuracy of ISOgray TPS: effect of source to surface distance

The tests D, E and F represented in Table 4 and Supplementary Figures 13-24 show the effect of the SSD parameter on the accuracy of dose calculations.

The results demonstrate that the pass rate values of the gamma index analysis for the 1 cm beam profiles of the adjacent radiation fields with various SSD values of 90, 100 and 110 cm were 100% (except in test F with DD = 5 %, pass rate = 97%). However, the accuracy of dose calculations for other depths (beam profiles of 1·5, 5 and 10 cm) declined; as the pass rate values for these depths varied between 56% and 94·9% for DD = 3%, 86% and 97% for DD = 4% and 94% and 98% for DD = 5%. As mentioned earlier, the declined dose calculation accuracy of the TPS is because of the decrease in the acceptance criterion of the DD parameter. According to the results (Table 4), it is observed when acceptance criteria of DD = 5% and DTA = 3 mm are applied in the gamma index formula, the overall dose calculation accuracy of the TPS for the depths after the build-up region is acceptable. The increasing/decreasing trend in the dose calculation accuracy of the TPS was not observed with increasing the SSD values. In general, it was found that the dose calculation accuracy of the TPS does not change under the various evaluated SSDs, especially for DD = 4% or 5%.

A number of studies have assessed the effect of the SSD parameter on the dose calculation accuracy of different TPS.[39–42] For instance, Murugan et al.[39] evaluated the effect of SSD variation on the dosimetric performance of PLATO TPS and reported that the maximum and minimum deviations between measured and calculated dose values were 0·15 % and −1·44%, respectively. In detail, it was shown that none of the thirteen test point measurements exceeded the 3% tolerance level. They also stated when the SSD value decreases, the absolute deviations between measured and calculated dose values increased for all evaluated field sizes but within the acceptable tolerance level of 3%.[39] In another study, the impact of SSD variation on Eclipse TPS dose calculations was assessed by Jamema et al.[40]. Their findings revealed the mean and maximum deviation between measured and calculated dose values of 1·2 ± 0·9% and 2·1%, respectively. They also reported that all the measured points were within the 3% tolerance limit. With the increase in SSD value (up to 120 cm), the deviations between measured and calculated dose values were found to increase, being within the acceptable tolerance level.[40] Bedford et al.[41] investigated absolute output measurements for a range of field sizes at SSD values between 90 cm and 120 cm. Their results demonstrated that all output measurements were in agreement with the output calculated values by Pinnacle TPS (within 2%). Moreover, the absolute output measurements performed at SSD of 441 cm (for evaluating the dosimetric performance of Pinnacle TPS at extended SSD such as total body irradiation) revealed an agreement with the calculated values still within 2%.[41]

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Table 6. The pass rate values of the gamma index analysis for different dose profiles in the match line regions of the adjacent radiation fields. The 'distance to agreement (DTA)' criterion for all dose profiles was 3 mm.

	Depth (cm)	DD (%)	Pass rate (%) Test A	Test B	Test C	Test D	Test E	Test F	Test G	Test H	Test I	Test J
Dose profile	1	5	100	100	90·0	100	100	100	100	100	100	100
		10	100	100	100	100	100	100	100	100	100	100
		15	100	100	100	100	100	100	100	100	100	100
	1·5	3	50·0	60·0	50·0	70·0	60·0	60·0	60·0	72·7	60·0	40·0
		4	90·0	70·0	60·0	70·0	70·0	60·0	70·0	81·8	80·0	60·0
		5	100	80·0	60·0	80·0	80·0	80·0	80·0	90·9	90·0	70·0
	5	3	40·0	60·0	50·0	50·0	60·0	60·0	60·0	50·0	44·4	30·0
		4	70·0	70·0	60·0	80·0	70·0	70·0	70·0	60·0	44·4	50·0
		5	100	80·0	60·0	80·0	80·0	70·0	80·0	70·0	66·7	70·0
	10	3	40·0	40·0	60·0	40·0	40·0	60·0	40·0	44·4	40·0	10·0
		4	70·0	100	60·0	90·0	100	70·0	100	44·4	50·0	30·0
		5	100	100	80·0	100	100	90·0	100	66·7	60·0	30·0

Evaluating the dose calculation accuracy of ISOgray TPS: effect of beam angle

To evaluate whether the beam angle affects the accuracy of dose calculations, tests G, H, I and J were performed, and the obtained results are presented in Table 5 and Supplementary Figures 25-40.

For most of the points evaluated in the 1 cm beam profile (build-up region), the dose calculation accuracy of the TPS for the adjacent radiation fields with different beam angles was acceptable (gamma index values ≤ 1). The findings obtained from the other depths revealed that the accuracy of dose calculations after the build-up region decreases, especially for a larger beam angle (45º). The pass rate values for the depths after the build-up region ranged from 64·3% to 93·6% for DD = 3%, from 82·5% to 97·3% for DD = 4% and from 85·5% to 99·3% for DD = 5%. Moreover, assessing the dose calculation accuracy of the TPS as a function of beam angle demonstrated no declining or increasing trend in the accuracy of dose calculations over the beam angle. In general, it was found that the dose calculation accuracy of the TPS varies under the various evaluated beam angles.

The effect of beam angle variation on the dose calculation accuracy of different TPSs has been investigated by researchers.[39,43,58–60] Murugan et al.[39] evaluated the dose calculation accuracy of PLATO TPS as a function of beam angle and reported that the differences between measured and calculated dose values were within the acceptance limit of 3%. Moreover, they showed that the differences between measured and calculated dose values increase with an oblique angle.[39] Farhood et al.[58] quantified the dose calculation accuracy of Prowess Panther and TiGRT TPSs in the build-up region of a 10×10 cm^2 wedged field (wedge angle of 30°) with gantry angles of 15°, 30° and 60°. Their findings revealed that the dose calculation accuracy of Prowess Panther TPS with fast photon effective algorithm at a large gantry angle (60°) was within the acceptance limit, while the gantry angles of 15° and 45° were not within the acceptance limit. Moreover, the dose calculation accuracy of TiGRT TPS at gantry angles of 15° and 45° was within the tolerance limit, while for 60°gantry angle was not within the tolerance limit. Additionally, they reported that no increasing/decreasing trend in the dose calculation accuracy of TPSs was observed with increasing the beam angle.[58]

Evaluating the dose calculation accuracy of ISOgray TPS based on geometry type

According to technical reports series (TRS) No. 430, the geometry evaluated in the current study (adjacent radiation fields) falls into the category of more complex geometries. In these types of geometries, the DD parameter considered for the build-up and penumbra regions is 15%, for the regions on the central beam axis is 4% and for the regions outside the beam edges is 5%.[56]

To assess the overall dose calculation accuracy of ISOgray TPS at the adjacent radiation fields in the 1 cm depth (as the beam profile), located in the build-up region, the acceptance criterion for the DD parameter was considered 15%, while this parameter for other depths was considered 5%. The DTA parameter for all evaluated tests was also equal to 3 mm. As seen from Tables 3-5, the accuracy of the dose profile calculations is satisfactory for the majority of assessed points at all depths. Furthermore, the evaluated points with gamma index values > 1 (indicating the failure of the dose calculation accuracy in the intended points) were mostly in the penumbra and match line regions of adjacent radiation fields. Of note, the acceptance criterion for the DD parameter in the penumbra region was equal to 5% (except for the 1 cm depth, which was considered 15% for all points of this depth), while the acceptance criterion for this parameter should have been considered 15%; hence, this issue led to a decrease in the pass rate values of the evaluated tests. Furthermore, the inaccurate dose modeling by ISOgray TPS in the penumbra and match line regions of adjacent radiation fields can be considered as a source of deviation between the dose measurements and the dose calculations.

There are some studies conducting the dose calculation accuracy of different TPS in more complex geometries.[14,27,59,24,23,61–63] Bahreyni Toossi et al.[27] quantified dose calculation accuracy of TiGRT TPS in a RANDO phantom. In that study, they planned two lateral parallel opposed fields on the head and neck region of

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the phantom, in which one of them was an open field and another was wedged field. Their results showed that for most points, the dose calculation accuracy of TiGRT TPS was acceptable for in-field and out-of-field regions.[27] Hasani et al.[14] assessed the dosimetric performance of different algorithms (Monte Carlo, collapse cone and pencil beam) of Monaco TPS in accordance with the practical clinical tests presented by TECDOC 1583. They reported that the dose calculation accuracy of the TPS in all three algorithms was within the agreed criteria for the majority of the assessed points. Moreover, it was found that for low-dose regions, the deviations between the measured and calculated dose values were higher than the agreement criteria in several assessed points. Hence, they stated that the TPS user should be cautious when using the dose calculation of Monaco TPS for appropriate clinical decision making in out-of-field regions, particularly for the pencil beam algorithm.[14] Mahmoudi et al.[63] evaluated the impact of dose rate variations in the out-of-field regions on the dose calculation accuracy of Monaco TPS (a Monte Carlo-based TPS). They reported that Monaco TPS underestimated the out-of-field dose values by an average of 40% at a 1–2 cm distance range from the radiation field edge and the underestimated dose values worsened at a 10–13 cm distance range from the radiation field edge. Furthermore, it was shown that the dose rate variations had a remarkable effect on the dose calculation accuracy of the TPS in the out-of-field regions. In conclusion, they stated the dose calculation accuracy of Monaco TPS for the regions outside the beam edge (at various dose rates) was not reliable.[63]

Evaluating the dose calculation accuracy of ISOgray TPS in the match line region

The pass rate values of the gamma index analysis related to the match line regions of the adjacent radiation fields are listed in Table 6. The findings of 1 cm beam profiles show that the dose calculation accuracy of the TPS is within the acceptable range; as the gamma index values were less than 1 in all evaluated beam profiles, except for test C with DD = 5% (pass rate = 90%). The results obtained from other depths revealed that the accuracy of dose calculations declines and this issue is more evident when the acceptance criterion for the DD parameter equal to 3% or 4% is selected. The gamma index values for the beam profiles of 1·5, 5 and 10 cm in all tests ranged from 10·0% to 72·7% for DD = 3%, from 30·0% to 100% for DD = 4% and from 30·0% to 100% for DD = 5%. As a result, it can be mentioned that the dose calculation accuracy of the TPS depends on the field size, SSD and beam angle.

Conclusion

In the current study, the dose calculation accuracy of ISOgray TPS in the photon–photon adjacent fields was investigated. Moreover, the effects of field size, SSD and beam angle on the accuracy of dose calculations were assessed. The findings showed that the overall dose calculation accuracy of ISOgray TPS is acceptable for 1) the build-up region with acceptance criteria of DD = 15% and DTA = 3 mm and 2) the depths after the build-up region with acceptance criteria of DD = 5% and DTA = 3 mm. It was also found that the overall accuracy of dose calculations (with the above-mentioned acceptance criteria) is not affected by the field size and the SSD. Additionally, it was shown that the accuracy of dose calculations is similar for the adjacent radiation fields with beam angles of 0°, 15° and 30°, while a considerable decrease in the pass rate values is obtained for the adjacent radiation field with 45° beam angle; as the pass rate values for the adjacent radiation field with 45° beam angle were different from the pass rate values for the adjacent radiation fields with other beam angles.

The pass rate values of the gamma index analysis related to the match line regions of the adjacent radiation fields showed that the dose calculation accuracy of ISOgray TPS for the 1 cm beam profiles was within the acceptable range; however, the accuracy of dose calculations for other depths declined, especially for the gamma index formula set with the acceptance criterion of DD = 3% or 4%. It was also found that the accuracy of dose calculations depends on the field size, SSD and beam angle.

As a future work, it is suggested to evaluate the dose accuracy of radiotherapy TPSs for adjacent radiation fields on an anthropomorphic phantom (such as Rando phantom); as the obtained findings can be more generalizable to a real patient condition.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S146039692300016X.

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