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Interfacility variation in treatment planning parameters in tomotherapy: field width, pitch, and modulation factor

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ABSTRACT

Several studies have reported changes in dose distribution and delivery time based on the value of specific planning parameters [field width (FW), pitch, and modulation factor (MF)] in tomotherapy. However, the variation in the parameters between different facilities is unknown. The purpose of this study was to determine standard values of the above parameters for cases of head and neck cancer (HNC) and prostate cancer (PC) in Japan. In this survey, a web-based questionnaire was sent to 48 facilities performing radiation therapy with tomotherapy in March 2016. The deadline for data submission was April 2016. In the questionnaire, the values of the planning parameters usually used were requested and 23 responses were received, representing a response rate of 48% (23/48). The FW selected was 2.5 cm in most facilities, and facilities with a tomoEDGE license used dynamic FW rather than fixed FW. Facilities changed the pitch based on FW, dose per fraction, or target offset more frequently in HNC than in PC. In contrast, >50% of the facilities used the magic number proposed by Kissick *et al.* Median preset MFs (range, min to max) in HNC and PC were 2.4 (1.8–2.8) and 2.0 (1.8–3.0), respectively, and MF values showed large variations between the facilities. Our results are likely to be useful to several facilities designing treatment plans in tomotherapy.

Keywords: tomotherapy; modulation factor; prostate; field width; head and neck

INTRODUCTION

Tomotherapy (Accuray, Inc.) is a machine type that can conduct intensity-modulated radiotherapy (IMRT). Dose delivery in tomotherapy involves movement of a couch with continuous gantry rotations. In addition, binary multileaf collimators that work by high-pressure gas are used for intensity modulation [1]. Dose delivery in tomotherapy follows a unique methodology, and treatment planning involves specific parameters: field width (FW), pitch, and modulation factor (MF) [2]. The treatment planner needs to assign an arbitrary value within the limited range of each parameter before carrying out the dose optimization calculation. The parameters influence the dose distribution and the delivery time. Therefore, several studies have reported changes in dose distribution and delivery time being dependent on the value of each parameter [3–12]. However, variation in parameter values between facilities is not known. Determination of a standard value would aid new installations and contribute to shortening the time needed for designing the treatment plan. The purpose of this study was to determine the standard values of specific planning parameters in tomotherapy for cases of head and neck cancer (HNC) and prostate cancer (PC) in Japan.

MATERIALS AND METHODS

Specific planning parameters

Field width

FW is defined as the full width at half the maximum of the longitudinal dose profile within the isocenter plane. The TomoEDGE™ mode was released as an optional function in 2013. In this mode, dynamic jaw technology with dynamic adaptation of FW at the cranial–caudal (CC) edges of the target is used [3]. Facilities with the TomoEDGE mode license can select from two dynamic FWs (2.5 and 5.0 cm) and three fixed FWs (1.0, 2.5 and 5.0 cm). Conversely, facilities without the license can select from one of three fixed FWs. In general, the use of small FW or dynamic FW improves dose distribution in the CC direction; however, delivery time is prolonged compared with the use of a larger FW or a fixed FW of the same value [4].

Pitch

Pitch is defined as the extent of couch movement per gantry rotation, as in that of helical CT scanners. In 2005, Kissick *et al.* proposed a magic number (= $0.86/n$, n; integer) to reduce the thread effect, which is indicated by ripples in the longitudinal dose profile [13]. Thereafter, in 2011, Chen *et al.* reported that the optimal pitch for ripple reduction depended on FW, dose per fraction, and target offset [14].

Modulation factor

MF is defined as the longest leaf opening time divided by the average of all non-zero leaf opening times [2]. The longest leaf opening time is determined on the basis of dose optimization calculation, and the MF lower than the preset value is adopted as the actual MF [15]. In general, the use of large preset values improves dose distribution in the axial plane; however, delivery time is prolonged compared with the use of smaller preset values.

Multiple investigations

In this survey, a web-based questionnaire was sent to 48 facilities performing radiation therapy with tomotherapy in March 2016. The deadline for data submission was April 2016. In the questionnaire, the values of the planning parameters usually used were requested. The subject of this investigation was limited to HNC cases, including the whole neck region, and PC cases, excluding the whole pelvis region. Regarding FW and pitch, typical values were requested. In addition, it was verified whether the pitch was changed for ripple reduction based on FW, dose per fraction, and target offset, as recommended by Chen *et al.* For MF, both the representative preset MF value and the average actual MF values in the last 10 cases were requested. Further, we sought the occupation of treatment planner (radiation oncologist, radiation therapist, or medical physicist) and

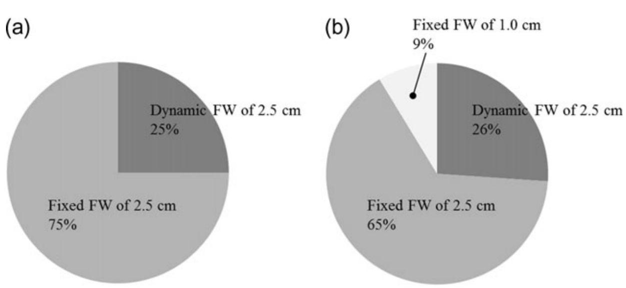

Fig. 1. Selection of field width (FW) in facilities: (a) head and neck cancer; (b) prostate cancer.

whether the tomotherapy facilities were equipped with TomoEDGE mode or voxel-less optimization™ (VoLO) systems. The VoLO system performs the dose optimization calculation using the beamlet coordinate system (radiation passing through open leaves) [16]. It can shorten treatment planning time, especially for small FW cases, which consume significant calculation time. Supplementary Table 1 shows the question items. Space for free comments were not included in the questionnaire.

We obtained permission from each institution to disclose the data without disclosing the institution's identity.

For statistical analysis, the statistical software R (Version 3.0.2) was used for all analyses [17]. P values <0.01 were considered to indicate significance.

RESULTS

For the web questionnaire, 23 responses were received, representing a response rate of 48% (23/48). Three of the 23 facilities had no experience in radiotherapy for HNC involving the whole neck region. Based on the collected answers to the questionnaires, 67% of the facilities had a TomoEDGE mode license as well as the VoLO system. The proportion of treatment planner roles was radiation oncologist, 65%; radiation therapist, 13%; and medical physicist, 22%.

Field width

For HNC cases, the majority (75%) of facilities used a fixed FW of 2.5 cm, and the remainder (25%) used a dynamic FW of 2.5 cm (Fig. 1a). Most facilities with TomoEDGE mode licenses (83%) used a dynamic FW of 2.5 cm (Fig. 2a). For PC cases, a similar tendency to that for HNC was observed, as shown in Figs 1b and 2b, though 9% of the facilities used a fixed FW of 1.0 cm (Fig. 1b).

Pitch

In HNC cases, the values of the pitch were variable; however, use of the magic numbers of Kissick *et al.* was confirmed at 94% (0.43, 50%; 0.287, 33%; 0.215, 11%) of the facilities (Fig. 3a). The facilities that changed pitch based on the FW, dose per fraction, and target offset as per Chen *et al.* represented less than half of the total facilities, as shown in Fig. 4a. In addition, the ratio of pitch change as per Chen *et al.* was the largest for medical physicists (80%, Fig. 5a). For PC cases, an approximately similar trend was obtained to that for HNC, as shown in Figs 3b, 4b and 5b. Facilities that changed the pitch based on parameters in PC cases were fewer than those in HNC cases (Figs 4b and 5b).

Modulation factor

Figure 6 shows the range of the preset and actual MF values. The median preset MF (range, minimum to maximum) in HNC and PC cases was 2.4 (1.8–2.8) and 2.0 (1.8–3.0), respectively. The median actual MF (range, min to max) in HNC and PC cases was 2.0 (1.6–2.8) and 1.9 (1.5–2.9), respectively. Both the preset MF and the actual MF in HNC cases had greater median values compared with those in PC cases; nevertheless, no significant differences were found (Wilcoxon's signed rank test, $P = 0.075$ and $P = 0.068$, respectively).

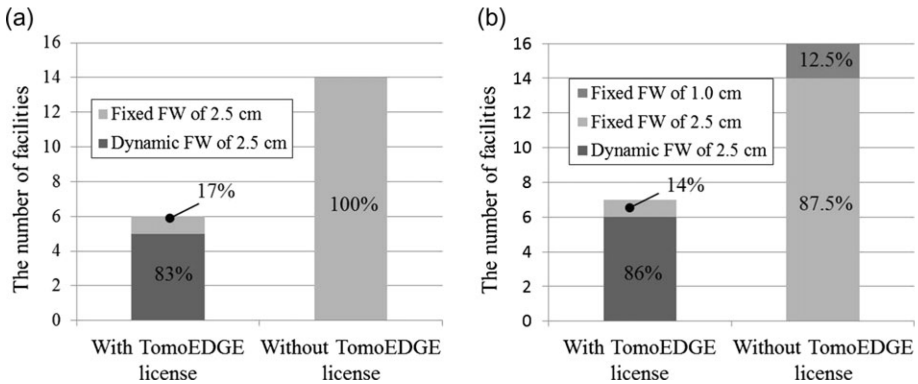

Fig. 2. Selection of field width in facilities with or without a TomoEDGE license: (a) head and neck cancer; (b) prostate cancer.

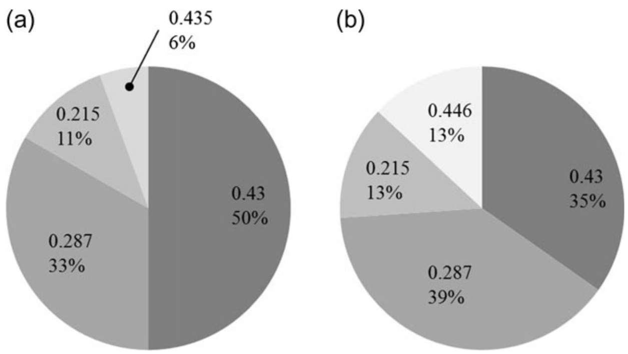

Fig. 3. Selection of pitch in facilities: (a) head and neck cancer; (b) prostate cancer.

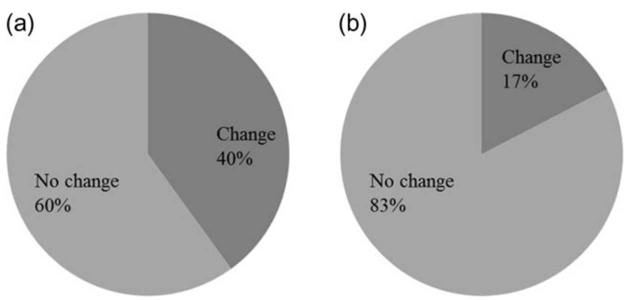

Fig. 4. Percentage of facilities that changed the pitch based on field width, dose per fraction, or target offset: (a) head and neck cancer, (b) prostate cancer.

DISCUSSION

To the best of our knowledge, this is the first report of standard values of treatment planning parameters in tomotherapy across multiple facilities. Our results are likely to be useful to many facilities designing treatment plans in tomotherapy.

The TomoEDGE mode can reduce the longitudinal penumbra, and studies have reported an improvement in longitudinal dose distribution in a few clinical cases [3, 4, 9, 11]. Based on our questionnaire results, 67% of all the cooperating facilities had TomoEDGE licenses, and >80% of these facilities used a dynamic FW (Fig. 2). This result indicated that there has been a shift from a fixed FW to a dynamic one, associated with the increase in TomoEDGE licenses. The facility that did not use TomoEDGE, although it had the license, might not yet have performed commissioning of dynamic FW.

It is reported that stepping up one FW (e.g.; from a fixed jaw of 2.5 cm to a dynamic jaw of 5.0 cm) reduces the delivery time, while possibly increasing the low-dose area within the length of the target [4]. In particular, targets with shape changes in the CC direction would experience expanded low-dose areas [4]. Based on our results, the most common value for the fixed FW selected in HNC and PC cases was 2.5 cm (Fig. 1). Furthermore, the choice for the dynamic FW was also 2.5 cm (Fig. 1). In order to shorten the delivery time, a dynamic FW of 5.0 cm is likely to be adopted; however, this was not used in any facility. There appeared to be a preference for avoiding poor dose distribution over shortening the delivery time (e.g. dose escalation to the brain stem and spinal cord in HNC cases or rectum and bladder in PC cases). Therefore, the commissioning of a dynamic FW of 5.0 cm might not have been made in most facilities.

Regarding the pitch, several facilities used the magic number proposed by Kissick *et al.* (0.43, 0.287 and 0.215 in Fig. 3). Conversely, as shown in Fig. 4a, 40% of the facilities changed the pitch for ripple reduction in the HNC treatment plan, based on the data from Chen *et al.* This indicates that facilities use the magic numbers of Kissick *et al.* as the initial selection, and if the thread effect is significant, the pitch is changed based on Chen *et al.* to reduce this effect. In addition, the topics of this questionnaire were HNC involving the whole neck region and PC cases not involving the whole pelvis region; target offset in HNC cases is generally larger than that in PC cases. Therefore, facilities changing the pitch were more common in HNC cases (40%) than in PC cases (17%) (Fig. 4). According to Fig. 5, the proportion of facilities changing

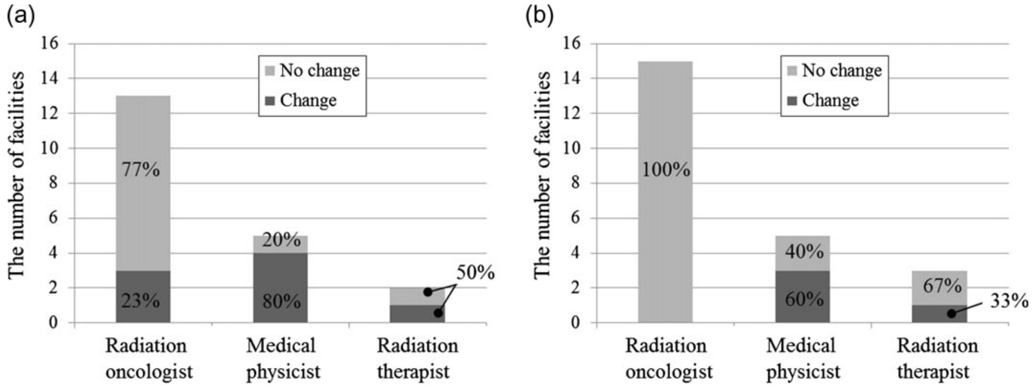

Fig. 5. Percentage of job type that changed the pitch based on field width, dose per fraction, or target offset: (a) head and neck cancer; (b) prostate cancer.

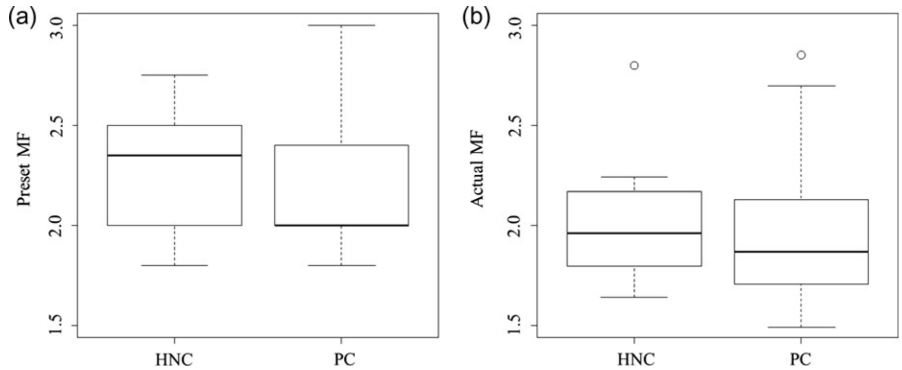

Fig. 6. Value of modulation factor (MF) used for head and neck cancer (HNC) and prostate cancer (PC) in the facilities: (a) preset MF; (b) actual MF.

the pitch based on the FW, dose per fraction, or target offset using the data of Chen *et al.* was large when planned by a medical physicist or a radiation therapist. Conversely, it was small when planned by a radiation oncologist. This result might indicate that the thread effect in the subject of this investigation had a small clinical impact for a radiation oncologist, or that a radiation oncologist has fewer opportunities to learn in detail about the thread effect than a medical physicist or radiation therapist.

A large MF increases the delivery time; therefore, a clinically meaningless large value increases the risk of dose escalation to organs at risk because of patient movement during dose delivery. As shown in Fig. 6, the difference in MF between the facilities was large. A treatment planner uses a high preset MF for difficult plans, such as for cases involving a complex target shape surrounding an organ at risk; therefore, the selection of MF depends on the difficulty of the case. We have found that the preset MF values of 2.3 in HNC and 2.0 in PC fulfilled clinical goals regarding dose distribution [15]. Therefore, we believe that MF in many facilities can be slightly reduced by using these setting values.

Delivery time for tomotherapy increases as the target length increases. Therefore, a small MF or a large FW or both are applied to avoid increase in delivery time. To lower the impact of target length, the topic of this questionnaire was limited to HNC involving the whole neck region and PC not involving the whole pelvis region.

This study had limitations. There was no reward for cooperating facilities and no cooperation with the associated society; therefore, the response rate for our questionnaire survey was not sufficient (48%). We believe that, in our future work, a higher response rate could be obtained by offering a reward for cooperating facilities and/or with the cooperation of the associated society. Moreover, the plan quality (dose constraints and delivery times) that a facility allows and the facility scale (numbers of staff and treatment machines) might differ between facilities; however, the plan quality and facility scale were not investigated in this questionnaire. Therefore, our results may include variations in parameters because of a difference in plan quality and/or medical treatment procedure between facilities.

In conclusion, we identified interfacility variations in treatment planning parameters in tomotherapy in HNC and PC via a questionnaire. The selection of FW was 2.5 cm in most facilities, and facilities with the tomoEDGE license usually used dynamic FW rather than fixed FW. Facilities that changed the pitch based on FW, dose per fraction, or target offset did so more in HNC cases than in PC cases. In contrast, more than half of the facilities used the magic numbers of Kissick *et al.* Finally, median preset MFs (range, min to max) in HNC and PC were 2.4 (1.8–2.8) and 2.0 (1.8–3.0), respectively, and the MF values showed large variations between the facilities.

SUPPLEMENTARY DATA

Supplementary data are available at *Journal of Radiation Research* online.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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