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Planning target volume (PTV) margin practice patterns in adults and paediatrics among the Paediatric Radiation Oncology Society (PROS) members: an international survey*

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Abstract

Aim: Evolving data are showing the need of considering smaller planning target volume (PTV) margin in paediatrics compared with adults treated for the same body site. This study proposed to evaluate the current patterns of practice regarding the PTV margin in paediatric patients compared with adult patients through an international survey. **Materials and methods:** A four-item questionnaire was created to address the PTV margins for paediatrics and adults as part of a comprehensive survey. International Paediatric Radiation Oncology Society (PROS) members were selected to partake and were contacted via email. **Results:** In total, 43 responded to the survey. The majority of the responders have written guidelines for PTV margin while the majority of those who have guidelines do not have separate guidelines for paediatrics. The implemented PTV margin for paediatric patients was in the majority 3–5 mm for the head region and 5–10 mm for the torso region and the difference from the PTV margin implemented in adults was not statistically significant. **Conclusion:** The majority of responders employ a series of site-specific PTV margin protocols that are applied to both adults and paediatrics, and do not take into consideration patient age or size. These results highlight the need of a separate policy for PTV margin in adults and paediatrics in every institution.

Introduction

The clinical target volume (CTV) to the planning target volume (PTV) expansion, as outlined by International Commission on Radiation Units (ICRU), is added to account for delineation uncertainties, internal organ motion, patient motion and set-up uncertainties.¹ It is applied to both adult and paediatric patients.

Van Herk et al.² defined the PTV margin as the margin needed to ensure, in the presence of set-up and other uncertainties, that the dose to the CTV was 95% in 90% of the treated patients. Many centres use an empirical PTV expansion of 5–10 mm based on historical practice and clinical experience.³ There are several published formulations for calculating the necessary PTV.^{4,5}

The factors affecting the PTV margin are different in different tumour sites and also differ based on delineation uncertainties, immobilisation devices used, imaging frequency, imaging modality and the whole image-guided radiotherapy (IGRT) strategy implemented. This is why most radiotherapy protocols define fixed CTV margin based on the treatment site but give some flexibility for PTV margin for each individual institution considering the factors mentioned above which are different from one centre to another.

Some of these factors are likely to be similar in adults and paediatrics patients such as delineation uncertainties while other factors like organ motion and setup errors may be different in adults compared with paediatric patients.⁶ In spite of this, many centres apply the same PTV margin based on the treatment site in both adult or paediatric patients.⁷

While the PTV margin calculation has been evaluated in adult patients in numerous publications,^{8–10} the evidences of evaluation of PTV margin for paediatric patients are sparse,^{3,11,12} with very few data available regarding the need for different PTV margin in paediatric patients compared with adult patients. Recently conducted analyses of the PTV margin in adult patients (>18 year old) and paediatric patients (<7 year old) treated in one centre showed a clinically significant difference (>2 mm) of the PTV margin needed in the longitudinal direction in the abdominal region.⁷

The aim of this study was to evaluate the international patterns of practice regarding the PTV margin in paediatric versus adult patients and to identify the PTV margins employed per treatment site in both paediatric and adult patients treated in the same institution.

Materials and Methods

Paediatric Radiation Oncology Society (PROS) members were selected to participate in this study to evaluate the patterns of PTV margin practice in the treatment of paediatric patients (this was done as a part of a comprehensive survey including other aspects like IGRT). A total of 119 members in 116 institutions were eligible to participate. Eligibility was granted to departments that treat both paediatric and adult patients, and employ IGRT. Data regarding PTV margin will be discussed in this paper.

Each participant was provided with a four-item survey comprised of closed and open-ended questions (Appendix) related to five treatment sites: central nervous system (CNS), head and neck (H&N), torso, pelvis and others. The presence of PTV margin guidelines was investigated, and whether these guidelines were specific to adult and paediatric patients.

Data was collected by means of an anonymous questionnaire distributed via SurveyMonkey. This survey was distributed to all participants along with a participant information leaflet and cover letter by email. Participation was voluntary and without remuneration. Participants returned completed surveys on the SurveyMonkey site. The survey was open from 1st of September 2015 until 31 October 2015.

Ethical approval for this study was sought and obtained from the School of Medicine Research Ethics Committee, Trinity College Dublin in August 2015.

Results

In total, 43 out of 119 ($n = 43$) (36%) participants responded to the survey over a 2-month period.

PTV margin guidelines

The majority of the responders 74% (32/43) have written guidelines for CTV to PTV expansion in different treatment sites. Details are shown in Table 1.

Different PTV margins for adults and paediatrics

Only one-third, 33% (14/43), of the responders use separate guidelines for adult and paediatric patients. Details are shown in Table 2.

Centres that do not have separate guidelines were asked to comment on whether they feel the need for paediatric specific guidelines for PTV margins in the major sites. In total, 23 commented on this part. Four said yes, they feel there is a need for consensus guidelines, for both paediatric and adult patients. Two said no, they do not feel there is a need for it. Seven said margins are applied on an individual basis, while six elaborated on the different other factors affecting the PTV margin. Four commented that they treat patients in a paediatric protocol and they follow the protocol guidelines for the PTV.

PTV expansions

There are slight differences recorded in PTV margins between adult and paediatric patients. Figures 1a–1d show the PTV

Table 1. Answer to question 1 (Do you have written guidelines regarding the planning target volume margin in different sites?)

	Yes (%)	No (%)	Total
CNS	74	26	43
Head and neck	71	29	41
Torso	71	29	42
Pelvis	74	26	42
Other	77	23	30

Abbreviation: CNS, central nervous system.

Table 2. Answer to question 2 (Do you have separate guidelines regarding the planning target volume margin for adults and paediatrics?)

	Yes (%)	No (%)	Total
CNS	33	67	43
Head and neck	34	66	41
Torso	33	67	42
Pelvis	38	62	42
Other	32	68	28

Note: The % not having separate guidelines are of all respondents, including those that do not have guidelines at all.

Abbreviation: CNS, central nervous system.

margin for adult and paediatric patients reported for different treatment sites. For CNS and head and neck regions the majority of the responders apply margins of 3–5 mm with 3 mm used more frequently in paediatric patients (27 versus 23 in CNS and 19 versus 12 in H&N). For torso and pelvic area, the majority of the responders apply PTV margin of 5–10 mm with 5 mm used more frequently in paediatric patients (21 versus 14 in the torso region and 22 versus 13 in the pelvic region). These differences were not statistically significant as shown in Table 3.

Additional comments

In all, 17 participants highlighted other points like, the difference in tumour type between both patient groups, the reduction in PTV margin depends on immobilisation technique and individual protocol, anisotropic PTV margins are often applied and individual patient considerations are often taken into account.

Discussion

A recent publication showed that the average response rate of physicians to mailed surveys has traditionally been demonstrated to be only 54–58%, and among oncologists varied from 31 to 61%.¹³ Although low, the response rate to this survey was within this range at 36% and to the best of our knowledge the absolute number of the responders (43 institutions) is the highest for paediatric radiation oncology surveys published ever.³

The PTV margin policy used in different radiation oncology departments was explored in this study and it was found that 74% of responders have written guidelines for CTV–PTV expansion in different treatment sites, with 33% having separate guidelines for both adult and paediatric patients.

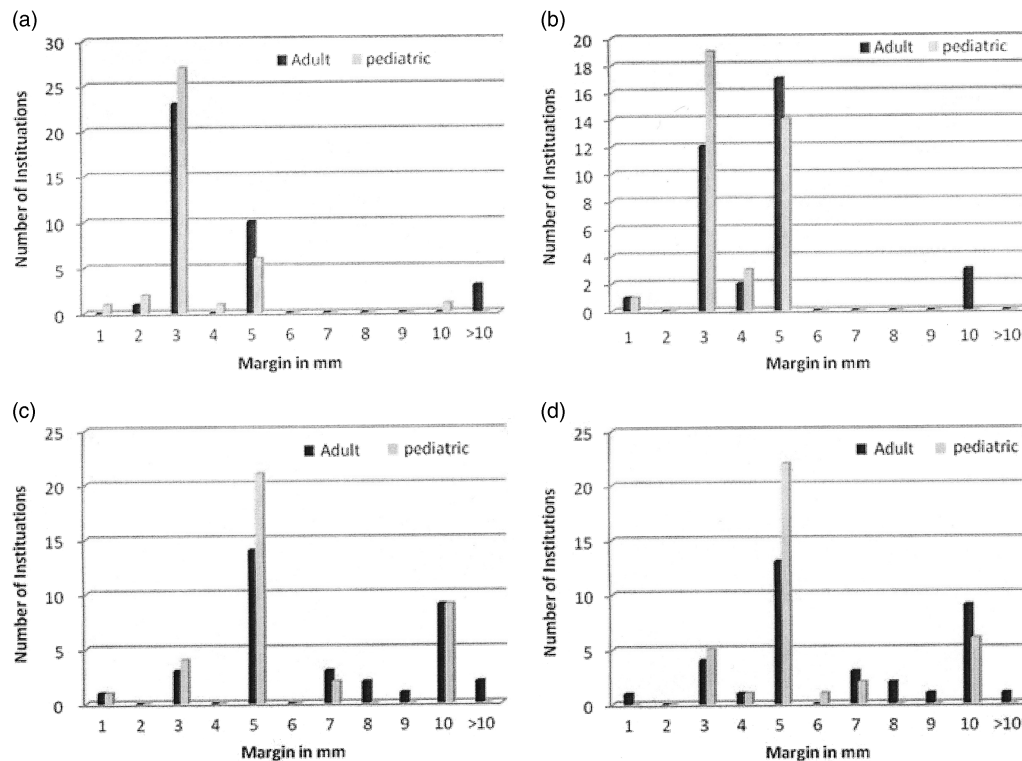


Figure 1. (a) Planning target volume (PTV) margins for central nervous system area. (b) PTV margins for head and neck area. (c) PTV margins for torso area. (d) PTV margins for pelvic area.

Factors affecting the PTV margins may be different between adult and paediatric patients, so it was important to look at the PTV margin needed for adult as compared with paediatric patients especially if the patients are treated in the same institution with the same IGRT strategy and level of expertise.

In paediatrics, a recently published survey of seven institutions showed that half reported the use of different PTV expansions when treating with or without IGRT. The PTV margin was based on data from the literature, clinical data or margins suggested by Children's Oncology Group protocols. The PTV expansions used for CNS ranged from 3 to 5 mm regardless of IGRT use and there was notable institutional variability in the ranges of PTV expansions in other sites with or without IGRT ranging from 3 mm to 20 mm.³ Eldebaawy et al. reported that the required PTV margins of 4, 4.5 and 5.5 mm in the lateral, longitudinal and vertical directions, respectively, for the H&N area in the paediatric age group, and PTV margins of 5.5, 7.5 and 4.5 mm in the lateral, longitudinal and vertical directions, respectively, for the abdomen and pelvis area. In this work they defined the paediatric population as age 2–16 years old.¹¹

In adults, PTV margins of as low as 3.0 mm in the lateral direction, 1.3 mm in longitudinal direction and 2.6 mm in vertical direction were recommended for nasopharyngeal cancer patients undergoing Intensity Modulated Radiotherapy (IMRT) with weekly Cone Beam CT scans.⁹ A recent survey of the American Society for Radiation Oncology members showed that the PTV margin used for H&N/CNS is 3–5 mm and the PTV margin used for torso/pelvis is 5–10 mm.¹⁰

The data of the trials mentioned above^{3,9–11} showed a difference in the PTV margin required in paediatrics versus adults especially in the torso regions. The results of this survey present the lack of consensus regarding the magnitude of the difference and the need to have a consensus.

Table 3. Difference in the planning target volume margin implemented in adults and paediatrics

	Adult patients	Paediatric patients	<i>p</i> -Value (χ^2 test)
CNS			
Margin \leq 3 mm	23	30	<i>p</i> = 0.11
Margin >3 mm	14	8	
Head and neck			
Margin \leq 3 mm	13	20	<i>p</i> = 0.15
Margin >3 mm	22	17	
Torso			
Margin \leq 5 mm	18	26	<i>p</i> = 0.10
Margin >5 mm	17	11	
Pelvis			
Margin \leq 5 mm	19	28	<i>p</i> = 0.57
Margin >5 mm	16	6	

Abbreviation: CNS, central nervous system.

Both patient age and height are numerical continuous variables. Panandiker et al. assessed renal motion in paediatric patients aged between 2 and 18 year old. The amount of renal motion increased for every yearly increase in the patients' age. Renal motion in the mediolateral direction correlated with height as well. For every 10 mm increase in height, the left kidney's movement increased by 0.006 ± 0.002 mm (*p* = 0.017) and the

right kidney moved 0.006 ± 0.003 mm ($p = 0.042$).¹⁴ It is clear from the data above that the required PTV margin for a 1-year-old baby is not the same as for a mature adult. Most of the paediatric protocols include patients up to 16–18 years old. Applying different PTV margin for adults and paediatric patients or per pubertal and post-pubertal patients may not be the simple answer. On the other hand it is not practical to consider different PTV margin for each patient based on age or height. Nazmy et al. showed a clinically significant difference in the PTV margin in the abdominal region between adult and paediatric patients treated in the same institution but they defined adult patients as age >18 and paediatric patients as age <7.⁷ A group exists in-between 7 and 18 years old wherein the margin should be considered individually.

Reduction of the PTV margin is crucial in paediatrics; it will decrease both the acute and long-term side effects. The relatively bigger radiation dose in children presents a greater risk to the Organs At Risks (OARs). This correlates directly with the size of the patient; OARs are closer in proximity in a child than in an adult.¹⁵ So while our paper highlights the need to develop consensus guidelines on PTV margins for paediatrics, it is important to take into consideration the size/height of the patient, not just the age. The relative increase in the irradiated volume by adding few mm margin in an adult patient is less than the relative increase of adding similar margin in young child.⁶

As with most research, we have identified limitations to the study specifically treatment technique (e.g., IMRT, 3D conformal radiotherapy) and modality (e.g., photons, protons) are not identified. Immobilisation devices are also not recorded and may have been useful given their impact on PTV margins. The survey did not elicit whether centres apply different planning goals (target coverage, OAR dose limits) to paediatric cases or other methods to treat paediatric patients in consideration of the different dose implications to this population. Finally, the relation between the PTV margin and IGRT protocol implemented or the use of anaesthesia has not been addressed, so a direct comparison is difficult to make between centres. During preparation for this survey it was important to spend time to phrase the questions in a way that will give usable answer. For example when we sought of asking about the immobilisation device used and we tried to make a list, we found a large number of commercially available fixation devices, the same applies to the IGRT protocol like frequency of imaging and action level. Even for anaesthesia, in the paediatric radiation oncology practice, it is known that many patients may start treatment under anaesthesia and after being familiar with the place they can get few fractions without anaesthesia so we felt addressing these issues will make the survey more complicated (lengthy and it is unlikely to get a usable information considering the wide variation of practice expected).

We did not also examine either the effect of treatment technique on the PTV margin or anisotropic margins, both of which are of salience in clinical practice. Treatment technique has been shown to impact on PTV expansion,¹⁶ while anisotropic margins are important in the delineation of treatment volumes where internal motion is greater in one direction than in another. In two studies published on extra-cranial paediatric organ motion, Huijskens et al. (2015)¹⁶ and Nazmy et al. (2012)⁶ found motion to be greatest in the cranial caudal direction for abdominal paediatric patients. Huijskens et al. suggested an individualised margin, with further research into inter- and intra-fraction motion warranted.

Because of the limitations above, it was not possible to draw conclusions regarding the PTV margin to be implemented in spite of the fact that the majority of the responders used PTV margins 3–5 mm for paediatric patients for brain and H&N and 5–10 mm

for torso and pelvic region. But these limitations do not affect the main aim of the survey which was addressed mainly in questions 1 and 2. The results of this survey provide insight into current paediatric PTV margin protocols within radiotherapy departments, the variation that exists in practice and the absence of consensus on the margin of the PTV. Based on the current information from 43 responders treating paediatric patients this study supports the need for the development of PTV margin guidelines in the treatment of this vulnerable patient cohort in each treatment centre based on the immobilisation technique and IGRT strategy.

Conclusion

In conclusion, the results of this study illustrate that the majority of responders employ a series of site-specific PTV margin protocols that are applied to both adults and paediatrics, and do not take into consideration patient age or size. These results highlight the need of a separate policy for PTV margin in adults and paediatrics in every institution.

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Conflicts of interest. None.

Ethical standards. This article does not contain any studies with human or animal subjects performed by any of the authors.

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Appendix: Survey Questions

1. Do you have written guidelines regarding PTV margin in different sites:

- (a) CNS
- (b) Head and neck
- (c) Torso

- (d) Pelvis
- (e) Other

2. Do you have separate guidelines regarding the PTV margin for adults and paediatrics?

- (a) CNS
- (b) Head and neck
- (c) Torso
- (d) Pelvis
- (e) Other

If no. Please comment on whether you feel the need for paediatric specific guidelines regarding PTV margins for the major sites.

3. Please indicate PTV margins employed for these sites

- (a) CNS adults _____ mm Paediatrics _____ mm
- (b) Head and neck Adults _____ mm Paediatrics _____ mm
- (c) Torso Adults _____ mm Paediatrics _____ mm
- (d) Pelvis Adults _____ mm Paediatrics _____ mm
- (e) Other Adults _____ mm Paediatrics _____ mm

4. Any additional comments
