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Rationality and Evidence of Pre-Prepared Treatment Plan in Oesophageal HDR Brachytherapy

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Abstract**—**As a part of routine oesophageal HDR Brachytherapy procedure, treatment planning takes about 45 minutes while patients are under light sedation. Some patients may suffer gagging and/or spasms before the 90-minute brachytherapy procedure complete, and the treatment may need to be aborted. A pre-prepared plan generated before patient's sedation may reduce the brachytherapy procedure time by 40 minutes. This paper reports rationality and evidence of pre-prepared treatment plans. A retrospective study of 28 patients confirms that pre-prepared plans would be acceptable for all reviewed patients. The rationality is further confirmed by a systemic study with a wide range of applicator curvature and treatment volume. Detailed comparison between CT based treatment plans and pre-prepared plans are discussed. The argument holds for endobronchial HDR brachytherapy too. With the above evidence, pre-prepared plans have been used for all oesophageal and endobronchial HDR brachytherapy cases in our clinic.

Keywords**—**HDR brachytherapy, treatment planning, oesophageal carcinoma.

I. Introduction

HIGH DOSE RATE (HDR) Brachytherapy has been used in the overall management of oesophageal carcinoma, either as a preoperative procedure in early stage disease or as part of radical radiotherapy for palliation in advanced cases [1].

Oesophagus is a muscular tube of about 25cm long. It follows the curve of the vertebral column and shows more or less a curvature. In oesophageal HDR Brachytherapy, a single channel applicator is inserted into the oesophagus and dose to the oesophageal tumour is prescribed at a constant distance of 1cm from the axis of the applicator.

Patients are under light sedation during the entire procedure including applicator insertion, treatment planning and radiation delivery. After the applicator insertion, it takes about 45 minutes to complete the treatment planning including CT scanning, plan generation, plan QA and plan transfer to the control console for radiation delivery. Radiation delivery time is in the range of 5 to 15 minutes, depending on the source activity and the tumour volume. While most patients had no problem during the procedure, 5 patients among the first 28 patients treated at Nova Scotia Cancer Centre suffered severe gagging and/or oesophageal spasms before the 90-minute brachytherapy procedure complete, and the treatment had to be aborted. In order to reduce the procedure time and avoid this failure, using a pre-prepared treatment plan was considered. The practice of replacing a customized CT based treatment plan with a straight applicator plan or standard plan was reported for rectal [2] and endobronchial HDR brachytherapy [3].

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CT based HDR treatment plan is generated by the Oncentra Brachy planning system (Oncentra brachy version 4.1) [4]. The plan is optimized automatically on a set of dose points. Dose points are defined at 1cm distance from each active source dwell position on both sides of the applicator. For a 10 cm treatment volume and 5mm dwell position step, for example, there are 40 dose points defined. The dose variation at dose points is within +/-1 % of prescribed dose for a straight applicator and higher for a curved applicator.

A pre-prepared plan is a plan based on a straight applicator using an empty image series (without any CT data), instead of real curved applicator as in a custom-build plan. The pre-prepared plan is generated, checked and ready for delivery before patient sedation and applicator insertion. After the insertion, only x ray film is required to confirm the applicator position and curvature. The usage of a pre-prepared plan makes it possible to reduce the entire brachytherapy procedure time by 40 minutes.

II. Methods and Materials

Retrospective study was completed as the first part of the study. Seven cases with an obvious curved applicator were selected among the 28 cases treated. For each case, a treatment plan was generated with a straight applicator and the same treatment volume as the real oesophageal case. Then a pre-prepared plan was created for the real curved applicator by replacing dwell time table of the curved applicator plan with the dwell time table of straight applicator plan. Comparing dose distribution of this pre-prepared plan with the original custom-built plan was done by comparing average doses of the two plans. The difference of the doses of the two plans is less than 0.2% for five cases, and is less than 0.5 % for the other two cases. This difference is considered insignificant, and a pre-prepared plan would be acceptable. Since these 7 cases were the most curved applicators among the 28 cases treated, it seems that all 28 cases could be treated without custom-built plans. This retrospective study of a limited number of real cases is, however, not enough to validate for all the future cases. In order to confirm the rationality of pre-prepared plans, a systematic study is necessary.

In the second part of the study, a set of four curved

applicators were created. These applicators are circular arcs with radius of 10, 15, 20 and 30cm respectively. For each curved applicator, 3 cases were created with treatment volume of 5, 8 and 10cm respectively. The treatment length of most oesophageal cases is in the range of 5-8cm. Radius of curvature less than 20cm was not seen in the past 28 cases. This wide range of curvature and treatment volume would cover most possible cases in the future and find out the limitation of this application.

For each case, 2 treatment plans were generated: a custom-built plan and a pre-prepared plan. For each dose point of each plan, a dose variation is calculated as the absolute value of the dose in % minus 100%.The smaller the dose variation, the closer the dose at that dose point to the prescribed dose. An average and standard deviation of the doses at all dose points in each plan was then calculated for comparison.

III. Results

Tables I and II show the results of the comparison between custom-built plans and pre-prepared plans.

TABLE I
AVERAGE DOSE VARIATION: PRE-PREPARED PLAN MINUS CUSTOM-BUILT PLAN

Radius curvature (cm)	5cm volume		8cm volume		10cm volume	
	concave side	convex side	concave side	convex side	concave side	convex side
30	-0.3%	0.3%	0.0%	0.1%	0.3%	-0.2%
20	-0.2%	0.3%	0.6%	-0.2%	0.8%	-0.6%
15	-0.1%	0.2%	1.0%	-0.4%	1.6%	-1.0%
10	0.5%	0.1%	2.3%	-0.5%	3.8%	-2.4%

TABLE II
STANDARD DEVIATION OF DOSE VARIATION: PRE-PREPARED PLAN MINUS CUSTOM-BUILT PLAN

Radius curvature (cm)	5cm volume		8cm volume		10cm volume	
	concave side	convex side	concave side	convex side	concave side	convex side
30	0.1%	-0.6%	-0.3%	-0.1%	0.3%	2.5%
20	-0.2%	-0.5%	0.1%	0.3%	0.2%	0.7%
15	-0.2%	-0.6%	0.1%	0.4%	1.2%	0.7%
10	0.1%	-0.6%	-0.7%	1.3%	2.2%	2.5%

Table I lists “additional” average dose variation away from the prescribed dose of 100% if using a pre-prepared plan instead of a custom-built plan. A value of 0% means the average dose variations of custom-built plans and the pre-prepared plans are the same. A positive value means the pre-prepared plan is of higher discrepancy to the prescribed dose of 100%. If this positive value is higher than 2%, this plan is considered not suitable. A negative value means the dose of pre-prepared plan is closer to the prescribed dose of 100% and is always a preferable treatment plan.

It can be seen from Table I that the shorter the treatment volume or the less sharp curvature, the less of the difference. For example, less than 0.5% difference of average dose value for 5cm volume for any curvature. The difference is less than 0.3% for 30cm curvature for any volume. This result is highly expected. In fact, a short volume or a less sharp curve means not much variation of the source dwell positions from a straight line. For radius of curvature greater than 15cm and volume less than 8cm, the difference is less than 1% and using a pre-prepared plan is clinically acceptable. A radius of curvature less than 15cm has not been seen in our experience so far.

A similar comparison is true for standard deviation listed in Table II. The values of standard deviation for 5 or 8cm volume are negative (better) or insignificant. This means the dose variation of standard plan among all dose points is better or insignificant. The case of 10cm volume and 10cm curvature (more than 2% additional deviation) is impossible for a real case. It was included in this study only for finding out the limitation of degree of curvature and treatment length.

It is interesting that about half of the values in Table I are negative. In fact, values at convex side are all positive, and values at concave side are all negative for 8 and 10cm volume. This means that dose gets worse (as expected) on the concave (overdose) side but improved on the convex (underdose) side due to neglect of the curvature. In other words, both sides receive higher dose in pre-prepared plan than custom-built plan. This can be explained as follows.

For a curved applicator, the dose to points at the concave side of the applicator is always higher than the dose to points of the same distance at the convex side. After normalization, dose points on the concave side are slightly ovedosed and dose points on the concave side are underdosed. Table III list the sum of total dwell time for treatment volume of 10cm. The straight applicator plan has the longest dwell time, and the more curved applicator, the shorter the total time. If the dwell time of straight applicator plan is manually reduced, then the concave side would be improved, but the convex side would get less improve. Fig. 1 shows the weighting of dwell time for treatment volume 10cm. Only a half of the dwell positions are shown with number 1 is at the end of the applicator and number 10 is at the middle. As shown in Fig. 1, the dwell time in the middle part of the applicator is the same for all applicators of different curvatures. The difference is at the first 3 dwell positions. Therefore, manually reducing dwell time of the first 3 dwell positions at both ends in a pre-prepared plan may produce a better treatment plan.

TABLE III
TOTAL DWELL TIME FOR TREATMENT VOLUME OF 10 CM

Radius curvature	10cm	15cm	20cm	30cm	Straight
Total dwell time (seconds)	386	397	401	404	406

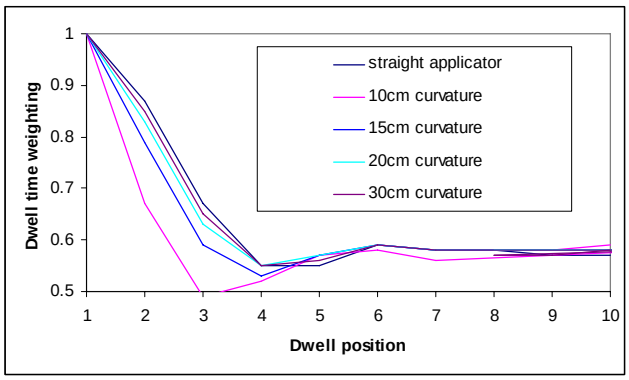

Fig. 1 Weighting of dwell time for treatment volume 10cm

IV. Conclusion

In this paper, the rationality of pre-prepared HDR brachytherapy plans for patients with cancer of the oesophagus is confirmed by both retrospective study and systemic study with a wide range of applicator curvature and treatment volume. Pre-prepared plans can significantly reduce simulation and treatment planning time. Patients would benefit from this 40 minute time saving with much less discomfort to say the least. This study provides evidence and limitation of applicator curvature and treatment volume for using pre-prepared plans. The same argument holds for endobronchial HDR brachytherapy. With the above evidence, pre-prepared plans have been used for all oesophagus and bronchus HDR brachytherapy cases in our clinic. All straight applicator plans can be saved in plan library for future use.

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