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Original research article

Use of planar kV vs. CBCT in evaluation of setup errors in oesophagus carcinoma radiotherapy

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ABSTRACT

Aim: The aim of this study is to evaluate differences in terms of the setup errors observed using kV planar image compared to CBCT for oesophageal cancer patients.

Background: Planar kV images are quick to acquire but only allow the observation of bony structures. CBCT allows the evaluation of soft tissues, which includes the oesophagus (and tumour) and OAR, giving a more accurate verification of the positioning.

Materials and Methods: All patients were imaged with both techniques between January 2012 and March 2014 were included in the study (16 patients, 212 kV images and 116 CBCT images). Differences between the setup errors observed on the two images modalities were studied. A correlation study between TNM staging, tumour location and immobilization systems with setup errors was also done. Finally, the calculation of systematic and random errors allowed to determine the CTV–PTV margin.

Results: A significant discrepancy ($p < 0.05$) between the setup errors observed with kV and CBCT was observed in the lateral direction. No statistical correlation was found between setup errors and tumour location, immobilization system or TNM staging. The CTV–PTV margin was smaller with CBCT in the vertical (0.6 cm vs. 0.9 cm) and longitudinal (0.7 cm vs. 1 cm) directions and smaller with kV for the lateral directions (0.8 cm vs. 0.9 cm).

Conclusions: The chosen modality influences the setup error observed which will influence the correction applied. Allowing a better observation of the volumes of interest, CBCT should be the modality of choice in this pathology. The CTV–PTV margins could be shrunk if CBCT is used.

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1. Background

The use of ionizing radiation to cause damage in biomolecules that cause the cell death is the basic principle of Radiation Oncology, but if, on one hand, the death of cancer cells is the objective, the radiation therapy, on the other hand, is not precise enough to only damage cancer cells, so healthy tissues are also irradiated, resulting in unwanted side-effects.

The best dose prescription and dose distribution are proposed to achieve the best result, although the dose distribution that is achieved on the treatment planning system is not what happens in reality due to some differences between the planned position (acquired on planning CT scan) and the actual position of the patient on the treatment unit.

Nowadays, dose administration has been improved by the raising of special techniques that are being used more often due to their proven advantages,¹ including intensity modulated techniques and arc therapy. Those advantages can only be achieved if there is accuracy in the delivery of this dose; for that reason, quality assurance of the patient position in treatment unit should be part of the treatment procedure²: radiological images are acquired in treatment position and compared with the corresponding planning images. Nowadays, a variety of image techniques are available such as planar MV images, planar kV images, CBCT, in-room systems, etc.³

Since the opening of our new radiotherapy department with three linear accelerators equipped with On-Board Imager[®] (Varian Medical Systems, Palo Alto, USA) (in addition to EPID for portal MV imaging), it is possible to acquire planar kV and CBCT images of the patient at the treatment position.

There are several differences between both techniques: with CBCT, it becomes possible to observe soft tissues^{4–9} (including the oesophagus, the tumour and the OAR). The kV images are quicker to acquire and with lower exposure to the patient but they have low contrast for soft tissues,^{8–13} the objective of this study is to evaluate if there are significant differences in terms of setup errors observed between the two techniques in this particular tumour location.

The main objective of this study is to verify if there are differences in the setup errors when they are observed with planar kV or CBCT. Regarding that with the CBCT it is possible to visualize soft tissue, including the target and the OAR,^{4–8} if significant differences are observed that suggest that the planar kV is not an accurate way to predict the position of the structures of interest.

Although with the kV it is possible to determine setup errors by the matching of bony structures, internal movement of the organs cannot be observed (only with CBCT). So, the eventual differences between the errors observed would result from this internal movement of the organs.

The correlation between the setup errors was observed and the following variables were studied: TNM staging, location of the tumour and immobilization system. In addition, the necessary CTV–PTV margins were evaluated according to the image modality used, regarding the possibility of shrinking this margin, allowing the reduction of the OAR irradiation.^{14,15}

Table 1 – Sample descriptives.

	N	%
Sex		
Feminine	1	6.3
Masculine	15	93.8
Number of images analysed		
kV	212	64.6
CBCT	116	35.4
Immobilization		
Thermoplastic mask	13	81.3
Thorax board	3	18.8
Tumour location		
Cervical	3	18.8
Upper thoracic	10	62.5
Mid-thoracic	3	18.8
T staging		
T2	2	12.5
T3	9	56.3
T3/4	2	12.5
T4	3	18.8
N staging		
Nx	10	62.5
N0	2	12.5
N1	2	12.5
N2	2	12.5
M staging		
M0	15	93.8
M1	1	6.3

2. Methods and materials

The patients treated between January 2012 and the end of this research in March 2014 were included if during their treatment they had both verification images being studied: planar kV or CBCT. A total of 16 patients were included resulting in a total of 212 kV images and 116 CBCT analysed. The average age of the patients in the sample is 62 ± 9 -years-old, and other descriptives of the sample can be observed in [Table 1](#).

Those patients underwent radiotherapy to the oesophagus using conformal technique or IMRT. The decision regarding the technique used is individual and it is based on the technique that best satisfies the target coverage and OAR constraints.

The standard verification methodology at the department is the online evaluation of orthogonal acquisition of kV images with On Board Imager[®] (Varian Medical Systems, Palo Alto, USA). In some cases, for clinical (e.g. tumour shrinkage) or technical (e.g. overlap of bony structures) reasons a CBCT would be acquired either after a kV image or as a single modality. After deciding what the best image verification modality would be to each particular case, from that moment on, only one modality would be used since the use of both modalities would be considered an unnecessary extra dose to the patient. The setup error was calculated as the shift between the setup position and the final treatment position (after image analysis).

According to the protocol at the institution, a verification image is acquired on the three first days after which the average observed setup error is calculated and if the average is above 3 mm a shift is applied daily. A weekly imaging verification is performed and if the patient presents a setup error greater than 3 mm an image is acquired the next day and if it persists the average is recalculated and applied from that

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