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Commissioning of virtual simulation and its role in the treatment planning of sixty-three (63) head and neck cancer patients – the Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) experience

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Abstract

The objective of this paper is to share the experience of commissioning the virtual simulation (VSim) software, GE Advantage Sim ver 4.3, and its use in the radiation therapy of head and neck cancers at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH). The first sixty-three (63) head and neck cases, planned on the VSim workstation, were retrospectively analysed, as well as the impression of staff members after using the system. A semi-structured survey revealed that members of the multi-disciplinary team were overall satisfied with the system. A follow-up study, with more cases and other treatment sites, will be conducted to confirm these findings.

Keywords radiation therapy, computed tomography, bone necrosis, dental reviews

Introduction

Head and neck cancers are one of the most troublesome cancer groups, with 60% of them presenting at locally advanced stages; local regional recurrence constitutes the predominant recurrent pattern.[1] Radiotherapy is a standard non-surgical therapy for locally advanced head and neck cancers. These cancers account for approximately 10% of the 3000 cancer cases treated at the Charlotte Maxeke Johannesburg Academic Hospital (CMJAH). Eighty percent of these cases present in advanced stages. In 1998/1999 head and neck cancer constituted approximately 4% of all cancer cases treated in South Africa.[2]

In order to maximise the chances of cure, while at the same time minimising complication rates, radiotherapy, for head and neck cancer, aims to administer high radiation doses to target volumes, whilst sparing critical structures like the mucous membranes, spinal-cord, parotid glands, etc. To prevent tooth decay, and the risk of subsequent bone necrosis, dental reviews are crucial before commencing irradiation of head and neck tumours.[3,4] Treatment planning is an essential component for radiation therapy, especially in curative treatments where doses up to 70Gy may be delivered to the primary site. Radiotherapy treatment planning includes: hand planning by means of a single patient contour; two-dimensional (2D)

planning by means of bony-land marks on a conventional simulator; and three dimensional (3D) planning by means of computed tomography (CT), which provides information, not only about target volumes but also about critical (normal) organs. Simulation 'mimics' the actual radiation treatment. It therefore forms an integral part of the treatment planning of head and neck cancers. Virtual simulation (VSim) is a multidimensional planning technique based on CT images, which "provides the user with an accurate reproduction of anatomical features from the viewpoint of the treatment source".[5] The virtual simulation workstation at CMJAH does not incorporate a 3D dose algorithm as it cannot calculate dose and optimise a plan. It is thus described as two and half-dimensional (2.5D) planning at CMJAH.

CMJAH radiation oncology is a multi-vendor environment with the following equipment: four Siemens Oncor™ linear accelerators (LINACS) (Siemens Medical Solutions, Concord, CA), two Equinox Cobalt-60 units (MDS Nordion, Canada), two Toshiba simulators (Toshiba, Japan), Helax_TMS ver. 6.1B (Philips Medical Systems, Fitchburg, WI) treatment planning system (TPS), Oncentra MasterPlan (Nucletron, Columbia, United States of America) TPS, one General Electric (GE) Lightspeed computed tomography unit (GE, Erlangen, Germany), virtual simulation (VSim) workstation with the GE Advantage Sim ver. 4.3 software (GE,

Erlangen, Germany), one 3 channel Nucletron high dose rate brachytherapy afterloader (Elekta AB, Sweden Stockholm), one 24 channel GammaMed*plus* high dose rate brachytherapy afterloader (Varian Medical Systems, Palo Alto, CA) and one DX3300 orthovoltage X-ray unit (Gulmay Medical Ltd., Surrey, United Kingdom), and LANTIS® (Elekta AB, Stockholm, Sweden) as the record and verify system.

Patients presenting at CMJAH, like in most South African university teaching hospitals, are most likely to experience long waiting times before they receive radiotherapy. It was therefore envisaged that the introduction of VSim would relieve the workload on the conventional simulators and consequently potentially reduce the patient waiting list. This paper provides our experience, and results, for the commissioning and utilisation of the VSim system at CMJAH for head and neck cancer radiotherapy during the period from 1 March to 30 November 2008.

Methods and materials

The VSim workstation underwent comprehensive customer acceptance testing (CAT) as per the vendor's customer acceptance testing procedure.[6-8] In addition, end-to-end testing, utilising a purposefully non-symmetric phantom, was performed to establish the fidelity of the data transfer from the CT scanner to the VSim worksta-

tion and to the treatment delivery LINAC through the record and verify system. Software functionalities, which were common between the VSim workstation and the TPS, were compared; the TPS being the reference. A common image dataset was used in both TPS and VSim. Functionalities that were tested, and compared, included contour volumes, and dimension measurement. To ensure non-drift in the performance of the VSim system, an ongoing quality control programme, informed by the prevailing workflow, was designed and implemented.[9]

The first 63 head and neck cases planned on the VSim system (from 1 March to 30 November 2008) were used in this study. The data collected was not gender specific as this would not have added any value to this study. Also there were no inclusion/exclusion criteria used for this study. The head and neck cancer cases that were planned, using VSim, were radical (curative intent) for doses ranging from 66 Gy to 70Gy. The treatment technique used was two lateral and two offcord fields, a matching anterior neck field, and two posterior neck electron fields.

To gauge the acceptance of the VSim system by the users, a survey was conducted by means of a semi-structured interview. Six radiation oncologist and eight radiotherapists participated in the survey. The participants were arbitrarily chosen from those who had already used the VSim system. The participants were asked the following questions.

• Is there a role for virtual simulation at CMJAH?
• What are the 'negatives' of the technique/workflow?
• What are the 'positives' of the technique/workflow?
• What is your overall impression of the virtual simulation technique as used at CMJAH?

Results

The CAT was successfully completed, with all the purchased software licences functioning correctly, including back-up and archiving capabilities. To complement the CAT, a collection of photon and electron beams, of different geometry combinations including asymmetric fields, was planned on the VSim system and transferred to LANTIS® for subsequent delivery on the LINAC. Upon downloading the VSim created fields on the LINAC, visual
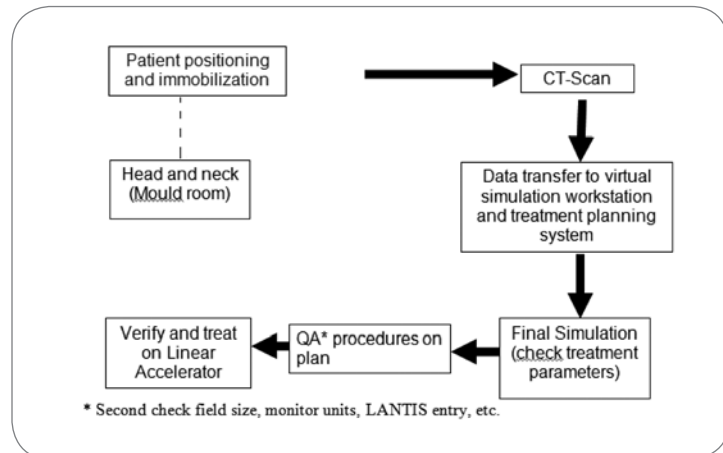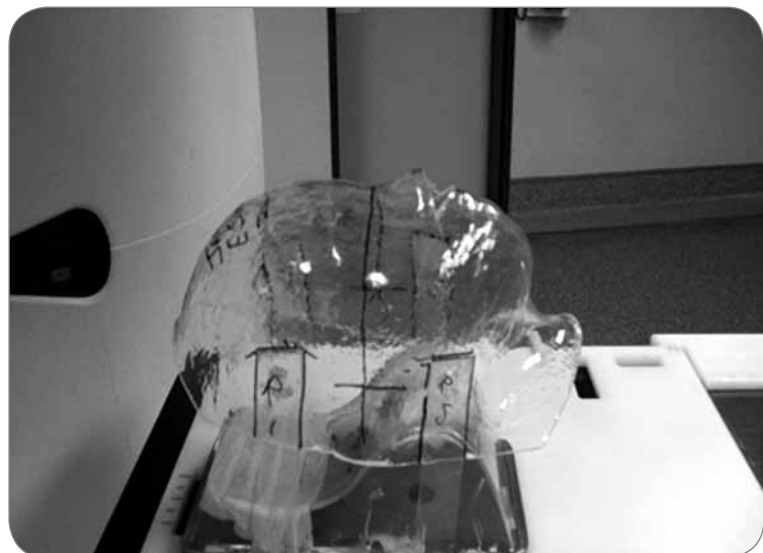

Figure 1: CMJAH VSim workflow
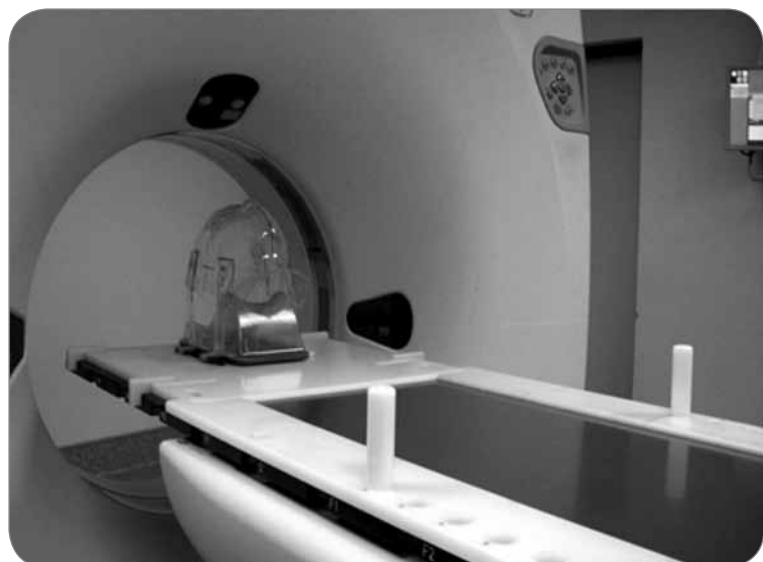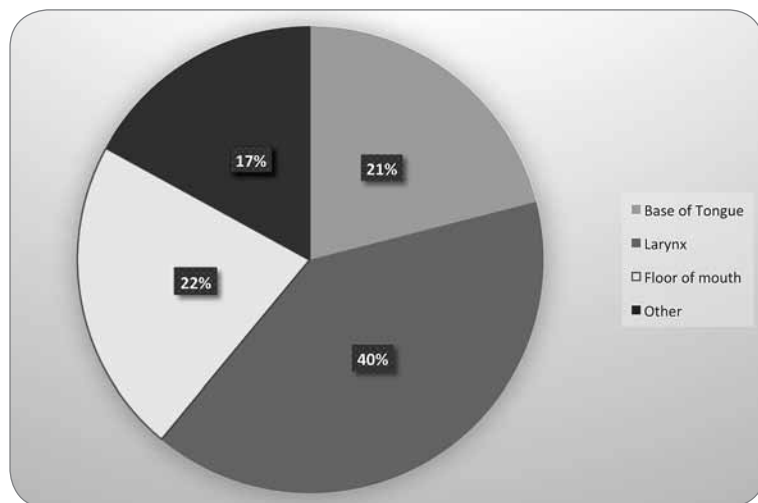

Figure 2: Head and neck immobilisation mask

Figure 3: Head and neck immobilisation

Table 1: Head and neck VSim protocol at CMJAH

SITE	IMMOBILISATION	PATIENT POSITIONING	CT SCAN PROTOCOL	SLICE THICKNESS	SCAN LIMIT
Head and neck	- Perspex Mask - ± Tongue depressor - Head rest - ± Bite block - Radical head and neck board	Supine	Head and neck	5 mm	Vertex to below supra sternal notch

Figure 4: Distribution by specific treatment site of first 63 head and neck cases who underwent virtual simulation

inspection of the field geometry and machine parameters (e.g. gantry angle, collimator angle, couch angle, etc.) was done to confirm data transfer fidelity. The results of these tests proved consistency across the workflow; proof that the VSim, TPS, LANTIS® and LINAC coordinates, movements, angles and scales were consistent with the configured International Electrotechnical Commission (IEC) 61217 convention. Comparison of the contour volumes, drawn on the VSim and on the TPS, showed that both systems yielded practically the same result. Furthermore the digitally reconstructed radiographs (DRRs), from the VSim system, were of adequate image quality and fidelity for the purpose of set-up verification.

For the clinical implementation, the VSim workflow is demonstrated in Figure 1. The workflow in Figure 1 was designed in order, where possible, that it retained the workflow components, from other treatment techniques in the radiotherapy clinic, to maintain familiarity and therefore increase the chances of a buy-in from the users. As the VSim program matures it is envisaged that the final simulation step in Figure 1 might become redundant, thus further streamlining the workflow and gaining on efficiency.

Head and neck cases are immobilised using individualised Perspex shells (masks) to prevent patient movement during treatment and to ensure accurate reproducibility in the treatment set-up. Figure 2 is an in-house fabricated mask used at CMJAH.

To further complement the immobilisation mask, an in-house manufactured head and neck immobilisation system was designed to incorporate the head rest and mask of a patient, and to keep a patient shoulders out of the field of treatment by providing indexed handles along the length of the board (Figure 3).

The CT and positioning protocol used for virtual simulated head and neck cases is given in Table 1. Patients are scanned and planned using the shift method, which does not necessitate a radiation oncologist to be available for the CT scan. After the scan is done the images are transferred to the VSim system. Physicians then place their treatment fields on the system, without contouring the target volumes. Similar to what happens on a conventional simulator, but with an added advantage of having a three dimensional CT image to plan on. Shifts (superiorly or inferiorly, laterally and anteriorly or posteriorly) from the reference marks on the CT scanner and the treatment isocenter are then

calculated based on the treatment plan. On the first day of treatment, the patient is positioned to the initial reference marks and then shifted to the treatment isocenter using the calculated shifts.

The distribution by treatment site of the head and neck cancers during the first nine months of the utilisation of the VSim system is demonstrated in Figure 4.

The survey revealed that the majority of oncologists (five out of six) and radiotherapists (six out of eight) demonstrated positive attitudes with regard to the use of VSim at CMAJH. The radiation oncologists highlighted the disadvantages of the shift method, namely, the inability to modify slice thickness; their preferred head position of the patient, etc. after the scan is taken by the radiotherapist. The radiotherapists were of the opinion that the use of the conventional simulator in the treatment technique of VSim was additional work.

Discussion

The commissioning tests were guided by medical physics' societal recommendations and also complemented by departmental workflow specific tests. Tests, relating to the CT hardware and software, have not been described in this work as the VSim system was a later addition to the CT-based treatment planning workflow which was already mature with a comprehensive quality assurance (QA) programme.

The present VSim system configuration is different from the conventional set-up as the CMAJH CT scanner does not have moveable lasers, and the VSim workstation is not stationed at the CT scanner console but is in the treatment planning room. Nevertheless the benefits of virtual simulation were realised.

There are a number of advantages associated with the chosen VSim technique. The time the patient spends on the CT-scanner as compared to conventional simulation is less, since we have a multi-sliced CT

scanner and we adopted the shift method. All data are transferred electronically over a secure internal network to the record and verify system and subsequently to the treatment machine, which eliminates the risky process of data being uploaded manually on the treatment machine. Use of the VSim system enables a more efficient process of 3D conformal radiotherapy through the use of multi-leaf collimators (MLC) instead of alloy shields. The advantages of MLCs over alloy shields are well documented in the literature. In our case the use of the VSim system meant that these MLC fields could be transferred automatically over the network to the treatment machine anytime during working hours. The previous practice required access to the treatment machine, but this was only feasible after-hours. In other words the physicists manually uploaded these fields onto the treatment machine only after patient treatment had been finished for the day.

The availability of the 3D image display is invaluable to radiation oncologists. It helps them target the tumour accurately and confidently compared to when using planar images. It also helps with optimum selection of the beam arrangement for the treatment plan. Another advantage offered by the availability of 3D view is the possibility to accurately measure the depth of treatment for the post electron fields for each individual patient and thus choose the optimum electron energy for therapy.

The general subjective nature of the semi-structured survey is acknowledged however in this setting it proved useful as it was a way to quickly provide information on the views of the users of the technology and therefore without unnecessary delay fully roll-out the treatment technique while at the same time addressing the concerns of the users. Radiotherapy technology is expensive thus it is necessary to have a buy-in from the end-users lest the technology lies idle at the cost of the taxpayer.

The challenges of VSim are the respective cost implications associated with the system and training the users. In addition, such technology driven processes necessitate the need for QA programmes which add to a physicist's workload.

Conclusion

Virtual simulation, as a technique of radiotherapy treatment planning, was successfully commissioned and implemented at CMJAH. From the semi-structured survey it can be concluded that the initial core group of users embraced the use of the VSim system and its associated workflow processes. The need for staff training, when new technology is introduced in a radiotherapy clinic, cannot be overstated. It is envisaged that after the successfully roll-out of the head and neck cancer virtual simulation, other cancer sites will also become eligible for virtual simulation.

Competing interests

The authors do not have financial or personal relationships which may have inappropriately influenced him in writing this article. They do not have any conflicts of interest.

Contributions of authors

BVW=40%, TN=30%, LM=20%, VS=10% in the research survey, interpretation of results, drafting and editing the manuscript.

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