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A virtual radiation therapy workflow training simulation

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ABSTRACT

Aim: Simulation forms an increasingly vital component of clinical skills development in a wide range of professional disciplines. Simulation of clinical techniques and equipment is designed to better prepare students for placement by providing an opportunity to learn technical skills in a "safe" academic environment. In radiotherapy training over the last decade or so this has predominantly comprised treatment planning software and small ancillary equipment such as mould room apparatus. Recent virtual reality developments have dramatically changed this approach. Innovative new simulation applications and file processing and interrogation software have helped to fill in the gaps to provide a streamlined virtual workflow solution. This paper outlines the innovations that have enabled this, along with an evaluation of the impact on students and educators.

Method: Virtual reality software and workflow applications have been developed to enable the following steps of radiation therapy to be simulated in an academic environment: CT scanning using a 3D virtual CT scanner simulation; batch CT duplication; treatment planning; 3D plan evaluation using a virtual linear accelerator; quantitative plan assessment, patient setup with lasers; and image guided radiotherapy software.

Results: Evaluation of the impact of the virtual reality workflow system highlighted substantial time saving for academic staff as well as positive feedback from students relating to preparation for clinical placements. Students valued practice in the "safe" environment and the opportunity to understand the clinical workflow ahead of clinical department experience.

Conclusion: Simulation of most of the radiation therapy workflow and tasks is feasible using a raft of virtual reality simulation applications and supporting software. Benefits of this approach include time-saving, embedding of a case-study based approach, increased student confidence, and optimal use of the clinical environment. Ongoing work seeks to determine the impact of simulation on clinical skills.

Introduction

Radiotherapy education, as in other health professions, aims to equip students with a combination of essential knowledge and understanding, clinical professional skills and clinical technical competencies. Traditionally, academic teaching blocks have provided the underpinning theoretical understanding while clinical placements have facilitated integration of theory into clinical skills development. At Queensland University of Technology students undertake 6 separate placements at a variety of clinical sites spending a total of 32 weeks in radiotherapy departments over the 3 year Course. During these placements students are expected to develop a wide range of technical and interpersonal skills. The variety of sites provides students with exposure to a range of equipment and techniques. While this has great value in terms of providing a wide educational experience, it can lead to challenges when students are faced with learning to handle different situations. Students also need to maximize their patient-care skills, and concentrating on equipment skills can distract them from this.

Simulation forms an increasingly vital component of clinical skills development in a wide range of professional disciplines including medicine,[2] surgery,[1] physiotherapy,[3] podiatry,[4] pharmacy,[5] chiropractice,[6] paramedicine,[7] psychiatry[8] and nursing.[9] Simulation of clinical techniques and equipment is designed to better prepare students for clinical placement by providing an opportunity to learn technical skills in a "safe" academic environment. Fear of making an error or inconveniencing clinical staff and patients

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is removed, allowing students to learn at their own pace. By familiarising students with complex equipment or processes before arrival in clinical departments, students are able to make optimal use of this valuable time and concentrate their efforts on patient care and applying their technical skills in a professional manner.

In radiotherapy training over the last decade or so, clinical simulation has predominantly comprised treatment planning software and small ancillary equipment such as mould room apparatus. The large and expensive nature of treatment delivery systems has until recently made their use in an academic training environment unfeasible. With the advent of the Virtual Environment for Radiotherapy Training (VERT), however, the potential for treatment simulation has increased. Published studies highlight the value of VERT for pre-clinical skills development[10,11] although it is only capable of simulating a couple of components of the radiotherapy workflow. Over the past 12 months at Queensland University of Technology, an initiative to develop and integrate new simulation applications, Digital Imaging and Communications in Medicine (DICOM)[12] processing, and interrogation software has aimed to fill in the gaps left in the existing simulation solutions to provide a streamlined virtual workflow solution. This paper outlines the innovations that have enabled this, along with an evaluation of the potential benefits for students, educators and patients.

Materials and methods

A series of new simulation applications and software solutions were developed to link existing simulation equipment and provide students with a continuous patient journey simulation. Table 1 illustrates how the various stages of a patient's radiotherapy course can be simulated using these tools. Although space prevents a detailed description of each tool an overview of each follows.

Virtual CT-scanner

With support from a Health Workforce Australia grant, a 3D virtual environment was developed to simulate a CT-scanner. Although primarily developed as a medical imaging simulation, it has demonstrated clear value for radiation therapy teaching. Students are able to “position” a patient on the couch and use the CT controls to set the correct parameters for their chosen radiotherapy planning scan. The application reinforces the importance of selecting correct scan limits, scan thickness and patient position. A gaming environment and realistic patient and equipment visualization along with 3D glasses engenders a genuine and high fidelity experience. Full class teaching using a PC laboratory can enable 40 students to undertake a rudimentary CT experience concurrently.

Batch CT handler

The planning of multiple treatments on copies of a single CT dataset is an ideal teaching opportunity as students' solutions and skills can be directly compared. This can be problematic since clinical DICOM systems do not allow simultaneous user access, there is greater potential for data loss through human error, and file access can be slower. To overcome these problems a new tool was developed, the DICOM CT Duplicator, allowing the automated production of duplicate CT datasets with unique identifiers. The user is able to specify override values for the Study ID, Patient ID and Patient Name DICOM attributes, such that files can be more easily organised in the planning system and beyond. This enables multiple students to plan the same dataset while retaining individual identification for each plan and thus allowing plan export and evaluation in all DICOM environments. The software was developed in the C# programming language and uses the Fellow Oak DICOM for .NET library.

Table 1
Virtual radiotherapy workflow solutions.

Workflow stage	Simulation/Solution
Patient imaging	Virtual CT-scanner
Image transfer	Batch CT anonymisation, copying and labelling
Patient database preparation	Verification system
Radiotherapy planning	Treatment planning system
Plan evaluation	Virtual environment for radiotherapy training
Plan assessment	Batch plan comparison system
Patient setup	Patient alignment lasers
Room setup	Virtual environment for radiotherapy training
Treatment verification	Image-guided RT software

Radiotherapy information management system

The MOSAIQ patient management software is used clinically to administrate patient schedules, connect planning and treatment software, and record and verify treatment-unit parameters. The system allows for easy transfer of data between the planning system and the VERT virtual linear accelerator, while students can gain valuable and clinically relevant experience with data input and checking procedures.

Treatment planning system

The Pinnacle planning system (Philips Healthcare, Fitchburg) is used at Queensland University of Technology to provide students with a range of planning opportunities from simple phantom dosimetry to IMRT using clinical software. Teaching is conducted in a specialist simulation IT lab to enable whole-class teaching, tutoring input from multiple clinical experts and proximity to additional simulation equipment. Broadcast software allows students' work to be shared with the class and for live plan evaluations to be conducted. Although Pinnacle is tolerant of duplicate DICOM headers, other planning systems and DICOM tools refuse to distinguish between different copies of the same CT datasets. A case-study based approach provides students with genuine clinical details including diagnostic, IGRT and follow-up information to engender a holistic approach to each patient's radiation therapy workflow.

VERT plan evaluation

VERT is a radiotherapy-specific virtual reality application utilising a large-screen and 3D shutter glasses to provide a high level of realism and presence.[13] It offers the user the opportunity to control a virtual linear accelerator with a genuine hand control system, displays CT and plan data in 3D and is rapidly becoming an integral component of radiotherapy training globally. Since VERT's implementation in Australia in 2011 it has been mainly used for pre-clinical skills practice, demonstration of techniques and 3D plan evaluation. The latter facility allows student-created dosimetry plans to be imported and displayed in immersive 3D using 3D shutter glasses and large screen rear projection. At Queensland University of Technology all students have an opportunity to view their plans in 3D with at-elbow evaluation from a clinical tutor. With the ability to view the relative dose to target and critical structures; students can be informed of their plan development and provided with guidance as to how improvements may be made.

Batch plan comparison

The Treatment and Dose Assessor (TADA) software allows the batch analysis of dosimetric quality for treatment plans exported as