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# Human reliability assessment of a critical nursing task in a radiotherapy treatment process

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ABSTRACT

Radiotherapy treatment, like many other fields of medicine, has changed significantly in the last decade with the introduction of more advanced technology and automation. This change has often resulted in aspects of the system which cannot be automated due to technological feasibility and local implementation constraints. This has resulted in a requirement for significant human interaction. This combination of human operations and automation has introduced new error pathways. Traditionally, recommendations to improve the safety of such systems are typically made after the analysis of an adverse event or a significant series of incidents. In contrast, adopting a proactive approach to safety would enable prior identification of potential errors and the specification of appropriate defences against them, thus avoiding costs associated with adverse outcomes. In this paper, a modified version of the proactive Human Reliability Assessment (HRA) method Human Error Assessment and Reduction Technique (HEART) was used to analyse a critical nursing task within a modern radiotherapy system. The modified technique used a participative team approach to complete the assessment in contrast to the normal approach, which uses a single expert assessor. The HEART technique quantifies the likelihood of unreliability of a task and ranks the conditions which most affect the successful completion of that task. HEART has been proposed as a potentially useful HRA tool for applications in healthcare, but such applications have not previously been formally documented. As a result of the modified HEART analysis reported in this paper, remedial measures were identified which were both cost effective and easy to implement.



## 1. Introduction

### 1.1. Radiotherapy treatment

One in three people will be affected by cancer in the course of their lifetime (Hollywood, 2003). Of these, approximately 50% should receive radiotherapy treatment at least once as part of their recovery (Delaney et al., 2005; The Royal College of Radiologists et al., 2008). Radiotherapy is generally regarded as a safe treatment practice in modern medicine. However, errors do occur and when they do, the consequence of their effect can be serious injury and/or death of the patient (Scottish Executive, 2006; WHO, 2008). The quantification of error in radiotherapy is difficult. One paper reported error rates of approximately 5% (Yeung et al., 2005), which is comparable to rates in radiology (Goddard et al., 2001). When adverse events in radiotherapy occur, they are regularly the subject of intense media attention and affect the patient, their family and treatment staff (English, 2006; Scottish Executive, 2006).

### 1.2. Recent developments in radiotherapy treatment processes

Until relatively recently, radiotherapy treatment machines were analogue, planning was performed using 2-dimensional computer calculations and treatment prescriptions from the Consultant Radiation Oncologists were processed through a series of manual tasks. These practices have significantly changed in recent years through, for example, the introduction of computer controlled accelerators, on-line *in-vivo* imaging systems and highly sophisticated software-based treatment planning models. These advanced technology systems encompass all aspects of the process which have system critical functionality; Electronic Medical Record (EMR), image transfer and storage, treatment simulation and planning, treatment administration and treatment dosage verification (Fallon et al., 2009c). These systems have been introduced to support staff

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in meeting the demands of increasing patient numbers, to enable the delivery of advanced treatment modalities e.g. Intensity-Modulated Radiation Therapy (IMRT) and to reduce the potential risk of human errors which contribute to radiotherapy adverse events (Donaldson, 2007; Kohn et al., 1999).

However, it should not be taken for granted that the introduction of automation and advanced technology systems alone will reduce the risk of errors. In reality, this may actually increase the probability of their occurrence by introducing new error pathways (Han et al., 2005; Koppel et al., 2005). Often, the advanced technologies introduced in this environment are from competing manufacturers and are not necessarily compatible with each other. This can compound the potential for error. In such cases, healthcare staff can 'inherit' system defects caused by the lack of integration of automated, organisational and human components, and are frequently forced to adapt to poorly designed technology (Reason, 1990; Zhang, 2005).

### 1.3. Post-incident recommendations in radiotherapy treatment

A review of the literature reporting errors in radiotherapy treatment reveals that interventions and recommendations introduced are reactive and only appear to occur as responses to adverse events (Klein et al., 2005; Patton et al., 2003; WHO, 2008; Williams, 2007; Yeung et al., 2005). Examples of this in the United Kingdom are, the introduction of external audits after the radiotherapy incident in Exeter (UK) in the 1980s and the introduction of formal Quality Assurance (QA), including ISO accreditation, after the North Staffordshire incident in the mid 1990s (Aspley, 1996; The Royal College of Radiologists et al., 2008). In France and Spain similar steps were taken after incidents there (c.f. Zaragosa, Spain (Nenot, 1998) and Epinal, France (Ash, 2007)). Worldwide, recommendations have been made related to the extensive testing and formal analysis of new software used in treatment machines following the Therac 25 events in Canada and the US (Leveson, 1995; WHO, 2008).

There has been little or no reporting of proactive analyses of the potential errors associated with human operator tasks within modern advanced technological radiotherapy treatment systems. These tasks range from the control and operation of complex equipment and virtual treatment planning, to the manual data entry of patient information and results. They are dependent on the extent and precise nature of the technology and automation implemented.

### 1.4. The radiotherapy treatment process

The radiotherapy treatment process has the following generic stages as outlined in Fig. 1. The process begins when a patient is referred (typically by their General Practitioner) for assessment to a Consultant Radiation Oncologist. A file is created consisting of his/her biographical data, referral letter, radiology and histology reports. If the patient requires treatment, the Consultant Radiation Oncologist's assessment results and the patient's treatment prescription are entered in the patient file. The patient is then added to the department's treatment programme schedule. Subsequently, a Computed Tomography (CT) scan is completed and a treatment plan is developed based on the results of the scan and the treatment prescription.

After the first radiation dose has been administered to patients and after each subsequent dose, their condition is reviewed by means of a Consultant Radiation Oncologist assessment and biochemical/blood testing. If abnormalities are found at this stage, the Consultant Radiation Oncologist may decide to change the treatment plan or prescription, resulting in one of the following possible outcomes:

- Reduction/increase in the prescribed radiation dose.
- Modification of the treatment plan in terms of individual beam shapes or intensities, radiation dose per fraction, number of treatments or frequency of treatments.
- Suspension of treatment.
- Discontinuation of treatment.

Abnormalities may result as a direct side effect of the treatment or because the patient has become sick during the treatment period, e.g. suffering from an infection. Patients are reviewed on a weekly basis for the duration of the treatment to ensure that abnormalities have not occurred.

### 1.5. Description of the participating radiotherapy department

The department in which this study took place was established in 2004–2005 and consists of 3 Linear Accelerators, CT and conventional simulators, 3D- treatment planning and a fully electronic, film and paperless radiotherapy Electronic Medical Record (EMR) system. The department performs conformal, Intensity Modulated Radiation Therapy (IMRT), Image-Guided Radiation Therapy (IGRT), High Dose Rate (HDR), Low Dose Rate (LDR) and orthovoltage treatments. At the time of the study, it employed 3 consultant radiation oncologists, 25 radiotherapists, 4.5 nurses and treats on average 1,500 patients per year.

The approach adopted to the implementation of advanced technology in the department, was less than ideal from a human factors engineering or allocation of functions perspective. System developers automated what was possible within the capabilities of the technology and the context of the local organisation, and

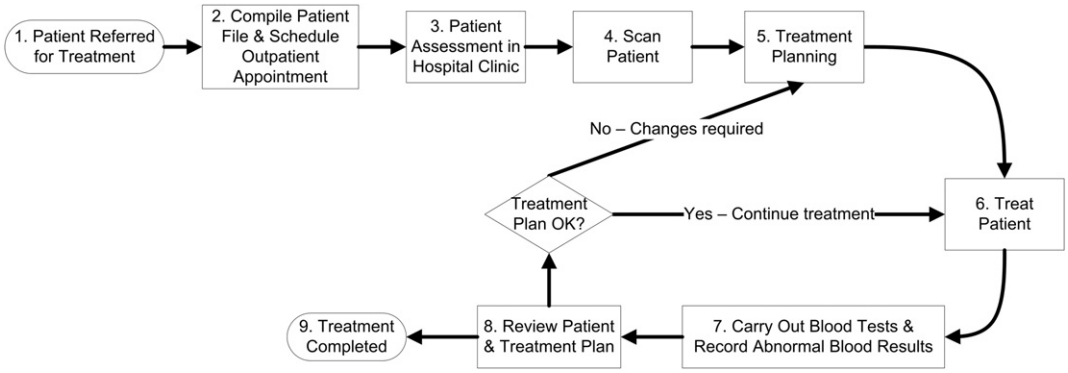


**Fig. 1.** Radiotherapy treatment process.