Original Article

Reducing Patient Waiting Times for Radiation Therapy and Improving the Treatment Planning Process: a Discrete-event Simulation Model (Radiation Treatment Planning)

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Abstract

Aims: We analysed the radiotherapy planning process at the London Regional Cancer Program to determine the bottlenecks and to quantify the effect of specific resource levels with the goal of reducing waiting times.

Materials and methods: We developed a discrete-event simulation model of a patient’s journey from the point of referral to a radiation oncologist to the start of radiotherapy, considering the sequential steps and resources of the treatment planning process. We measured the effect of several resource changes on the ready-to-treat to treatment (RTTT) waiting time and on the percentage treated within a 14 calendar day target.

Results: Increasing the number of dosimetrists by one reduced the mean RTTT by 6.55%, leading to 84.92% of patients being treated within the 14 calendar day target. Adding one more oncologist decreased the mean RTTT from 10.83 to 10.55 days, whereas a 15% increase in arriving patients increased the waiting time by 22.53%. The model was relatively robust to the changes in quantity of other resources.

Conclusions: Our model identified sensitive and non-sensitive system parameters. A similar approach could be applied by other cancer programmes, using their respective data and individualised adjustments, which may be beneficial in making the most effective use of limited resources.

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Key words: Discrete-event simulation; modelling; radiotherapy; waiting time

Introduction

A recent report showed that many Canadians are waiting for some form of medical treatment [1]. In particular, Canadian cancer patients have experienced long waiting times in radiotherapy for many years [2–4]. Lengthy waiting times for radiation treatment may have a negative clinical impact. For example, delayed radiation treatment may increase the risk of local recurrence [5–7] and poor survival [8,9].

Several population-based studies have been conducted to investigate waiting times for radiotherapy and to determine the predictors of long waits. A higher incidence of cancer, together with an increase in the demand for radiotherapy, insufficient resources and certain patient characteristics represent some of the predictors for longer waiting times [10–12]. Conversely, radiotherapy waiting times decrease with an increase in the number of radiation therapists, medical physicists, radiation oncologists and radiation planning and therapy equipment [13].
Discrete-event simulation (DES) is a valuable tool for investigating system capacity and throughput. The use of DES models with healthcare application includes hospitals, outpatient clinics, emergency departments and pharmacies [14,15]. DES can help decision-makers to carry out a ‘what-if?’ analysis to determine good policies for scheduling patients, optimising resources, reducing waiting times of patients in clinics and improving work flows [16,17]. DES models have also been used to investigate patient scheduling challenges [18], waiting time bottlenecks, overall system throughput and system configuration in emergency rooms [19], optimal intensive care unit size [20], as well as staffing levels and bed requirements [21] in various healthcare settings.

Simulation modelling has been applied in the field of radiation therapy to explore target waiting times through varying capacities [22,23] and to analyse the number of linear accelerators to achieve shorter waiting times [24]. Kapamara et al. [25] and Proctor et al. [26] used DES modelling to understand the treatment process, complexities, patient flow and bottlenecks at the radiotherapy unit. More recently, Werker et al. [27] modelled a portion of the planning process of the radiation therapy at the British Columbia Cancer Agency, with the aid of a DES model. Our work extends this study [27] by modelling the entire radiotherapy planning process, from patient arrival to treatment completion. To the best of our knowledge, this is the first paper to model and analyse the entire radiotherapy planning process at a cancer treatment facility.

The primary objectives of our study were to understand how to improve the radiotherapy planning process, to understand which resources were the most important in decreasing waiting times, to increase throughput of patients treated within the 14 calendar day target (set by the Province of Ontario and the Canadian Association of Radiation Oncology) and to provide an optimal strategy for deploying existing and new resources.

**Materials and Methods**

We modelled a patient’s complete journey from the point of referral to radiation oncology at the London Regional Cancer Program (LRCP) to the point of starting radiation therapy, accounting for every sequential step of the treatment planning process (Fig. 1). We used the Simul8 software package (SIMUL8 Corporation), which allows for visualisation and modelling of patient flow, queues and resource utilisation. This software can project flow times and identify system bottlenecks. Our study was approved by the London Health Sciences Research Ethics Board.

**Data Sources**

Patient-level process data from 2009, available through ‘in-house’ decision support and tracking software at LRCP, served as the primary data source for our study. After a patient is referred to the LRCP and receives a consultation, a file is opened for the patient and the status of the file is tracked through this software, showing each step and each healthcare professional who works on the case. We populated the model using 3888 radiation consultation records, which corresponded to all referred patients over a 1 year period (2009–2010). We consulted with LRCP staff members, including therapists, dosimetrists, physicists and administrative staff, to ensure the face validity of the model data extracted from the decision support and tracking software database.

![Fig 1. Treatment process flow diagram of key tasks.](http://dx.doi.org/10.1016/j.clon.2017.01.039)
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