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Original Article

# Radiotherapy Demand and Activity in England 2006–2020

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## Abstract

*Aims:* This paper compares the predictions of radiotherapy demand for England from the Malthus model with those from the earlier National Radiotherapy Advisory Group (NRAG) model, from the international literature and also with observed radiotherapy usage in England as a whole as recorded in the English radiotherapy dataset (RTDS).

*Materials and methods:* We reviewed the evidence base for radiotherapy for each type and stage of cancer using national and international guidelines, meta-analyses, systematic reviews and key clinical trials. Twenty-two decision trees were constructed and radiotherapy demand was calculated using English cancer incidence data for 2007, 2008 and 2009, accurate to the Primary Care Trust (PCT) level (population 91 500–1 282 384). The stage at presentation was obtained from English cancer registry data. In predictive mode, the model can take account of changes in cancer incidence as the population grows and ages.

*Results:* The Malthus model indicates reduced indications for radiotherapy, principally for lung cancer and rarer tumours. Our estimate of the proportion of patients who should receive radiotherapy at some stage of their illness is 40.6%. This is lower than previous estimates of about 50%. Nevertheless, the overall estimate of demand in terms of attendances is similar for the NRAG and Malthus models. The latter models that 48 827 attendances should have been delivered per million population in 2011. National data from RTDS show 32 071 attendances per million in 2011. A 50% increase in activity would be required to match estimated demand. This underprovision extends across all cancers and represents reduced access and the use of dose fractionation at odds with international norms of evidence-based practice. By 2016, demand is predicted to grow to about 55 206 attendances per million and by 2020 to 60 057.

*Discussion:* Services have increased their activity by 14% between 2006 and 2011, but estimated demand has increased by 11%. Access remains low and English radiotherapy dose fractionation still does not comply with international evidence-based practice.



*Key words:* Access; capacity; demand; fractionation; modelling; radiotherapy

## Introduction

One in three people will develop cancer, and radiotherapy is used in the treatment of 40% of those who are cured of their disease. Services in England have been perceived to lag behind the rest of Europe in terms of radiotherapy provision [1]: in 2003, 70% of patients waited longer than a month to start treatment [2]. In response, the National Radiotherapy Advisory Group (NRAG) was established and its report recommended substantial expansion of services [3]. It included a model of radiotherapy demand, but it did not take into account the three-fold local variation in cancer incidence in England [4]. The National Cancer Action Team therefore commissioned a new modelling tool for radiotherapy demand, called Malthus (Monte-Carlo Application for Local Treatment and Healthcare Usage Simulation). Our aim was to produce the most accurate model that we could for England and to design one that accounted for local differences in cancer incidence.

The proportion of patients who require radiotherapy at least once during the course of their illness has been termed the access rate and estimated at 52% for an Australian population [5]. Accurate determination at an individual level requires follow-up out to 20 years and is then affected by changes in practice [6]. An alternative cross-sectional method compares cancer incidence with radiotherapy treatment given for the first time to 'new' patients [7,8]. This includes patients treated initially with radiotherapy and

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also those with late recurrences receiving radiotherapy for the first time, having been diagnosed and treated (without radiotherapy) in earlier years [7,8]. From the access rate, radiotherapy demand can be estimated in terms of courses of radiotherapy required after an adjustment for re-treatment [5,8–10]. We have used a more direct approach and constructed 22 treatment trees that include the radiotherapy attendance requirement as a direct measure of workload [3,8,11,12]. To estimate re-treatment we used English audit data [8] and applied a multiplication factor at the completion of each treatment tree.

Malthus is a decision aid for planning and commissioning radiotherapy services at a local or regional level. Malthus can be used to estimate demand and therefore linear accelerator requirements, but does not model brachytherapy, nor does it include benign indications, non-melanoma skin cancer or paediatric cancer. In England, radiotherapy services were commissioned at the level of the Primary Care Trust (PCT). This was a body commissioning National Health Service (NHS) medical services for its local population. PCTs have now been abolished and radiotherapy services will be commissioned nationally by the NHS Commissioning Board through specialised commissioning. Private patients are treated on NHS machines, but in addition there were 12 (4%) private linear accelerators in 2011 (personal communication, H Forbes and C Ball, Nat-CanSAT, 2012).

Malthus is driven by differences in cancer incidence that vary by a factor of three and largely depend on the age structure of the population [4]. For example, the highest incidence of breast cancer in England was 0.36% annually in the Devon PCT because of a higher proportion of older people in this retirement centre. By contrast, the lowest burden was observed in Tower Hamlets PCT, where the annual incidence was 0.11% (being an inner London suburb with a younger population) [4].

This paper compares the predictions of radiotherapy demand derived from the Malthus model with those from the previous NRAG model [3], from the international literature and also with observed rates of use of radiotherapy in England as a whole as recorded in the radiotherapy dataset (RTDS) [13].

## Materials and Methods

We reviewed the evidence base for radiotherapy for each type and stage of cancer using national and international guidelines, meta-analyses, systematic reviews and key clinical trials [4,14]. We constructed evidence-based radiotherapy decision trees based on English local cancer incidence data from the National Cancer Intelligence Network. Cancer incidence data for the 3 years 2007, 2008 and 2009, accurate to the PCT level were curated and used to populate the model. The population served by PCTs ranged in size from 91 500 to 1 282 384. A 3 year dataset was used to provide an adequate incidence of cancer for even the smallest PCT [4,14]. We obtained details of stage and the use of surgery from the Eastern Cancer Registry and Information Centre [4,14].

Malthus is a discrete event simulation model of radiotherapy utilisation. It is available as a downloadable application; registration is required before it will run [15]. Age-stratified cancer registration data for each PCT or Cancer Network are used to establish a virtual population of cancer patients. Treatment events for each patient are encoded in the form of 22 tumour-specific decision trees, which can be downloaded with the supporting evidence base [16]. The trees encode evidence-based radiotherapy treatment practice accounting for both tumour factors (tumour type, stage and grade) and patient factors (type of surgery, fitness level). Each node in the decision tree stores the probability of transition from their parent node, a radiotherapy fraction burden and an evidence base reference (see Figure 1). Each virtual patient accumulates radiotherapy treatment fractions as they traverse the decision tree. In the proximal stages of the decision tree, the transition probabilities relate to the stage distribution of the tumour, values for which have been obtained from regional cancer registry data. The distal nodes encode treatment alternatives for a given tumour type and stage, together with the associated fraction burden. For some nodes the proportion of patients entering each of the alternative treatment arms depends on the performance status, patient choice and the role of surgery: appropriate values were established from national audits and expert peer-review [4,14].

To account for the stochastic nature of the simulation, 2000 iterations of the decision tree are carried out for each virtual patient identified in the curated incidence data. Summary statistics are collected for each tree for the final report. Re-treatment of patients for recurrent or metastatic disease increases radiotherapy workload, accounting for 18% of patients and 5% of fractions [8]. To take account of this we used audit data indicating the additional workload for each cancer site [8] and applied the appropriate figure as a multiplier after the calculation of radiotherapy demand for the first treatment for that cancer.

The output of Malthus is attendances, each defined as a visit for one or more fractions of radiotherapy, including multiple treatments to different parts of the body. It is an objective, consistent measure and is the same unit of measurement as that used by NRAG and by the RTDS [3,13,17]. A series of attendances is termed an episode: detailed definitions of this and other terms are provided in the Appendix [17].

To allow for future changes in the population size, and in tumour incidence through to the year 2031, the base cancer registration data can be modified. Malthus uses the Office of National Statistics 2008 population growth model [18] to produce age-stratified estimates of population growth, and the Cancer Research UK/Association of Cancer Registries model for changes in cancer incidence [19]. However, the model describes change for England as a whole and may not be correct for a particular locality if there are substantial differences in, for example, migration patterns or demographics.

Details of all radiotherapy administered in England over the three financial years 2009–2012 are now held in the English RTDS and some of these data have been published [13]. We have been provided with a summary of attendances and episodes by cancer diagnosis for the financial year