journal homepage: www.intl.elsevierhealth.com/journals/cmpb

An approach to plan and evaluate the location of radiotherapy services and its application in the New South Wales, Australia

Nagesh Shukla[a,*], *Rohan Wickramasuriya*[a], *Andrew Miller*[a,b], *Pascal Perez*[a]

[a] *SMART Infrastructure Facility, Engineering and Information Sciences, University of Wollongong, Wollongong, NSW 2522, Australia*

[b] *Illawarra Cancer Care Centre, Wollongong Hospital, Wollongong, NSW 2500, Australia*

ARTICLE INFO

Article history:
Received 22 April 2015
Received in revised form
17 July 2015
Accepted 3 August 2015

Keywords:
Radiotherapy services
Cancer
Location planning
Accessibility

ABSTRACT

This paper proposes an integrated modelling approach for location planning of radiotherapy treatment services based on cancer incidence and road network-based accessibility. Previous research efforts have established travel distance/time barriers as a key factor affecting access to cancer treatment services, as well as epidemiological studies have shown that cancer incidence rates vary with population demography. Our study is built on the evidence that the travel distances to treatment centres and demographic profiles of the accessible regions greatly influence the uptake of cancer radiotherapy (RT) services. An integrated service planning approach that combines spatially-explicit cancer incidence projections, and the placement of new RT services based on road network based accessibility measures have never been attempted. This research presents a novel approach for the location planning of RT services, and demonstrates its viability by modelling cancer incidence rates for different age–sex groups in New South Wales, Australia based on observed cancer incidence trends; and estimations of the road network-based access to current NSW treatment centres. Using three indices (General Efficiency, Service Availability and Equity), we show how the best location for a new RT centre may be chosen when there are multiple competing locations.

1. Introduction

Cancer control is a health priority. Cancer is estimated to be the leading cause of burden of disease in Australia in 2010, accounting for 19% of the total burden, and has a major impact on the Australian community, since one in three men and one in four women in Australia will be diagnosed with cancer by the age of 75. By age 85, the risk increases to one in two for men and one in three for women [1]. The proportion of elderly people in the population will steadily increase over the next decades due to increased life expectancy [2] and the 'baby boomers' ageing population is entering the high incidence period, thereby increasing the number of cancer cases.

Beyond demographic influences, other factors like socio-economic status and ethnicity have also an effect on cancer

* *Corresponding author*. Tel.: +61 2 4239 2329.
E-mail address: nshukla@uow.edu.au (N. Shukla).

http://dx.doi.org/10.1016/j.cmpb.2015.08.005
0169-2607/

incidence [2] along with geographical variations in the rate of treatment and survival from cancer [3,4]. As the number and diversity of cancer cases increase, the pressure on specialised treatment services will increase, calling for better planning and allocation of healthcare resources, particularly at the regional level.

Radiotherapy (RT) is an essential cancer therapy whether aimed at cure or palliation. The Collaboration for Cancer Outcomes Research and Evaluation (CCORE) literature-based findings were used by the Radiation Oncology Reform Implementation Committee (RORIC) to estimate that 52.3% of all diagnosed cancer cases in Australia would benefit from radiotherapy at some point after diagnosis. The Australian state health department uses this estimate for planning their RT services ([5,6,50]). Radiotherapy is considered to be most cost effective than surgery and chemotherapy, when all costs across the life cycle are considered [7]. According to the RANZCR, radiotherapy provides similar benefit with lower costs for cancer patient treatment for cures. RT generally costs about 6% of each health dollar spent fighting cancer, but it is a vital part of curing about 40% of all cured cancers. As radiation therapy is provided as an outpatient treatment service, the overall treatment costs are less than other treatments. In terms of effectiveness, an Australian study stated that external-beam radiation therapy is at least as effective as modern Australian surgical techniques [8]. It states that men with localised prostate cancer (≈30.0% of all new cancers in men) who are treated with external-beam radiation therapy have a cure rate of 95.5% for intermediate-risk prostate cancer and 91.3% for high-risk prostate cancer. Also, for breast cancer (≈28% of all new cancers in women) treatment studies conducted in Canada and Denmark, have shown a 9–10% improvement in overall survival at 10 years for patients that received radiotherapy compared with patients who did not receive radiotherapy [9,10]. Like these there are other studies which show better outcomes and cost-effectiveness for RT treatments for different types of cancer and their stages.

However, measured access to RT services has established that utilisation rates are well below this optimal number [11–14] clearly demonstrating the existence of barriers to access existing RT services. Currently, only 38% of cancer sufferers receive radiotherapy during their disease journey [2,15,16] indicating that ∼14% of cancer sufferers, miss the benefit from RT services that may improved cancer control and appropriate evidence-based management [2,15]. Since the proximity of RT facilities to home has been identified as a major factor enhancing accessibility to and utilisation of RT services [11,16], it is likely that remote and rural patients are facing limited accessibility to radiotherapy on the basis of inadequate transportation and lengthy travel. A literature review has highlighted travel as a perceived barrier to cancer treatment [17]. Several national and international studies supported the relation between travel distance from radiotherapy centres and uptake rates [18–21]; [49]; [22]; [23–25]). Although the configuration of centralised networks may be driven by resource efficiency savings, it has reflecting clinical need in rural and remote areas will appear less resource efficient [26].

Various studies have examined the effect of geographical accessibility, based on travel times/distances as proxy to travel effort, on uptake of RT based cancer treatment. For example, Madelaine et al. [27] reported lower treatment rates for rural lung cancer patients in France. Punglia et al. [28] found that increasing distance to the nearest radiotherapy centre was associated with a decreasing likelihood of receiving post-mastectomy radiation therapy. Greenberg et al. [29] asserted that lung cancer patients living at greater straight line distance from a specialist cancer centre, in rural USA, were significantly more likely to undergo surgery but were less likely to receive radiotherapy or chemotherapy than closer patients. Athas et al. [14] also found that breast cancer patients living further than 75 miles from a radiotherapy services centre were significantly less likely to receive radiotherapy than those living closer. It is possible that the detriment of transportation may be even more pronounced in patients who are faced with weeks of daily outpatient treatment, as is common for radiation therapy. Some recent studies have reported the location assessment for public healthcare facilities in US. Batta et al. [30] has used *p*-maxian model considering dispersion, population, and equity for obtaining the optimal locations of public facilities. Another study by Burkey et al. [31] has used location-based comparisons based on efficiency and equity to compare healthcare services in four US states. Our paper will use some of these indices (general efficiency, service availability and distance-based equity) to evaluate the potential RT service locations.

Recently, Gabriel et al. [32] presented the results from the data linkage study for radiotherapy utilisation rates in NSW and Australian Capital Territory (ACT) for years 2004–2006. They concluded that the radiotherapy utilisation rates decreased with increasing distance from patient's residence to the nearest RT facility ($p < 0.0001$). The study quantified RT rates ranging from 27% for patient living within 50 km of RT facility to 19% for patients living more than 400 km from the nearest RT facility. Recently, various studies (Shukla et al. [33,34]; Tyagi et al. [35]) have only focussed on within organisation (or hospital) level process improvements but have not considered patient accessibility measures for improvements.

The planning of efficient and accessible RT services for cancer care at regional level requires estimates of current and future cancer demand based on the spatial distribution and evolution of various socio-demographic groups, spatial accessibility based on transport network and probabilities of re-treatment. In this study, we will develop a modelling tool which can be systematically used for planning of radiotherapy services.

After detailing the data and methods used in the modelling effort, we will demonstrate how we have applied these modelling methods to plan and evaluate RT services in NSW.

2. Approach for planning of radiotherapy services

The proposed approach for modelling and predicting the future cancer incidences and their accessibility to existing RT centres in the state is visualised in Fig. 1, and involves datasets such as Australian Institute of Health and Welfare (AIHW) cancer incidence data, Australian Bureau of Statistics (ABS) population projection dataset, 1 km Australian