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Original Article

Who Should Bear the Cost of Convenience? A Cost-effectiveness Analysis Comparing External Beam and Brachytherapy Radiotherapy Techniques for Early Stage Breast Cancer

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Abstract

Aims: Standard treatment for early breast cancer includes whole breast irradiation (WBI) after breast-conserving surgery. Recently, accelerated partial breast irradiation (APBI) has been proposed for well-selected patients. A cost and cost-effectiveness analysis was carried out comparing WBI with two APBI techniques.
Materials and methods: An activity-based costing method was used to determine the treatment cost from a societal perspective of WBI, high dose rate brachytherapy (HDR) and permanent breast seed implants (PBSI). A Markov model comparing the three techniques was developed with downstream costs, utilities and probabilities adapted from the literature. Sensitivity analyses were carried out for a wide range of variables, including treatment costs, patient costs, utilities and probability of developing recurrences.
Results: Overall, HDR was the most expensive ($14 400), followed by PBSI ($8700), with WBI proving the least expensive ($6200). The least costly method to the health care system was WBI, whereas PBSI and HDR were less costly for the patient. Under cost-effectiveness analyses, downstream costs added about $10 000 to the total societal cost of the treatment. As the outcomes are very similar between techniques, WBI dominated under cost-effectiveness analyses.
Conclusions: WBI was found to be the most cost-effective radiotherapy technique for early breast cancer. However, both APBI techniques were less costly to the patient. Although innovation may increase costs for the health care system it can provide cost savings for the patient in addition to convenience.

Key words: Adjuvant radiotherapy; brachytherapy; cost-effectiveness; partial breast irradiation

Introduction

Breast cancer is one of the most common cancers in women [1] and with the increased use of screening mammography in developed countries most patients are diagnosed at an early stage. In the USA alone, over 200 000 women are diagnosed with invasive breast cancer each year [2], resulting in a major economic burden to both the patient and society.

In the 1980s, several randomised trials and meta-analyses established breast-conserving surgery followed by adjuvant radiotherapy as the gold standard treatment, resulting in the same survival as mastectomy with the advantage of conserving the breast [3,4]. With continued survival reaching 99% for localised disease [5], there have been many attempts to reduce the cost and inconvenience of this treatment. Several studies have tried to identify a subgroup of patients for which omitting radiotherapy might be safe, but apart from elderly patients with very small tumour size taking 5 years of Tamoxifen, most patients benefit from adjuvant radiotherapy at least in terms of locoregional recurrence [6–8]. More recently, studies have shown that the duration of whole breast irradiation (WBI) can be abbreviated from 6 to 3 weeks [9–11] and for well-selected cases the amount of breast tissue treated can be reduced [12,13]. This in turn has led to a further reduction in the number of radiation treatments in a technique called accelerated partial breast irradiation (APBI).

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Although the tolerance of the various APBI techniques has been or is currently being evaluated through phase III trials [14,15], limited information has been published regarding their cost or cost-effectiveness. In studies where cost or cost-effectiveness has been examined, costs are often derived using American billing codes and Medicare reimbursements [16–19]. Although this method produces an accurate depiction of the reimbursement received for each technique in the USA, it does not accurately represent the costs incurred, resulting in overestimation [20]. This inevitably limits the value of such studies for health care systems outside the USA.

The purpose of the present study was to generate an accurate estimation of the cost of radiation therapy for early stage breast cancer in a public health care system and subject the results to a cost-effectiveness analysis. Activity-based costing (ABC) was used to determine and compare the cost of three early stage breast cancer radiation treatment techniques focusing on brachytherapy APBI. Those techniques included standard external beam WBI delivering 50 Gy in 25 fractions, high dose rate brachytherapy (HDR) delivering 34 Gy in 10 fractions twice daily over 5 days and permanent breast seed implants (PBSI) delivering 90 Gy in a single treatment. Second, a Markov model was developed and used to analyse the comparative cost-effectiveness of the three techniques over a 15 year time horizon.

Materials and Methods

Treatment Costs

Health Care Costs

An ABC method based on the model outlined by Lievens *et al.* [21] was used to allocate health care resource costs to each of the three radiotherapy techniques. Each technique was broken down into a series of discrete activities, including new patient consultation, computed tomography simulation, preoperative assessment, treatment planning, radiotherapy delivery, physician review consultation and follow-up. Resource costs for each activity were divided into three categories: disposable materials, personnel and equipment. The costs of disposable materials (e.g. radioactive seeds) were obtained directly from the staff involved in purchasing and attributed directly to each applicable activity. Personnel and equipment costs were attributed to the different discrete activities before being summed to determine the total cost of each technique. Personnel costs included the Provincial Health Insurance (OHIP) reimbursements of physician fees. For all other staff (e.g. radiation therapists, nurses, clerical staff), the average wage listed on collective agreements was weighted by the time spent on individual tasks that went into the completion of each activity. Activity times were estimated using treatment appointment times and times established by the National Hospital Productivity Improvement Project for non-treatment activities. The activities included the planning, dosimetry, clerical and preparation steps, inclusive of treatment quality assurance but exclusive of tumour contouring, which was carried out by the physician and hence included in the OHIP fees. Equipment costs were estimated by dividing the total cost of each piece of equipment (e.g. linear accelerator) by the approximate lifespan of the equipment to determine the cost per year. This was then divided over the average number of uses per year (e.g. treatment fractions) to determine the cost per use. There was no attempt made to account for depreciation over time. The cost of service contracts and parts were added where appropriate. All costs are reported in 2013 Canadian dollars rounded to the nearest $100.

Patient Costs

Patient costs were calculated in four areas: time, travel, parking and pharmaceutical costs. Time costs were estimated by multiplying patient time spent in the clinic for each technique by the average hourly wage for women reported by Statistics Canada in 2013 ($22.32/h) [22]. To estimate travel costs, an average one-way travel distance of 38 km was calculated based on the travel distance for patients undergoing cancer treatment reported by three previous studies [23–25]. This was multiplied by the Canada Revenue Agency travel allowance for 2013 ($0.54/km) [26] and summed over all appointments for each technique. Parking costs were calculated by multiplying the time spent in clinic for each technique by the hospital parking rate at our institution ($4.75/30 min). Pharmaceutical prescriptions were extracted from our patient database or from the treatment guidelines. The costs of pharmaceutical prescriptions (e.g. skin cream, pain medication) were obtained from the clinic pharmacy and attributed directly to the applicable techniques.

Markov Analysis

A Markov model was developed using the TreeAge Pro© software platform (TreeAge Software Inc., Williamstown, MA, USA). The model was constructed to simulate the clinical history of a cohort of 60-year-old breast cancer patients diagnosed with stage I disease (T1N0) over a 15 year time horizon (Figure 1). All patients begin in a cancer-free state having undergone breast-conserving surgery and a radical course of radiation therapy using one of the three techniques under study (WBI, HDR or PBSI). Patients progress through the model by transitioning between various possible health states, including the continuation of the cancer-free state, local recurrence in the same quadrant of the breast, elsewhere failure, distant metastasis and death. Utilities and probabilities of transitioning from one health state to another, including the background mortality, ipsilateral or elsewhere recurrence for WBI and APBI, distant metastases, death, were taken from several key publications reporting breast cancer outcomes from large randomised trials, which are listed in Table 1. All downstream costs were obtained from the literature, converted to Canadian dollars and adjusted for inflation [27]. Using estimates from Karnon *et al.* [27], which looked at resource use and the resulting health costs for treatment of breast cancer recurrences, we assumed the costs were higher in the first years after

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