Cost of radiotherapy

The cost of radiation therapy
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Abstract

Background and purpose: The rising cost of health care is of universal concern. If the cost effectiveness of conventional and novel radiotherapeutic strategies is to be established we need to have confidence in our estimates of both cost and effectiveness. The purpose of this study is to explore the degree of consistency of recently published cost estimates for radiation therapy.

Methods and materials: Eleven publications form the basis of this analysis. From each study we have estimated the cost of a 21 fraction course (when possible) of radiation therapy. The costs have been decomposed into the three inputs: process, clinical infrastructure and supporting infrastructure. We have also investigated the time course of radiation therapy costs over the last two decades.

Results: From the latest four studies we conclude that the cost of a 21 fraction course of radiation therapy is 3239 € ± 566 €. The percentages of this total spent on process, clinical infrastructure and supporting infrastructure over the last 15 years are 54, 29 and 17, respectively. The real increase in the cost of radiotherapy over the last 15 years is estimated to be approximately 5.5%.

Conclusion: Cost estimates for radiation therapy appear to be converging. However, we will need far more sophisticated analyses in the future if we are to establish the cost effectiveness of the newer treatment strategies currently under active clinical investigation.

Keywords: Radiation therapy; Cost; Economic analysis

The rising cost of health care is a cause for concern across the globe: cancer care, and radiation therapy in particular, are no exceptions. If the radiation therapy community is to contribute to the responsible use of limited health care resources it needs to develop a clear understanding of the cost effectiveness of this treatment modality in all the clinical situations in which it is employed. This point has been recently reinforced by Drummond and Mason [2] in the context of systemic cancer therapy. Effectiveness can be established through clinical trials or possibly through dosimetric predictors of outcome [15]. In principle, establishing the cost of radiation therapy should be easier and quicker than establishing effectiveness. However, in an analysis published in 1991, Goddard and Hutton remarked that the variation in cost estimates available at that time for radiation therapy was huge [7]. We revisit the issue of the cost of radiotherapy to see if any convergence of estimates has occurred over the intervening years.

This study examines and compares the cost of radiation therapy as presented in eleven published studies from Europe [1,6,8,10–13], North America [4,14,18,19] and Oceania [17]. Our costing framework groups the conventional economic resource categories [3,9] in a way which is helpful in identifying cost origins and illuminating the similarities and differences between published estimates.

Materials and methods

This analysis is based on publications in the open literature dated between 1981 and 2004. In December 2006, we performed a systematic search using the electronic database, Pub Med. The keywords used for performing the search were economic evaluation; cost, radiotherapy. The analysis which follows incorporates not only relevant articles identified during this search, but also further publications from the references and bibliography of the articles found by the Pub Med search. The eleven publications selected as being directly relevant to this study have used eleven different approaches which makes a comparison challenging. Some have calculated cost per patient, frequently with an unclear number of fractions. Some have used cost per fraction although the cost per course does not scale linearly with this quantity [7,16]. Two papers used
We also encountered the difficulty noted by Goddard and Hutton of a lack of clarity about which cost components were included and which were not in many of the published studies [7]. Acknowledging these difficulties, we have made our best estimate of the cost of a 21 fraction course of treatment given the data provided in these eleven publications.

Understanding the origins of the costs of radiation therapy may not only elucidate the reasons for differences between published estimates but will also be necessary for future studies of process and technological changes. For simplicity we have classified the resource inputs in one of three categories: process costs, clinical infrastructure costs and supporting infrastructure costs. Fig. 1 illustrates the relationship between this classification scheme and that usually employed in economic analyses, viz. land, capital and, labour [3].

The three cost categories used here will now be explained.

Process costs include those resources which are specific to, and can be identified with, a particular patient. Process costs include, for example, a radiation therapist’s or treatment planner’s time when dealing with one patient, any consumables required for that patient’s care and any patient specific quality assurance (QA) such as a chart check. Consumables can be, for example, the contrast required for a patient receiving a planning CT scan or a shell for the treatment of a specific patient for head-and-neck cancer. Patient specific QA is assuming greater importance as techniques such as IMRT and IGART become more widespread.

Clinical infrastructure encompasses those capital and human resources related to any equipment, procedures, protocols or data used in radiation therapy for all or a subgroup of patients. Clinical infrastructure costs include the capital cost, service and maintenance of equipment as well as the cost of commissioning and on-going quality control of equipment.

Supporting infrastructure refers to those resources that are required for any organization to function and are independent of the purpose of the organization. This includes maintenance of the building, for example, as well as any overhead administrative costs such as finance and human resources departments.

The various costs presented in the eleven studies included in this analysis were collated into the three cost categories described above. In order to be able to compare the cost per course of these eleven studies, we made the assumption that, on average, a patient would receive 21 fractions per treatment [19]. The cost per course presented in this paper was calculated directly from the figures given in the studies and normalized to 21 fractions per treatment (where possible) and, when necessary, to 3 fields per fraction.

The costs presented below are computed in 2005 euros taking into account the cumulative inflation rate, based on the consumer price index of the currency of the relevant country.

We are aware of the study by van der Giessen et al [18]. However, this study was excluded because the large variation of resources between countries made it very difficult to compare to the 11 other studies.

Data sources

Greene [8] was one of the first to give an estimate of the cost of radiation therapy. The salaries of radiation oncolo-
gists were excluded as were costs associated with administration, service and maintenance of the building and overheads. Depreciation and interest charges related to the equipment and building were considered. Excluding beam direction shells, the cost per fraction on a 4 MV accelerator is estimated at £12 (in 1981 sterling). Some of the cost figures, for example those for simulation, were prorated from fully utilized equipment so economies of scale would be present in this analysis. With the caution noted previously, we may deduce that a 21 fraction course of treatment would be approximately £252 (and £322 with a shell) in 1981 sterling.

Atherton [1] replied to Greene in a publication two years later. He presented an evaluation of the cost of radiation therapy based on the cost of setting up a department by Philips Medical Systems®. This author made a more rigorous estimate of equipment and building costs, included the salaries of radiation oncologists and included more supporting infrastructure costs. Atherton’s cost estimates are based on a two megavoltage facility with contact therapy, orthovoltage, simulation and planning. The cost per patient was estimated to be “around £484 [in 1983 sterling] for treatment regimes using a higher number of fractions…” It is unclear as to whether this cost estimate applies only to linear accelerator treatment or is an average over two linear accelerators, contact and orthovoltage therapy.

In 1985, Wodinsky and Jenkin [19] calculated the cost of radiation therapy in Canada. Their estimate came to $2583 per patient in 1985 Canadian dollars for 21 fractions. It appears that all process, clinical and supporting infrastructure costs have been included although Equivalent Annual Costs have been approximated. Their cost estimate for a course is again based directly on cost per fraction with the approximations that entails.

The cost of 21 fractions of radiation therapy as estimated by Goddard et al. [6] was £777 (in 1989 sterling). The analysis was rigorous and thorough within the inherent uncertainty of allocating resources, such as radiation oncologists, to different functions. Costs per fraction were averaged over a large centre so economies of scale would have been in effect. The cost per patient was again computed from a calculated average cost per fraction and these authors point out the shortcomings of this method of calculation.

The figure (£56/fraction in 1990 sterling) given by Penn [13] is higher by 45% than the one calculated by Goddard (£37/fraction in 1989 sterling). In his study, Penn compared the cost of radiation therapy from a one accelerator centre to a much larger operation and hence much of the difference in cost is likely due to the difference in size of the cancer centres and the relative number of patients treated per year and per linear accelerator. The number of referrals to the Torbay facility was 505; we assumed that 50% (252) of these patients received radiation therapy.

Perez et al. [14] calculated the cost per procedure. Three different procedures were considered: simple, intermediate and complex. Activity based costing was employed in this study. However, no details were given on how many fractions were delivered in each of these procedures. We have used their data to estimate the cost for an intermediate procedure including physician activities (consult comprehensive, treatment planning, simulation intermediate, wkly mgt intermediate, completion of therapy), physics and dosimetry (simulation intermediate, isodose intermediate, basic dosimetry, devices intermediate) and technical (rad tr del intermediate, treatment port film). The total cost came to $2483 in 1991 US dollars.

Smith et al. [17] calculated the cost of radiation therapy in New South Wales, Australia. All the necessary cost inputs seem to have been included in this study with the output being cost per field ($69/field in 1991 Australian dollars (AUD)). With costs based on a facility utilizing 3.17 accelerators, economies of scale should have been realized. With the assumption that the average number of fields per patient was 3, the estimated cost per patient for 21 fractions was the highest of all studies (AUD 4347). However, Smith’s costs scale directly with the number of fields per fraction. If the number is 2.5, and not 3 as we have assumed, then the cost per course drops to AUD 3623 in 1991 AUD. On the other hand, if the number of fields per fraction is 3.5, as suggested by Gabriele et al. [5], then the cost per course increases to AUD 5071 in 1991 AUD.

In 1996, Kesteloot et al. [10] estimated the cost of radiation therapy provided in accordance with Belgian accreditation requirements and based on the number of patients treated per year. All the relevant cost inputs seem to have been included. With maximum economies of scale the cost per patient is estimated to be 2324 € in 1996 euros at the time of the study. It is not clear what the average number of fractions per patient was.

Dunscombe et al. [4] provided an economic evaluation of radiation therapy treatment using activity based costing. All activities and cost inputs were included in this study. These authors estimate the cost per 18 fraction course of treatment to be $3889 ($4125 for 21 fractions) in 1997 Canadian dollars at the time of the study.

Lievens et al. [11] also used activity based costing. These authors also appear to have included all relevant cost inputs to arrive at a cost of a course of radiation therapy of 2575 € in 2000 euros. This estimate, which was averaged over a variety of fractionation schedules, has been used here.

The study by Norlund [12] was based on a questionnaire sent to all 16 cancer centres across Sweden. It was not possible to differentiate between the costs of the various professional groups and, hence, data from this study are not presented in Fig. 4. A cost per field (530 SEK in 2000 Swedish crowns) was determined in this study. As for Smith’s study [17], costs scale directly with the number of fields per fraction. If the number is 2.5, then the cost per course drops to SEK 27,825 in 1991 SEK and if the number increases to 3.5 fields per fraction, as suggested by Gabriele et al. [5], the cost per course increases to SEK 38,955 in 1991 SEK. Overall, the cost of radiation therapy (21 fractions and 3 fields per fraction) in Sweden was 33,390 SEK, which is of the same order of magnitude as Lievens et al. [11] and Dunscombe et al. [4].

The most recent study considered was that by van der Giessen et al. [18]. In this study, the cost of radiation therapy was calculated for 11 countries around the world. The large variation for all resources between developed and developing countries makes a comparison of the cost of radiation therapy between these countries particularly diffi-
cult. Only delivery was included in this economic evaluation. For these reasons, we decided to exclude this study from the analysis presented in this paper.

The conversion of the cost of radiation therapy for all these studies was calculated by correcting for the inflation of the country concerned and converting the currency to 2005 €.

Results

Fig. 2 shows, in histogram form, the cost, in 2005 euros, of a course of treatment of 21 fractions, when normalization was possible, for each of the eleven published studies. The large variation noted in a previous analysis is again observed here [7]. However, we are beginning to observe a degree of convergence. The mean and standard deviation of the latest four studies is 3239 € and 566 €.

Fig. 3 shows our evaluation of the percentage of the total costs attributed to process, clinical infrastructure and supporting infrastructure. A reasonable degree of consistency, particularly for the later studies, is observed here. Table 1 shows the same information but with the absolute cost of each category (in 2005 €).

In performing this comparative analysis, a significant difference between the published data seemed to arise from the differences in the salary costs of the various professional groups involved in radiation treatment. Fig. 4 shows the costs of medical and scientific/engineering human resources normalized to those of radiation therapists. The breakdown of salaries between staff categories was not available in three of the studies [11, 12, 14].

Fig. 5 shows the historical evolution of the inflation corrected cost of radiation therapy between 1981 and 2001. A weak correlation ($R^2 = 0.42$) was observed from the last four fitted data. However, an increasing cost trend is apparent with an average percentage increase of 5.5% in the past 12 years ($R^2 = 0.59$).

It is to be noted that the cost per course calculated in this paper from the data of Smith et al. [17] and Norlund [12] scales directly to the number of fields per fraction. The impact of this scaling of the cost of a course has been discussed above.

Discussion

The data presented in Fig. 2 show a considerable variation in the estimates of the cost of a course of radiation treatment from these eleven studies. In performing this analysis, we once again encountered the difficulties discussed by Goddard and Hutton [7]. Within the limitations imposed by the general paucity of detail in the publications forming the basis of this analysis, a degree of convergence of the cost estimates is observed particularly for the four studies reported in the past 15 years. With a mean and standard deviation of 3239 € and 566 € (2005 euros) our knowledge of the cost of radiation therapy would appear to be improving.

One possible explanation for the variability in cost estimates is differences in patient throughput on a treatment machine. Examination of this possibility yielded a weak relationship between cost and throughput ($R^2 = 0.59$) over all eleven studies included in this analysis.

From Fig. 2, there is also an indication that the cost of radiation treatment has increased steadily over the period encompassed by these eleven studies. The data of Fig. 2 are reformatted and presented in Fig. 5 which shows a weak correlation between cost and time ($R^2 = 0.59$). As all numbers are in 2005 euros, the effect of inflation as measured by the Consumer Price Index has been removed. The average rate of cost increase over all eleven studies is 4.0%.

![Fig. 2. Cost per patient (in 2005 euros) for the eleven studies included in this analysis.](image)
Fig. 3. Percentage of the total cost of radiation therapy per 21 fraction course attributed to the resource categories used in this study.

Table 1

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<td>776</td>
<td>428</td>
<td>436</td>
<td>1640</td>
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<td>352</td>
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<td>377</td>
<td>532</td>
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<td>736</td>
<td>585</td>
<td>2677</td>
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<td>681</td>
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<td>874</td>
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Fig. 4. Radiation Oncologists and Medical Physics/Engineering staff costs normalized to those of Radiation Therapists.
For the last four studies it is 5.5%. Particularly during and since the early 1990s increasing customization of radiation therapy has taken place, with IMRT being an example. Increasing customization has been made possible by the availability of new, technologically advanced equipment together with the human resources required to effectively utilize these new approaches.

In spite of the large range of total costs per course, the proportion of the total arising from process, clinical and supporting infrastructure components does exhibit increasing consistency, Fig. 4. The resources included in each of the eleven studies are outlined in the section above on Data Sources. With the exceptions noted there, all these studies included the major components of a valid economic evaluation of radiation therapy treatment. Thus, within the scope of this analysis it is not possible to attribute the slowly increasing cost of radiation treatment observed in Fig. 5 and Table 1 predominantly to one of the three cost components (Fig. 1).

The relative cost of medical staff compared to radiation therapists (Fig. 4) may be an explanation of Wodinsky and Jenkin’s [19] relatively high estimate of the cost of process. However, Kesteloot et al. [10] also present a relatively high cost estimate of medical staff: yet their total cost of a course is in line with other estimates of that time period [4,17].

Although our analysis has demonstrated a convergence in cost estimates in recent years, which was not present in an earlier study [7], we now need to move towards a more structured approach to costing in radiation treatment. With increasing emphasis on evidence based medicine, it is incumbent upon practitioners to demonstrate that the incremental costs of new technologies and treatment strategies can be justified in terms of improved outcome. Determining outcome in radiation therapy is, in itself, difficult. A far more tractable problem is the development of the tools necessary to quantify the incremental costs of new techniques and strategies. The most appropriate methodology for studying the financial impact of proposed technology and process changes is likely to be activity based costing. This approach has been adopted by very few authors [4,11,14,16]. The power of activity based costing lies in the fact that it allows the inclusion or exclusion of particular steps in the process, such as IMRT or portal verification. Different fractionation schedules can also be modeled without resorting to the very poor approximation that cost scales linearly with the number of fractions [16]. With a well-configured activity based costing model, the financial impact of increased quality assurance efforts resulting, for example, from the current, and appropriate, emphasis on patient safety could also be quantified.

Conclusion

The estimates of the cost of radiation therapy in six developed countries show significant variations, especially in the earlier studies. Based on the data from the latter four studies (excluding van Der Giessen et al. [18]), the average cost of a course of radiation therapy in recent years was 3239 ± 566 €. The distribution of the total cost between the three factors of production used here shows increasing consistency. The average percentages of the total cost of a course spent, respectively, on process, clinical infrastructure and supporting infrastructure were 54%, 29% and 17%. More detailed and explicit analyses of radiation therapy costs are required if the cost effectiveness of conventional and emerging treatment strategies is to be established.

Acknowledgement

The financial support of the Translational Research Training in Cancer Fellowship Program is gratefully acknowledged.
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Received 13 February 2007; received in revised form 6 January 2008; accepted 6 January 2008; Available online 30 January 2008

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