Outpatient care does shift the costs of relatively fixed "hotel" services to the patient and family. For example, in our study the outpatient fixed per-diem rate was $109.07 less than the inpatient rate. The cost implications for patients who receive outpatient care are relatively small; the average incremental nonmedical cost to patients and their families of outpatient chemotherapy was estimated in 1984 to be US$72.81 per week of active treatment and US$45.88 per week of nonactive treatment.[8] Patients benefit by being closer to their support group. The facility benefits by being able to treat more patients owing to reduced hospital service costs.

Conclusion

Our results indicate that outpatient administration reduces the total cost of chemotherapy. Hospital administrators, clinicians and pharmacists involved in the use of chemotherapy should be encouraged to undertake a similar examination to better define the implications of marginal increases in the oncology case load. The implications of incremental cost increases in certain types of cancer cases can be drawn in relation to the total chemotherapy drug budget requirements, which will facilitate appropriate planning. In light of this, alternative, equally effective but less expensive treatment regimens should be considered when possible.

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The cost of radiation treatment at an Ontario regional cancer centre

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The cost of radiation treatment in 1985 at an Ontario regional cancer centre accruing 2500 new patients annually was examined. The radiation treatment department was equipped with three high-energy treatment machines, a treatment simulator and a treatment planning computer and was appropriately staffed. The total average annual cost of operating one high-energy treatment machine was $668 963. Salaries and employee benefits accounted for 78% of the costs. An average of 5439 radiation treatments were given annually with each treatment machine, at a cost of $123 per treatment. The cost of a curative course of radiation treatment (average of 21 treatments) was $2583, and the cost of a palliative course (average of 7 treatments) was $861.

Examen des coûts de la radiothérapie en 1985 dans un centre anti-cancéreux régional ontarien recrutant chaque année 2500 nouveaux malades. Ce centre possède trois puissants appareils thérapeutiques, un simulateur, un ordinateur servant à l'établissement des plans de traitement et un personnel suffisant. Le prix annuel du fonctionnement d'un des appareils est 668 963 $.

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Les salaires et avantages sociaux du personnel rendent compte de 78% des coûts. Chaque appareil a servi à une moyenne de 5439 traitements dans l'année, soit un prix unitaire de 123 $. Une cure thérapeutique (une moyenne de 21 séances) coûte 2583 $ et une cure palliative (une moyenne de 7 séances) 861 $.

Radiation treatment is one of the cornerstones of current cancer therapy. Patients with cancer (excluding skin cancer) in Ontario Cancer Treatment and Research Foundation (OCTRF) regional cancer centres received 123 935 treatments during 12 775 courses of radiotherapy given by 23 high-energy treatment machines in 1985 (unpublished data, 1986). In addition, 83 363 treatments were given in 1984–85 at Princess Margaret Hospital, Toronto, the treatment centre of the Ontario Cancer Institute.[1] Despite this large volume of work in a "high-tech" specialty, no studies are currently available on the cost of radiation treatment in Canada. With the shrinking health care dollar and increasing pressure for cost-effectiveness, there has been a growing awareness by administrators and oncologists in regional cancer centres of the need to review the cost implications of radiation treatment. In this article we review the available data on the cost of radiation treatment at the Toronto–Bayview Regional Cancer Centre in 1985.

Description of the centre

The Toronto–Bayview Regional Cancer Centre is an outpatient cancer treatment and research facility affiliated with, and located on the grounds of, Sunnybrook Medical Centre, a 1190-bed tertiary care teaching hospital operated by the University of Toronto. The cancer centre is funded by the OCTRF, a nonprofit organization whose mandate includes the operation of regional cancer centres in Ontario. The centre provides all radiation-treatment services for a joint oncology program in conjunction with Sunnybrook Medical Centre. In 1985 the cancer centre had three high-energy radiation-treatment machines, one cobalt unit and two linear accelerators. The total number of radiation-treatment visits in 1985 was 16 317.

For the purposes of this review it will be assumed that one high-energy treatment machine operating 8 hours per day has 7.5 hours of effective treatment time, since technologists must, under existing provincial legislation, take a lunch break as well as two other breaks. Since the average duration of treatment is 15 minutes, the potential number of treatments per day is 30. Excluding weekends, statutory holidays (11 days per year), scheduled downtime (12 days) and estimated unscheduled downtime (5 days), there are 232 treatment days annually. Therefore, there are potentially 6960 treatments per machine each year. Because of cancellation of appointments and unscheduled machine downtime it is unlikely that the potential number of treatments could ever be achieved. The treatment machines at the cancer centre operated at 78% of the potential load for the hours of operation in 1985, and an average of 5439 treatments were given per machine.

Cost calculations

The following costs were included in the calculation of direct and indirect costs of radiotherapy: salaries of direct care staff, professional fees and salaries of radiation oncologists, allocated salaries of support and technical staff, employee benefits (at 14% of salary costs), allocated or assigned costs of supplies and other expenses, and depreciated costs of major equipment and construction. Straight-line depreciation was used for estimating the annual cost of major equipment and construction. This reflected the provincial government's remuneration scheme for regional cancer centres. It would obviously not be appropriate to use this method in proprietary health care environments, where the funding system differs. The amount noted reflects depreciation, not interest due on loans for equipment. It was also assumed in all calculations that the primary purpose of staff whose tasks or functions were a direct or indirect result of radiation treatment was in service; hence, the costs of education and research time were not included. This is admittedly a flaw, but because of the variability it was felt to be appropriate. Each facility using radiation treatment must determine what proportion of available time can be allotted to education and research. The costs of overhead (e.g., utilities), administrative department supplies, stationery supplies, diagnostic services and room modifications other than for the high-energy treatment machines were not considered in the calculations.

Salaries and benefits

Radiation technology: The costs of providing radiation treatment are most readily identified in the department directly responsible for the technical component of the physician's treatment decision, the Department of Radiotherapy. The department consists of radiation technologists, who operate the treatment machines. In 1985 each treatment machine was staffed by an average of 2.5 full-time-equivalent (FTE) technologists. The associated treatment simulator and the mould room had two FTE technologists each. The total remuneration of radiation technologists in 1985 was $397 995, including 14% benefits, or $132 665 per treatment machine.

Medical physics: The responsibilities of the Division of Medical Physics include quality assurance of all treatment and treatment planning

machines, the technical aspects of repair (the centre has no maintenance contracts on treatment machines, finding it less expensive and more expedient to provide the services) and dosimetry. The centre had three FTE physicists, two FTE dosimetrists, two FTE mechanical technicians and two FTE electrical technicians in 1985. After discussion it was estimated that approximately 33% of the physicists' time, 50% of the mechanical technicians' time, 90% of the electrical technicians' time and 100% of the dosimetrists' time was spent in treatment planning, preventive maintenance, quality assurance and repair of the three treatment machines and simulator. It is estimated that the total remuneration for the division, including 14% benefits, was $215 688, or $71 896 per treatment machine.

Nursing: The centre practises primary nursing in all areas of treatment and follow-up. In 1985 it employed two registered nurses as primary radiotherapy nurses and one registered nursing assistant as a nursing aide. The total remuneration for nursing staff, including 14% benefits, was $90 348, or $30 116 per treatment machine.

Radiation oncology: Radiation oncologists employed by the OCTRF are not permitted under the existing provincial regulation to bill the Ontario Health Insurance Plan (OHIP) for radiation-treatment planning or treatment. The OCTRF remunerates its radiation oncologists for the technical aspects of radiation treatment through salary. If radiation oncologists were permitted to bill OHIP, the total annual billing from one treatment machine and the associated treatment planning would be approximately $126 498.

Radiation oncologists do bill OHIP for patient consultations (maximum of one per patient per year), partial assessments (approximately one per patient per week during treatment) and any general medical intervention or procedure. Annual billings for consultations and partial assessments per treatment machine were approximately $39 375 and $25 938 respectively, for an annual total fee cost of $195 939. We estimated that each course of treatment required an average of 3 hours of time by a radiation oncologist in treatment planning, conferencing and other areas of indirect care. Given the 1985 hourly rate for radiation oncologists of $36, including 14% benefits, the total amount of radiation oncologists' salaries attributable to preparation for and the technical components of radiation treatment was $470 340, or $156 780 per treatment machine. The total remuneration for radiation oncologists was therefore $666 279, or $222 093 per treatment machine.

Other salaries: Administrative overhead, such as the operations of the finance, health records, dictation and reception departments, must also be considered. Since 52% of the patient visits to the cancer centre in 1985 were for radiation treatment, it is reasonable to propose that one-third of 52% (17.3%) of these departments' resources be designated as required for the annual operation of a treatment machine. This assumes no fixed costs in departmental operations. The total staff cost, including 14% benefits, was $204 591, or $68 197 per treatment machine.

Depreciation on equipment and construction

The equipment expense was calculated on the average 15-year depreciated cost of major high-energy treatment machines; initial capital costs were for one 25-MeV linear accelerator ($1.5 million), one cobalt treatment machine ($250 000) and one 6-MeV linear accelerator (approximately $750 000). The treatment planning simulator $400 000) and treatment planning computer ($250 000) were depreciated over 15 and 10 years respectively. The total average annual depreciation of a high-energy treatment machine or the depreciation attributed to its use was $72 778.

The cost of constructing a treatment machine bunker of a concrete and ilmenite mixture approximately 1.2 m thick was estimated to be $250 000, not including the door, which cost $50 000. The cost of furnishings for the room was approximately $10 000. The useful life of a treatment bunker in Ontario has been 30 years without major modification. In all cases known to us, treatment rooms have outlived the buildings in which they are located. The annual depreciation of the bunker over 25 years and the furnishings over 10 years was estimated to be $13 000.

Supplies and other expenses

The cost of supplies was estimated through random surveys and discussions with the users and can be categorized as the average annualized cost of replacement parts for a major treatment machine over the useful life of the machine ($32 150), the annualized cost of parts for one major machine overhaul during the machine's useful life ($4000), the cost of a proportion (one-third) of photographic film for the simulator ($2500), the costs of allocated mould room materials and general therapeutic supplies for radiation treatment ($4333), the average annualized cost of replacement parts for a treatment simulator over the useful life of the machine ($1500) and the average annual cost of the maintenance contract for the treatment planning computer ($5667) and the treatment machine control computers ($568). Cobalt source replacement is required every 3 to 5 years, at a cost of approximately $30 000. The total average annual cost of supplies per treatment machine was $58 218.

Total costs

The total average annual cost in 1985 of operating one high-energy treatment machine, in-

cluding allocated treatment planning expenses, was $668 963 (Table I). Salaries and benefits accounted for 78% of the costs. The average cost per treatment for the 5439 treatments per machine given in 1985 was $122.99, or $860.93 for a palliative course (average of 7 treatments) and $2582.79 for a curative course (average of 21 treatments). The corresponding costs, assuming the potential 6960 annual treatments per machine, would be $96.12, $672.84 and $2018.52. The total estimated amount spent on all radiation treatments accounted for approximately one-third of the centre's total operating budget in 1985–86. The total cost of a course of treatment does not include transportation expenses. Most patients treated (approximately 80%) were ambulatory. The costs of radiation treatment for inpatients would be considerably higher, given the per-diem rate (approximately $490). In 1985 there were, on average, 126 inpatients receiving radiation therapy per high-energy treatment machine. The average length of stay for an oncology inpatient at Sunnybrook Medical Centre was 15.7 days. The associated per-diem charges were approximately $970 000.

Discussion

The average cost of radiotherapy per treatment has been calculated by several investigators,[2-6] most of whom used 1981 data. The reported costs, from England, Australia and the United States, range from approximately $20 to $110 in equivalent constant (i.e., noninflated) Canadian dollars. A recent US study revealed the cost of external-beam radiotherapy to be approximately $162 US per treatment.[7] However, no single method has been established for cost analyses of radiation treatment, which makes comparisons difficult. Our estimate tends to confirm the previous findings.

The cost of radiotherapy per treatment within a given centre will vary. For obvious reasons of capital expense depreciation the cost of radiation treatment with a new high-energy linear accelerator is higher than that with an older, partially depreciated high-energy treatment machine. As the volume of patients increases for all treatment machines, the cost per treatment would be expected to decrease owing to economies of scale. Fixed costs can also be reduced: treatment planning computers are capable of addressing the demands of a relatively large department if the operating software is modified. In our experience, however, the simulator can accommodate only three treatment machines; the ratio of treatment planning to radiotherapy visits has been relatively constant since 1982, at 1:8. One simulator can accommodate 12 to 17 visits per day.

The Toronto–Bayview Regional Cancer Centre operated a medium-sized, appropriately equipped and staffed radiation-treatment program in 1985 and, in our opinion, made efficient use of its fixed resources. We feel that the observed estimates of the cost of radiation treatment are neither conservative nor excessive but, rather, reflect the requirements of providing an appropriate facility in Canada.

Table I — Cost of operating a high-energy treatment machine for radiotherapy at the Toronto–Bayview Regional Cancer Centre in 1985

	Cost, $	
Salaries and benefits	524 967	
Radiation technology		132 665
Medical physics		71 896
Nursing		30 116
Radiation oncology		222 093
Other		68 197
Depreciation on capital	85 778	
High-energy treatment machines		55 556
Treatment simulator		8 889
Treatment planning system		8 333
Construction		13 000
Supplies, other expenses	58 218	
Supplies		51 965
Maintenance contracts		6 253
Total	668 963	

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