The generation of two specific cancer costing algorithms using Ontario administrative databases

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ABSTRACT

Cancer treatment and management have become increasingly economically burdensome. Consequently, to help with planning health service delivery, it is vital to understand the associated costs. Administrative databases can be used to help understand and generate real-world system-level costs. Using databases to generate costs can take one of two approaches: top-down or bottom-up. Top-down approaches disaggregate the total health care spending from a global health care budget by sector and provider. A bottom-up approach begins with individual-level health care use and its costs, which are then aggregated.

Key Words Costing algorithms

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RATIONALE

Cancer treatment and management have become increasingly economically burdensome. Consequently, to help with planning health service delivery, it is vital to understand the costs associated with cancer treatment. Administrative databases can be used to help understand and generate real-world system-level costs. Using databases to generate costs can take one of two approaches: top-down or bottom-up. Top-down approaches disaggregate the total health care spending from a global health care budget by sector and provider. A bottom-up approach begins with individual-level health care use and the associated costs, which are then aggregated.

In Ontario, health care administrative databases allow for the construction of bottom-up approaches to calculate patient-level use of health care encounters. Wodchis and colleagues developed a method to compute individual-level health care costs in the province of Ontario—hereinafter referred to as the Patient-Level Case Costing Methodology (plccm)—from data available in administrative databases. Briefly, the cost of services that are episodic in nature are estimated using a cost per weighted case method, and the cost of services that are reported by visits or claims are more directly obtained. A number of studies have used and validated the plccm to estimate the costs of various diseases across the continuum of care.

In the field of cancer care, the plccm does not allow for a robust estimate of the costs for the some of the key components of cancer treatment—namely, systemic chemotherapies or cancer-related supportive medications. Furthermore, it does not offer comprehensive information for radiation planning and treatment costs. Finally, it does not attribute costs to oncology-specific care and non-oncology care because it measures costs of all resources regardless of indication. Consequently, the plccm underestimates the health system costs associated with cancer management.

For more specific, comprehensive cancer costing evaluations, we created, with funding from the Ontario Institute of Cancer Research, two oncology-specific costing methods: one for cancer-related medications [the cancer medication costing algorithm (cmca)] and one for radiation treatment [the cancer radiation costing algorithm (crca)]. Here, we illustrate the components of those oncology-specific costing methodologies through a worked example in which we compute the costs in year 1 after diagnosis for a cohort of women with breast cancer by stage of disease. The objectives of the present work were both to describe the structure of the two algorithms and to illustrate their application to a specific cancer cohort.

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METHODS

We used a bottom-up approach to determine cost of treatment at the level of the individual patient encounter. Where individual-patient health sector costs were not available (for example, for system or institutional costs), a top-down approach was then used to allocate aggregated costs to each patient encounter. Direct treatment costs are calculated from the perspective of the Ontario public health care payer; costs incurred by the individual patient or private insurers are not addressed. Person-level data for treatment encounters are available in province-wide administrative databases maintained by the Ministry of Health and Long-Term Care, the Canadian Institute for Health Information, and Cancer Care Ontario. We used a method similar to the one published by Wodchis et al., which extracted patient use of resources from a number of administrative database sources and used provincial-level costing (2017–2018) applied to those resources to generate a cost per patient. All datasets were linked using unique encoded identifiers and were analyzed at ICES.

The CMCA

Ontario has a complex system of medication databases that record the scope and cost of cancer-related medications used. Three separate and sometimes overlapping databases—the Ontario Drug Benefit (odb), which contains records of outpatient oral and injectable medications for individuals more than 65 years of age or on social assistance; Activity Level Reporting, which contains records of systemic chemotherapies; and the New Drug Funding Program (ndfp), which contains records of newer, expensive cancer agents both oral and intravenous—were used to understand drug administration. A medical oncologist and a pharmacist reviewed the cancer medications in each of the databases and grouped them by whether they were indicated for treatment or supportive use. Because prescriptions and medication information might be duplicated in the three drug databases, a hierarchy was implemented to avoid duplication. For example, if, on the same day, the same treatment drug was recorded in both the ndfp and Activity Level Reporting or in the odb and Activity Level Reporting, then its cost was obtained from the ndfp or the odb because of the comparative completeness of those databases. Costs for supportive drugs were obtained only from the odb and ndfp. Supportive drugs were further subcategorized into these classes: anti-diarrheals, antiemetics, bisphosphonates, corticosteroids, erythropoiesis-stimulating agents, granulocyte colony–stimulating factors, iron, laxatives, pain medications, and somatostatins. The costs are summarized by drug class and are reported as a total cost, not an incremental cost. Table 1 outlines the cost elements included in the cmca. Figure 1(A) illustrates the component costs for the cmca, and how costs are aggregated to obtain treatment and supportive costs and total cancer medication costs.

The CRCA

The crca provides both individual-level and aggregated output to summarize the costs incurred for radiation delivery, organized into 3 types of health system encounters: planning; treatment, which involves outpatient cancer clinic visits, physician, and radiation therapist; and operational costs, which consist of equipment, supplies, and the institutional cost for the medical physicist. Cost sources for radiation therapy pertain to one of hospital use, visit, or claim. Planning and radiation consider physician costs. Radiation therapist costs include dosimetry, mould room, simulation, patient support, quality assurance, planning, and other. The cost by modality is included (for example, external-beam radiation therapy, intensity-modulated radiation therapy, stereotactic and whole-body radiation therapy, brachytherapy). Table i outlines the cost elements included in the algorithm, and Figure 1(B) illustrates the component costs for the crca, and how the costs are aggregated to obtain phase, sector, and modality-specific costs, and total cancer radiation therapy costs.

Algorithm Implementation

The algorithms were implemented using the SAS Enterprise Guide software application (version 7.15: SAS Institute, Cary, NC, U.S.A.). In both algorithms, the costs for each component of care delivery (as illustrated in Figure 1) are calculated for every individual in the analysis cohort, and a companion report is produced that summarizes cost metrics for the entire analysis cohort, including the total number of patients who incurred each cost component, and descriptive statistics about the cost (total, mean and standard deviation, median and interquartile range, minimum and maximum).

No double counting occurs across the two algorithms. Because many of the components consist of annual figures (salaries, institutional costs, and so on), costs will be adjusted by year. Moreover, the algorithms are themselves dynamic and will evolve over time as treatments change.

A Worked Example

We present a worked example determining the cost of treatment for a cohort of women diagnosed with breast cancer. A cohort of 50,141 ohip (Ontario Health Insurance Plan)–eligible women with an initial diagnosis of breast cancer between 2010 and 2015 was obtained from the Ontario Cancer Registry. This example cohort was followed for 1 year after diagnosis to determine the costs associated with initial treatment of their cancer. Here, for illustrative purposes, we use descriptive statistics (median, interquartile range) to present the cohort costs for medications and radiation treatment for overall and stage breast cancer (Tables iv and v), although normally distributed values such as means (with standard deviation) and ranges could also be used. Total and median costs by stage for stages i to iv disease are presented in Tables iv and v.

a Exclusions: previous cancer before index diagnosis, 8,183 (13.7%); another cancer diagnosed on the same day as the index date, 77 (0.1%); invalid sex, 385 (0.6%); age less than 18 or more than 105 years, 18 (0.0%); died on diagnosis date, 192 (0.3%); error in dates (for example, died before index date), 13 (0.0%); not eligible for OHIP coverage from date of diagnosis to the end of follow-up, 399 (0.7%); stage 0 noninvasive cancer, 240 (0.4%).
### TABLE 1  Summary of data sources for the cancer medication costing algorithm and the cancer radiation costing algorithm

| Data source                                      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Cancer medication costing algorithm**          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Activity Level Reporting (ALR)                   | Patient-level activity within the cancer system, focused on systemic therapy services. The ALR consists of all chemotherapy visits (that is, chemotherapy use) at a hospital or regional cancer centre. Drugs within this database are identified using a Cancer Care Ontario drug code. Although the ALR contains both treatment and supportive therapy drugs, only drugs in the ALR that are used for cancer treatment were considered; supportive therapy drugs were costed from the Ontario Drug Benefit (ODB). Utilization data include dose given and route of administration. If the drug was funded in the New Drug Funding Program (NDFP), the unit cost was derived from the average unit cost (that is, dollar per milligram of active ingredient) in the NDFP. Otherwise, a unit cost for each drug, specific to the route of administration, was determined from a general wholesale drug cost. The wholesale cost could vary depending on a number of factors, including manufacturer, dose strength, and package size. For a conservative estimate, the lowest unit cost was used. Unit cost = dose administered × lowest unit cost |
| New Drug Funding Program                         | Publicly funded drug program for new, and very often expensive, cancer drugs. The NDFP is a publicly funded drug program under the Ontario Public Drug Programs and pays for newer intravenous or injectable cancer treatment drugs. Drug costs in the NDFP were based on the total amount reimbursed to the administering hospital or regional cancer centre. A small number of expensive supportive therapy drugs are also found in the NDFP: denosumab and intravenous clodronate, pamidronate, and zoledronic acid. Unit cost = amount paid per administration |
| Ontario Drug Benefit                             | Prescription drugs for eligible patients, mostly those 65 years of age and older, but also for patients eligible under other ODB programs (for example, the Trillium Drug Program). Drugs in the ODB are identified by a drug identification number (DIN), unique by formulation, manufacturer, dose strength, and route of administration. The DINs of interest were identified in the ODB e-formulary. Prescription drug costs in the ODB are based on the total amount paid to the dispensing pharmacy (including dispensing fees). Unit cost = fee paid per prescription |
| **Cancer radiation costing algorithm**           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Activity Level Reporting                         | **Radiation therapist** Patient-level activity within the cancer system focused on radiation therapy services using National Hospital Productivity Improvement Project codes. Activity cost was calculated by multiplying the radiation therapist hourly salary by the duration for each activity (in hours) by the number of radiation therapists required to perform the activity. Planning-related activity is aggregated by planning subcategories:  
  - Mould room  
  - Patient support  
  - Dosimetry  
  - Quality assurance  
  - Simulation  
  - Planning  
  - Other Treatment-related activity was aggregated by the modality of radiation therapy, summing all activity costs for that modality as identified by National Hospital Productivity Improvement Project codes. Activity cost = (radiation therapist salary) × (activity duration) × (n radiation therapists) |
| National Ambulatory Care Reporting System (NACRS) | **Outpatient oncology visits** For each cancer clinic in NACRS, up to 10 intervention codes can be recorded using Canadian Classification of Health Intervention codes. Radiation therapy visits were identified using those codes, which are able to distinguish between external-beam radiation therapy and brachytherapy. Case cost for an ambulatory clinic (including oncology) is estimated by multiplying the year- and visit-specific Comprehensive Ambulatory Classification System (CACS) weight (RIW) by the provincial cost per weighted case. Visit cost = CACS RIW × cost per weighted case |
The use of these two costing algorithms based on provincial administrative databases provides a robust understanding of costs associated with medications and radiation treatment in cancer patients in the province of Ontario. Our efforts in designing more representative costing algorithms have face validity with respect to resources and costs when compared with the methods and studies of other international investigators. For example, our 1-year post-diagnosis radiation costs for women with stage I breast cancer (CA$16,886) are in line with those derived from insurance claims for radiation (US$14,910) in women with stage I/II breast cancer. In contrast, medication costs were quite different for our cohort of women with early-stage disease (CA$578) compared with the U.S. cohort (US$13,373). That variance might reflect differences in universal compared with insurer coverage for medications, or in treatment patterns or differences in costs for treatments. Furthermore, drug prices in the United States, which leaves drug prices to market competition, are considerably higher than they are in other developed countries, including Canada. In contrast to the third-party payment system in the United States, Canada has a provincial single-payer health care system covered mostly by publicly funded provincial health insurance, with some funding through private insurance. For medications, that approach is further complemented by Canada’s Patented Medicine Prices Review Board, which restricts drug prices to ensure that they are not excessive for Canada.
### TABLE II  Cancer medication costing algorithm, worked example

| Medication   | Overall | Stage I |
|--------------|---------|---------|
|              | Pts (n) | Costs ($) | Pts (n) | Costs ($) |
|              |         | Total | Median | IQR     | Total | Median | IQR     |
| Summary      |         |       |        |         |       |        |         |
| TOTAL        | 37,623  | 309,353,167 | 1,636  | 406–7,690 | 13,106 | 70,618,378 | 578  | 173–2,445 |
| Total treatment | 32,956  | 246,917,014 | 1,343  | 397–3,895 | 10,484 | 59,676,724 | 528  | 192–2,484 |
| Total supportive | 27,647  | 62,436,153  | 253    | 47–1,730  | 10,297 | 10,941,654 | 119  | 15–424    |
| Cancer treatment |       |         |        |         |       |        |         |
| Anastrozole    | 6,380   | 4,395,523  | 445    | 275–1,076 | 2,892  | 2,106,305  | 464  | 305–1,161 |
| Capecitabine    | 135     | 187,833   | 1,087   | 375–1,987 | NR     | NR       | NR     | NR      |
| Carboplatin    | 298     | 987,927   | 2,769   | 1,755–4,586 | 70     | 258,427   | 3,314  | 1,919–5,729 |
| Cisplatin      | 84      | 6,572     | 67      | 42–97     | 7      | 637      | 72    | 52–136   |
| Cyclophosphamide | 12,404 | 3,888,312 | 330    | 237–379  | 2,477  | 802,216   | 341   | 255–383  |
| Docetaxel      | 12,686  | 26,785,628 | 1,338  | 588–2,548 | 2,836  | 5,829,954 | 1,385  | 594–2,539 |
| Doxorubicin    | 5,513   | 11,790,235 | 2,186   | 1,986–2,375 | 850   | 1,789,548 | 2,165  | 1,976–2,349 |
| Epirubicin     | 8,098   | 2,665,291 | 198    | 141–547   | 1,123  | 378,587   | 710   | 139–547  |
| Eribulin       | 13      | 51,063    | 3,904   | 1,902–4,685 | —     | —      | —     | —       |
| Etoposide      | 16      | 11,102    | 112    | 40–173    | NR     | NR       | NR     | NR      |
| Everolimus     | NR      | NR       | NR     | NR       | NR     | —      | —     | —       |
| Exemestane     | 249     | 81,640    | 180    | 100–446   | 83     | 26,207   | 170   | 100–441  |
| Fluorouracil   | 4,880   | 464,140   | 91     | 83–99     | 703    | 67,761   | 89    | 81–99    |
| Gemcitabine    | 70      | 76,444    | 665    | 330–1,282 | 6      | 8,207    | 97    | 255–2,745 |
| Goserelin      | 109     | 171,339   | 1,234  | 454–2,176 | 14     | 21,040   | 1,259  | 454–2,185 |
| Lapatinib      | 6       | 42,452    | 6,234  | 5,343–10,680 | —     | —      | —     | —       |
| Letrozole      | 6,219   | 2,105,538 | 332    | 188–462   | 2,085  | 713,239  | 360   | 192–457  |
| Megestrol      | 30      | 19,306    | 364    | 195–628   | NR     | NR       | NR     | NR      |
| Methotrexate   | 178     | 28,410    | 111    | 70–155    | 35     | 4,938    | 136   | 83–157   |
| Nab-paclitaxel | 91      | 851,470   | 8,138  | 4,173–12,294 | NR    | NR       | NR     | NR      |
| Paclitaxel     | 6,806   | 1,887,557 | 190    | 153–295   | 952    | 334,286  | 196   | 153–365  |
| Pertuzumab     | 232     | 9,590,837 | 47,712 | 27,119–56,161 | NR   | NR       | NR     | NR      |
| Tamoxifen      | 6,989   | 573,980   | 76     | 40–115    | 2,931  | 252,814  | 87    | 48–122   |
| Trastuzumab    | 5,926   | 179,864,484 | 29,644 | 23,301–36,734 | 1,515 | 46,987,634 | 30,101 | 23,973–36,948 |
| Trastuzumab emtansine | 21 | 295,969 | 9,057 | 5,529–18,443 | — | — | — | — |
| Vinorelbine    | 72      | 24,625    | 275    | 123–492   | NR     | NR       | NR     | NR      |
| Supportive care |       |         |        |         |       |        |         |
| Denosumab      | 458     | 273,189   | 698    | 385–778   | 215    | 129,661  | 715   | 385–777  |
| Pamidronate    | 954     | 111,243   | 82     | 37–133    | 15     | 1,239    | 37    | 21–133   |
| Anti-diarrheals | 791     | 24,192    | 12     | 10–24     | 151    | 6,094    | 13    | 10–29    |
| Antiemetics    | 12,484  | 3,083,376 | 168    | 85–341    | 2,581  | 541,933  | 141   | 66–263   |
| Bisphosphonates | 5,055  | 1,329,325 | 148    | 82–285    | 2,278  | 464,419  | 142   | 82–262   |
| Corticosteroids | 16,805 | 1,010,589 | 37     | 18–60     | 4,973  | 304,611  | 26    | 10–50    |
TABLE II

| Medication          | Overall                      | Stage I                      |
|---------------------|------------------------------|------------------------------|
|                     | Pts (n) | Cost ($) | IQR | Total | Median | IQR | Total | Median | IQR |
| ESAs                | 52      | 138,312  | 2,688 | 1,771–3,549 | 6 | 11,202  | 1,411 | 927–3,091 |
| G-CSF               | 6,593   | 53,070,382 | 7,348 | 4,283–11,200 | 1,122 | 8,370,504 | 6,255 | 4,275–10,110 |
| Iron                | 1,717   | 97,379   | 27 | 11–71 | 576 | 28,327  | 24 | 11–62 |
| Laxatives           | 6,653   | 232,235  | 15 | 10–34 | 1,880 | 69,375  | 14 | 9–34 |
| Pain adjunct        | 7,693   | 1,418,550 | 99 | 31–240 | 2,938 | 548,142 | 107 | 35–234 |
| Pain opiates        | 19,630  | 1,580,293 | 11 | 6–27 | 7,421 | 443,677 | 8 | 4–17 |
| Somatostatins       | 11      | 67,087   | 322 | 90–3,800 | NR | NR | NR | NR |

Pts = patients using the medication; IQR = 25%–75% interquartile range; NR = not reportable (fewer than 6 individuals); ESAs = erythropoietin-stimulating factors; G-CSF = granulocyte colony-stimulating factor.

SUMMARY

As constructed, both costing algorithms can be widely applied to various cancer disease sites (for example, melanoma23 or breast cancer24) and to procedure-based cohorts as defined by the investigator. The results can be used as inputs for budget impact analyses, burden-of-illness studies, and incremental cost-effectiveness comparisons. As constructed, both algorithms can be extended to also incorporate additions such as screening, diagnostic phase of care, addition of new medications, and more comprehensive medication costing that considers operational costs (for example, chair time, nursing, pharmacy, physician).

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood Current Oncology’s policy on disclosing conflicts of interest, and we declare the following interests: NC has received salary support from Cancer Care Ontario as the Clinical Lead in Patient Reported Outcomes and Symptom Management; WKE has received fees as an advisory board member for AbbVie, Astellas, Bristol–Myers Squibb, Eisai, Gilead, Lilly, Takeda, and Merck, and has received consulting fees from AstraZeneca, Boehringer Ingelheim, Celgene, Janssen, Lilly, Roche, Servier, and Sanofi Genzyme. NM, SYC, NL, SJS, FES, CD, NJLH, CCE, MC, and NL have no conflicts to disclose.

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TABLE III  Cancer radiation costing algorithm, worked example

| RT factor | Overall | Stage I |
|-----------|---------|---------|
|           | Pts (n) | Cost ($) | Pts (n) | Cost ($) |
|           | Total   | Median   | IQR     | Total   | Median   | IQR     |
| Summary   |         |          |         |         |          |         |
| TOTAL     | 40,084  | 745,423,098 | 19,383 | 12,182–26,225 | 17,221 | 282,899,160 | 16,886 | 11,672–22,591 |
| Total planning | 39,963  | 67,732,400 | 1,608 | 1,237–2,123 | 17,156 | 26,155,198 | 1,534 | 1,214–1,833 |
| Total treatment | 34,925  | 572,386,874 | 16,037 | 11,046–21,347 | 14,920 | 216,712,545 | 13,705 | 9,356–18,699 |
| Total equipment and supplies | 32,970  | 69,465,289 | 2,125 | 1,106–3,035 | 14,138 | 26,450,231 | 1,993 | 1,106–2,490 |
| Total medical physicist | 32,970  | 35,838,535 | 1,047 | 798–1,246 | 14,138 | 13,581,186 | 897 | 798–1,047 |
| Planning  |         |          |         |         |          |         |
| Physician |         |          |         |         |          |         |
| Consultation | 39,047  | 6,197,748 | 152 | 152–152 | 16,782 | 2,594,507 | 152 | 152–152 |
| Planning | 32,732  | 32,806,760 | 842 | 811–854 | 14,009 | 13,380,236 | 842 | 811–854 |
| Radiation therapist |         |          |         |         |          |         |
| Mold room | 12,239  | 576,924 | 26 | 26–52 | 4,995 | 211,131 | 26 | 26–39 |
| Patient support | 32,184  | 6,051,328 | 123 | 85–192 | 13,726 | 2,150,968 | 115 | 79–169 |
| Dosimetry | 31,133  | 11,621,471 | 313 | 185–506 | 13,274 | 4,153,773 | 273 | 159–386 |
| Quality assurance | 31,769  | 7,775,235 | 184 | 103–317 | 13,586 | 2,610,822 | 161 | 93–243 |
| Simulation | 30,895  | 1,817,060 | 39 | 39–78 | 13,196 | 719,531 | 39 | 39–65 |
| Planning | 19,766  | 859,610 | 39 | 19–58 | 8,345 | 324,207 | 32 | 19–39 |
| Other | 540 | 26,264 | 16 | 16–17 | 210 | 10,024 | 16 | 16–17 |
| Treatment |         |          |         |         |          |         |
| Physician assessment | 34,247  | 7,072,223 | 197 | 137–266 | 14,678 | 2,789,427 | 189 | 128–245 |
| External-beam RT |         |          |         |         |          |         |
| Cancer clinic | 32,922  | 546,387,133 | 16,100 | 10,697–20,597 | 14,094 | 208,130,787 | 13,416 | 10,479–18,254 |
| Radiation therapist |         |          |         |         |          |         |
| IMRT | 27,496  | 13,261,949 | 409 | 312–487 | 11,895 | 4,441,683 | 312 | 312–409 |
| Stereotactic | 61 | 12,854 | 156 | 78–234 | 11 | 1,207 | 39 | 39–78 |
| Total body irradiation | NR | NR | NR | NR | NR | NR | NR | NR |
| No special technique | 16,495  | 5,064,957 | 314 | 88–390 | 5,215 | 969,685 | 110 | 65–249 |
| Brachytherapy |         |          |         |         |          |         |
| Cancer clinic | 113 | 505,451 | 2,034 | 936–4,909 | 72 | 324,168 | 2,034 | 936–4,630 |
| Radiation therapist | 121 | 82,204 | 584 | 260–584 | 77 | 55,484 | 584 | 260–584 |

| RT | Radiation therapy; Pts = patients receiving the service; IQR = 25%–75% interquartile range; IMRT = intensity-modulated radiation therapy; NR = not reportable (fewer than 6 individuals). |

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### TABLE IV  
Cancer medication costing algorithm for all stages of breast cancer, median costs

| Medication         | Stage I    | Stage II   | Stage III   | Stage IV    |
|--------------------|------------|------------|-------------|-------------|
|                    | Total ($)  | Median ($) | Total ($)   | Median ($)  |
| TOTAL Stage I      | 70,618,378 | 578        | 136,408,966 | 2,405       |
| TOTAL Stage II     | 59,676,724 | 528        | 104,078,135 | 1,657       |
| TOTAL Stage III    | 10,941,654 | 119        | 32,330,830  | 356         |
| TOTAL Stage IV     |            |            |             |             |
| Summary            |            |            |             |             |
| TOTAL              | 70,618,378 | 578        | 136,408,966 | 2,405       |
| Total treatment    | 59,676,724 | 528        | 104,078,135 | 1,657       |
| Total supportive care | 10,941,654 | 119        | 32,330,830  | 356         |
| TOTAL              | 70,618,378 | 578        | 136,408,966 | 2,405       |
| Total treatment    | 59,676,724 | 528        | 104,078,135 | 1,657       |
| Total supportive care | 10,941,654 | 119        | 32,330,830  | 356         |

**Treatment**

| Medication         | Stage I    | Stage II   | Stage III   | Stage IV    |
|--------------------|------------|------------|-------------|-------------|
|                    | Total ($)  | Median ($) | Total ($)   | Median ($)  |
| Anastrozole        | 2,106,305  | 464        | 1,712,653   | 436         |
| Capecitabine       | NR         | NR         | 13,694      | 1,120       |
| Carboplatin        | 258,427    | 3,314      | 445,790     | 2,655       |
| Cisplatin          | 637        | 77         | 1,379       | 68          |
| Cyclophosphamide   | 802,216    | 341        | 1,983,539   | 325         |
| Docetaxel          | 5,829,954  | 1,385      | 13,489,315  | 1,275       |
| Docorubicin        | 1,789,548  | 2,165      | 12,365      | 223         |
| Epirubicin         | 378,587    | 210        | 1,412,648   | 192         |
| Eribulin           | —          | —          | NR          | NR          |
| Etoposide          | NR         | NR         | 431         | 73          |
| Everolimus         | —          | —          | NR          | NR          |
| Exemestane         | 26,207     | 170        | 29,806      | 223         |
| Fluorouracil       | 67,761     | 89         | 242,832     | 91          |
| Gemcitabine        | 8,207      | 971        | 12,365      | 426         |
| Goserelin          | 21,040     | 1,259      | 48,800      | 1,221       |
| Lapatinib          | —          | —          | —           | NR          |
| Letrozole          | 713,239    | 360        | 806,958     | 323         |
| Megestrol          | NR         | NR         | 5,066       | 320         |
| Methotrexate       | 4,938      | 136        | 12,047      | 124         |
| Nab-paclitaxel     | NR         | NR         | 102,894     | 5,206       |
| Paclitaxel         | 334,286    | 196        | 872,542     | 186         |
| Pertuzumab         | NR         | NR         | 564,717     | 22,439      |
| Tamoxifen          | 252,814    | 87         | 228,875     | 71          |
| Medication                     | Stage I                         | Stage II                      | Stage III                      | Stage IV                       |
|-------------------------------|--------------------------------|-------------------------------|-------------------------------|-------------------------------|
|                               | Total ($)                      | Median ($)                    | Total ($)                      | Median ($)                    | Total ($)                      | Median ($)                    |
| Treatment continued           |                                |                               |                               |                               |                                |                               |
| Trastuzumab                   | 46,987,634                     | 30,101                        | 76,192,498                    | 29,066                        | 44,324,497                    | 29,738                        |
| Trastuzumab emtansine         | —                              | —                             | NR                            | NR                            | NR                            | NR                            |
| Vinorelbine                   | NR                             | NR                            | 2,788                         | 164                           | 3,099                         | 140                           |
| Supportive care               |                                |                               |                               |                               |                                |                               |
| Denosumab                     | 129,661                        | 715                           | 107,361                       | 715                           | 29,696                        | 396                           |
| Pamidronate                   | 1,239                          | 37                            | 6,741                         | 62                            | 10,293                        | 62                            |
| Anti-diarrheals               | 6,094                          | 13                            | 9,928                         | 12                            | 5,400                         | 13                            |
| Antiemetics                   | 541,933                        | 141                           | 1,466,359                     | 176                           | 855,558                       | 194                           |
| Bisphosphonates               | 464,419                        | 142                           | 404,468                       | 144                           | 124,824                       | 143                           |
| Corticosteroids               | 304,611                        | 26                            | 443,281                       | 39                            | 206,635                       | 45                            |
| ESAs                          | 11,202                         | 1,411                         | 65,495                        | 2,613                         | 47,941                        | 2,674                         |
| G-CSF                         | 8,370,504                      | 6,255                         | 28,577,420                    | 7,308                         | 15,607,683                    | 8,202                         |
| Iron                          | 28,327                         | 24                            | 45,034                        | 31                            | 17,881                        | 25                            |
| Laxatives                     | 69,375                         | 14                            | 90,133                        | 14                            | 43,018                        | 14                            |
| Pain adjunct                  | 548,142                        | 107                           | 582,828                       | 97                            | 213,577                       | 85                            |
| Pain opiates                  | 443,677                        | 8                             | 531,387                       | 11                            | 273,060                       | 16                            |
| Somatostatins                 | NR                             | NR                            | NR                            | NR                            | NR                             | NR                            |

NR = not reportable (fewer than 6 individuals); — = not used; ESAs = erythropoietin-stimulating factors; G-CSF = granulocyte colony-stimulating factor.
## TABLE V  
Cancer radiation costing algorithm for all stages of breast cancer

| RT factor                        | Stage I                  | Stage II                  | Stage III                  | Stage IV                  |
|----------------------------------|--------------------------|---------------------------|---------------------------|---------------------------|
|                                  | Total ($), Median ($)    | Total ($), Median ($)    | Total ($), Median ($)    | Total ($), Median ($)    |
| **Summary**                      |                          |                           |                           |                           |
| TOTAL RT                         | 282,899,160, 16,886     | 305,705,643, 20,969       | 144,214,925, 24,473       | 12,603,369, 4,640         |
| Total planning                   | 26,155,198, 1,534       | 27,214,976, 1,676         | 12,192,765, 1,846         | 2,169,461, 1,251          |
| Total treatment                  | 216,712,545, 13,705     | 235,009,258, 17,312       | 111,845,067, 19,702       | 8,820,005, 4,197          |
| Total equipment and supplies     | 26,450,231, 1,993       | 28,695,614, 2,353         | 13,240,380, 2,552         | 1,079,064, 642            |
| Total medical physicist          | 13,581,186, 897         | 14,785,796, 1,246         | 6,936,714, 1,246          | 534,840, 299              |
| **Planning**                     |                          |                           |                           |                           |
| Physician                        |                          |                           |                           |                           |
| Consult                          | 2,594,507, 152          | 2,383,058, 152            | 959,033, 152              | 261,150, 152              |
| Planning                         | 13,380,236, 842         | 12,843,721, 842           | 5,413,855, 842            | 1,168,948, 811            |
| Radiation therapist              |                          |                           |                           |                           |
| Mold room                        | 211,131, 26             | 225,979, 26               | 118,373, 26               | 21,441, 26                |
| Patient support                  | 2,150,968, 115          | 2,513,040, 136            | 1,250,933, 141            | 136,387, 101              |
| Dosimetry                        | 4,153,773, 273          | 4,825,301, 360            | 2,322,669, 386            | 319,728, 266              |
| Quality assurance                | 2,610,822, 161          | 3,363,645, 203            | 1,638,693, 249            | 162,074, 103              |
| Simulation                       | 719,531, 39             | 696,381, 39               | 328,350, 39               | 72,799, 58                |
| Planning                         | 324,207, 32             | 352,835, 39               | 157,436, 39               | 25,132, 39                |
| Other                            | 10,024, 16              | 11,016, 16                | 3,422, 16                 | 1,802, 16                 |
| **Treatment**                    |                          |                           |                           |                           |
| Physician assessment             | 2,789,427, 189          | 2,798,538, 211            | 1,302,431, 230            | 181,827, 138              |
| External-beam RT                 |                          |                           |                           |                           |
| Cancer clinic                    | 208,130,787, 13,416     | 223,962,735, 16,564       | 106,015,040, 19,674       | 8,278,571, 5,176          |
| Radiation therapist              | 1,207, 39               | 3,817, 234                | 1,246, 78                 | 6,583, 195                |
| IMRT                             | 4,441,683, 312          | 5,744,930, 487            | 2,928,456, 487            | 146,880, 467              |
| Stereotactic                     | 1,207, 39               | 3,817, 234                | 1,246, 78                 | 6,583, 195                |
| Total body irradiation           | NR, NR                  | —, —                     | —, —                     | —, —                     |
| No special technique             | 969,685, 110            | 2,349,838, 390            | 1,591,623, 390            | 153,811, 110              |
| **Brachytherapy**                |                          |                           |                           |                           |
| Cancer clinic                    | 324,168, 2,034          | 127,548, 1,873            | NR, NR                    | NR, NR                    |
| Radiation therapist             | 55,484, 584             | 21,851, 584               | NR, NR                    | NR, NR                    |

RT = radiation therapy; NR = not reportable (fewer than 6 individuals); IMRT = intensity-modulated radiation therapy.
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