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Phase- and gender-specific, lifetime, and future costs of cancer
A retrospective population-based registry study
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Abstract
Valid estimates of cancer treatment costs are import for priority setting, but few studies have examined costs of multiple cancers in the same setting.

We performed a retrospective population-based registry study to evaluate phase-specific (initial, continuing, and terminal phase) direct medical costs and lifetime costs for 13 cancers and all cancers combined in Norway. Mean monthly cancer attributable costs were estimated using nationwide activity data from all Norwegian hospitals. Mean lifetime costs were estimated by combining phase-specific monthly costs and survival times from the national cancer registry. Scenarios for future costs were developed from the lifetime costs and the expected number of new cancer cases toward 2034 estimated by NORDCAN.

For all cancers combined, mean discounted per patient direct medical costs were Euros (EUR) 21,808 in the initial 12 months, EUR 4347 in the subsequent continuing phase, and EUR 12,085 in the terminal phase (last 12 months). Lifetime costs were higher for cancers with a 5-year relative survival between 50% and 70% (myeloma: EUR 89,686, mouth/pharynx: EUR 66,619, and non-Hodgkin lymphoma: EUR 65,528). The scenario analyses indicate that future cancer costs are highly dependent on future cancer incidence, changes in death risk, and cancer-specific unit costs.

Gender- and cancer-specific estimates of treatment costs are important for assessing equity of care and to better understand resource consumption associated with different cancers.

Cancers with an intermediate prognosis (50%–70% 5-year relative survival) are associated with higher direct medical costs than those with relatively good or poor prognosis.

Abbreviations: CRN = Cancer Registry of Norway, DRG = diagnosis-related group, EUR = euros, ICD-10 = International Classification of Diseases, Tenth Revision, NPR = Norwegian Patient Registry.

Keywords: cancer costs, cost analysis, cost of illness, lifetime costs, phase-specific costs

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CB, EMS, and ISK have all completed consultancy assignments for several pharmaceutical companies in recent years.

Data from the Norwegian Patient Registry has been used in this publication. The interpretation and reporting of these data are the sole responsibility of the authors, and no endorsement by the Norwegian Patient Registry is intended nor should be inferred. The study has used data from the Cancer Registry of Norway. The interpretation and reporting of these data are the sole responsibility of the authors, and no endorsement by the Cancer Registry of Norway is intended nor should be inferred.

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The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

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1. Introduction

The increasing financial pressure on public health care systems entails need for strict priority setting and planning of future health care. Valid estimates of treatment costs are a necessary input in cost-effectiveness analyses used for allocating resources and evaluating new interventions. The medical improvements in cancers care make the demand for accurate and updated costs estimates related to cancer even more important.

Globally, cancer is the second most frequent cause of death, and a major public health challenge that represents a significant economic burden to society.\(^1,2\) The NORDCAN-program presents projections of cancer incidence and mortality based on data from national cancer registries and cause of death registries in all the Nordic countries.\(^3\) NORDCAN projections indicate that the annual average number of new cancer cases in the Nordics will increase from 163,881 in 2012 to 2016 to 230,565 in 2032 to 2036 (+40.7%).\(^4\)

Analysts use different approaches to describe illness-related costs, including incidence, prevalence, and phase-specific approaches.\(^5\)–\(^10\) Costing by “phase of care” involves dividing care into clinically relevant phases and applying survival probabilities to the cost estimates for each phase.\(^11\) This approach has several appealing aspects as it incorporates the natural history of the disease and corresponding treatment patterns.\(^6\) When combined with survival data, these phase-specific cost estimates can be used to determine lifetime costs for individual cancers.\(^5,12\) Furthermore, when applied to projections of future incidence rates, such lifetime costs enable the estimation of future cost of care. Additionally, a phase-specific approach enables analysts to evaluate how changes in prognosis, and changes in time spent in each phase, influence the costs associated with the disease. Costs can be computed using cancer-related services and treatments (attributable costs) or by matching patients with individuals without cancer (net costs).\(^11\)

One key advantage with the former method is that it is fairly straightforward and simple if diagnosis-specific cost data are available, which is the case in Norway.

Several previous studies have presented phase-specific cancer costs.\(^5,6,12\)–\(^17\) Most studies, however, present lifetime costs for single cancers while few have examined multiple cancers in the same setting (examples of studies covering multiple cancers are Yabroff et al.\(^5\), de Oliveira et al.\(^6\) and Blakely et al.\(^16\)). The Nordic countries all have excellent registries capturing virtually all individuals residing in those countries.\(^18\) Having a universal public insurance system, where virtually all cancer patients are treated in public hospitals, provides a foundation for developing precise costs estimates. Additionally, Norway has diagnosis-specific data on hospital treatment and costs at the individual patient level and a national cancer registry which has had a mandatory reporting of new cancer cases to CRN since 1953 and is 99% complete.\(^19\)

The primary aim of this study was to estimate phase-specific and lifetime costs for cancer as a disease group and for the 13 most frequent individual cancers. A secondary aim was to develop scenarios of future cost of cancer based on incidence projections from the Nordic NORDCAN-project and estimated lifetime costs.

2. Methods

We performed a retrospective population-based registry study to evaluate phase-specific (initial treatment phase, continuing care, and terminal care) and lifetime cancer costs incurred in hospital (direct medical costs). This was done for 13 individual cancer types (representing 75% of all new cancer cases in Norway in 2017)\(^20\) and all cancers combined (International Classification of Diseases [ICD]-10 codes C00-99, D00-09, D37-48). We included costs of out-patient care, in-patient care, day treatment, and in-hospital drug use. Non-patient-related costs (research and development, capital costs, ambulance services, etc) and out-patient diagnostics imaging and laboratory services were not included due to lack of diagnosis-specific data.

2.1. Data sources

We used data from the Norwegian Patient Registry (NPR)\(^21\) with the following variables for each episode of care (i.e., hospital encounter: out-patient, in-patient or day care visit): unique patient identifier, patient age, gender, and county of residence, time of episode (year/month), main and supplementary diagnosis (ICD-10 code), Diagnosis Related Group (DRG) code and corresponding cost weight, and days until death. In NPR, each episode of care is assigned an ICD-10 main diagnostic code (possibly also a supplementary diagnostic code) that enables us to isolate cancer-specific treatment costs. Norway has a national health care system that provides health care for all residents. Virtually all cancer treatment is provided by publicly financed hospitals.\(^22\) The dataset from NPR encompasses all episodes of care (hospital encounters) for cancer patients during the period 2009 to 2017 with ICD-10 codes C00-99, D00-09, D37-48. In total, the dataset encompassed 7,423,828 episodes for 420,655 patients.

The Cancer Registry of Norway (CRN) holds data on type of cancer diagnosis, time of diagnosis, time of death, patient characteristics (gender and age), and cancer stage in condensed form at the time of diagnosis for all patients diagnosed with cancer in Norway. Notification of cancer cases to CRN is mandatory, and the data are collected from multiple sources, including hospitals, physicians, pathology laboratories, and by linkage with NPR. CRN data proved to be valid with 98.8% overall completeness for the registration period 2001 to 2005.\(^19\)

We collected data on patients diagnosed with cancer between 1953 and 2015, in total 1,107,088 patients. Patients were followed to the end of 2018, and the dataset included information on the month of death for all patients who died between January 1, 1953 and December 31, 2018.

Projections of future incidence were obtained from the NORDCAN-program (www.ancre.nu), a database that includes detailed information on cancer incidence, mortality, and prevalence in each of the Nordic countries.\(^3\) At the time of data collection (January 2020) the database included projections of cancer incidence until 2036 (presented as annual average for 5-year periods).

2.2. Patient classification

Patients were classified by tumor site into mutually exclusive cancer diagnosis for those with a diagnosis of cancer of mouth/pharynx, colon/rectum, lung, breast, cervix uteri, prostate, kidney (excl. renal pelvis), or urinary tract or with melanoma of the skin, non-Hodgkin lymphoma, leukemia or multiple myeloma. In cases where patients had multiple cancer diagnoses, diagnosis was assigned based on the most frequently listed diagnosis.\(^23\) Additionally, all cancers (C00-99, D00-09, D37-48) were evaluated together.
2.3. Survival analyses

We used the Kaplan–Meier estimator to estimate gender-specific survival models for each cancer site and all cancers combined. We estimated the probability of a patient surviving each month after diagnosis based on the month of first cancer diagnosis and month of death (or end of follow-up for patient alive by December 31, 2018). Patients who emigrated during the observation period were censored at the time of emigration. All survival analyses were performed on data with patients diagnosed with cancer between 1995 and 2015 (N = 560,265) from the cancer registry. The choice of time period was based on the need for long-term survival and also more recent treatment practice. Additionally, sensitivity analyses were conducted to examine the effects of using more updated data (2010–2018) for the first 8 years after diagnosis.

2.4. Estimation of phase-specific direct medical costs

We used an incidence-based cost approach where time between diagnosis and death were divided into 3 clinically relevant phases; initial treatment phase (primary course of therapy and adjuvant therapy), continuing care (surveillance, active follow-up, and active treatment of metastatic/relapsed disease), and terminal care (including palliative care). Length of each phase was defined as in a study by Yabroff et al. with the initial phase defined as the first 12 months after diagnosis, terminal phase as the last 12 months before death and continuing phase as the time in between the initial and terminal phase. To ensure comparability between cancers and with previous research, we employed the same length across all sites similar to previous studies. We used data from NPR to estimate monthly costs by cancer for each phase. We defined costs as the additional cost of care in hospitals due to cancer (direct medical costs) by estimating attributable costs, only including treatment related to the cancer diagnosis based on primary and secondary diagnosis. Costing method followed guidelines from the Norwegian Medicine Agency and the Norwegian Directorate of Health and were performed as in previous studies of cancer costs in Norway. We used the DRG weights for each episode of care and a price per DRG point from the Norwegian Directorate of Health of EUR 5238 ex. value added tax (2017 value). This unit price include all patient-related treatment costs associated with each episode of care in hospitals and is based on cost-per-patient calculation of reported accounting figures from the regional health authorities in Norway. There is virtually no patient copayment for cancer patients in Norway, and the DRG cost weights therefore reflect the actual resources consumption (economic cost) related to the patient care. Costs occurring before 2017 were adjusted for inflation to represent 2017 values. For the initial treatment phase and terminal care phase monthly costs were estimated for the first 12 months following diagnosis and the last year of life respectively. For the continuing phase, we estimated an average monthly cost for the entire phase.

We employed different patient cohorts to estimate costs for each phase. To estimate monthly costs in the initial phase we selected patients with no cancer related episodes prior to 2013 in NPR who survived at least 12 months and used activity data from 2013 through 2016. The 2008 to 2012 wash-out period was chosen to ensure that we only included newly diagnosed cancer patients, while 12 months follow-up were used to avoid including costs related to terminal care. Monthly costs in the terminal phase were estimated using decedents between 2013 and 2017 in NPR. For the continuing phase we selected patients diagnosed with cancer in 2010 who were alive by the end of 2017 in NPR. Average monthly costs were estimated by using cost data from 2013 through 2017. The treatment intensity may be higher in the initial seven years as compared with longer follow-up. To adjust for this, we excluded treatment costs in the second and third year after diagnosis when computing costs in the continuing phase.

2.5. Estimation of lifetime costs

By utilizing the phase-specific monthly unit costs from the patient registry and the survival models from the cancer registry we computed lifetime costs as \( Lifetime \ costs (t_T) = \sum_{t=1}^{T} S(t)C_t \) where \( S(t) \) is the Kaplan–Meier survival estimate at month \( t \) (i.e., the probability of being alive in month \( t \)) and \( C_t \) is the monthly cost in month \( t \) after diagnosis.

Lifetime costs were expressed in 2017 Euros using a 4% real (inflation-adjusted) discount rate according to national guidelines. Patients who died within 24 months of diagnosis did not contribute with costs to all phases. For patients with less than 24 months follow-up we first allocated costs to the terminal phase. If the patient survived more than 12 months (but less than 24), the remainder of the costs were allocated to the initial phase. More precisely, we defined the length (L) of the terminal phase \( T \) as \( L(T) = \min (12, t_T-t_0) \), initial phase (I) as \( L(I) = \min (12, t_I-t_0-L(T)) \), and continuing phase (C) as \( L(C) = t_T-t_0-L(T)-L(I) \), where \( t_0 \) denotes time of diagnosis and \( t_T \) time of death. This way of allocating costs for patients with short follow-up is consistent with previous studies and was chosen to ensure comparability with previous research.

2.6. Scenarios for costs toward 2034

To compute scenarios for future costs we multiplied lifetime costs per new cancer case with projections of the number of new cases from the NORDCAN-program. NORDCAN reports average yearly incidence in 5-year intervals (until the period 2032–2036 at the time of data collection). As a simplification the predicted incidence were assumed to occur in the middle of the 5-year interval (i.e., 2034). We evaluated the following scenarios: a hypothetical 10% decrease in the death risk per month for cases diagnosed in 2034 (i.e., an increase in the proportion of patients alive each month by 10%); a 3% annual increase in incidence (compared with the 2.4% increase estimated by NORDCAN); and a hypothetical 30% increase in the monthly unit costs in each phase and all phases combined. For all scenarios, costs were presented as 2017 EUR.

2.7. Statistical analyses

All analyses were performed using Microsoft Excel (2016) and STATA software version 14 (College Station, TX).

2.8. Ethical review

Approval to use data from Norwegian Patient Registry was granted by the Norwegian Data Inspectorate (17/00565-2/CDG) and the Regional Committees for Medical and Health Research Ethics (2017/769/REK).
3. Results

3.1. Monthly phase-specific costs per patient

In general, cost per patient was highest during the first month after diagnosis and the last month before death (Fig. 1). The monthly cost per patient decreased with time after diagnosis and increased as death approached following a U-shaped curve for all 13 cancers (see Table S1, S2, and S3, Supplemental Digital Content 1, http://links.lww.com/MD2/A257 which presents monthly per patient costs by phase, cancer site and gender). For all cancers combined, the mean cost per patient during the first month after diagnosis were EUR 8454 for males and EUR 7362 for females, with mouth/pharynx (EUR 18,128) and cancer of colon, rectum, and rectosigmoid (EUR 16,975) having the highest monthly cost per patient (both genders). During the last month before death the mean monthly cost was EUR 5777 for males and EUR 5240 for females, while the monthly costs in the continuing phase were EUR 111 for males and EUR 75 for females (all cancers combined). Multiple myeloma was associated with particularly high costs in the continuing phase with EUR 968 for males and EUR 913 for females.

3.2. Lifetime and phase-specific costs

Based on the survival models estimated from CRN data the mean durations were 10.2 months for the initial phase (30.9% of the patients lived less than 24 months from diagnosis), 96.9 months for the continuing phase, and 7.7 months for the terminal phase (22.1% died within less than 12 months from diagnosis). Patients with cervical cancer (155.5), breast cancer (148.2 months), melanoma of the skin (147.2 months), and prostate cancer (109.0 months) spent relatively longer time in the continuing phase when compared with other cancers (Table 1). The expected remaining lifetime for a patient diagnosed with cancer in 2010 was higher than for those diagnosed in 1995 (5-year survival of 61.5% and 55.5%, respectively). When data from 2010 through 2018 were used to estimate the probability of surviving for the first 8 years (compared with using data from 1995) the discounted lifetime costs for all cancers combined increased from 38,241 to 38,428 (+0.5%). Costs shifted from the terminal phase to the initial and continuing phase.

3.3. Cost scenarios toward 2034

When the lifetime costs were applied to NORDCAN projections for future incidence (assuming constant unit costs and survival), the yearly mean costs for all cancers combined were estimated at EUR 1911 million in 2034 (Table 2). This represents an annual growth of 2.4% (total growth of 52%) from 2016. The average annual growth in hospital costs was highest for melanoma of the skin (3.2%), kidney (2.9%), pancreatic (2.9%), and prostate cancer (2.9%).

In the scenario with a 10% decrease in the death risk in 2034 (scenario A), the yearly mean costs for all cancers combined were estimated at EUR 2039, corresponding to an increase in the yearly average costs of 130 million EUR (+6.7%) compared with the scenario with constant unit costs and survival. In the scenario with an annual increase in incidence of 3% (compared with 2.4% from NORDCAN) (scenario B) the yearly average cost totaled EUR 2139 (+230 million EUR), while a 30% increase in monthly unit costs (scenario C1) implied a total cost of EUR 2485 (+575 million EUR). Finally, when scenario A and C1 were combined, the total costs was estimated at EUR 2651 (+740 million EUR),
while the combination of scenario A, B, and C1 implied a total cost of EUR 2967 (+1050 million EUR) in 2034.

4. Discussion

Lifetime costs were highest for patients with myeloma (EUR 89,686), mouth/pharynx cancer (EUR 66,619), and non-Hodgkin lymphoma (EUR 65,528), and lowest for melanoma (EUR 25,363), urinary tract (EUR 33,839), and cervical cancer (EUR 38,294). With constant prices, survival, and health care utilization, future cancer costs were estimated to increase by 2.4% annually toward 2034.

Several studies have estimated cancer-specific costs by using a “phase of care” approach,[5,6,12–17] making it a standard method to estimate costs over time.[6] Consistent with similar studies, we found that cancer-related costs followed a U-shaped curve, with most costs occurring in the initial and terminal phases.[5,6,15] Like previous estimates from United States,[1]
**Table 2**

Scenario analysis: future total direct medical cancer costs under different assumptions, by cancer type in Norway, million 2017-EUR (1 EUR = 9.8 NOK).

| Cancer Type                   | 2016 | Constant unit costs without changes in prognosis | 10% decrease in the death risk per month (A) | 3% annual increase in incidence (B) | 30% increase monthly unit costs all phases (C1) | 30% increase monthly unit costs initial phase (C2) | 30% increase monthly unit costs continuing phase (C3) | 30% increase monthly unit costs terminal phase (C4) | 10% decreased death risk and 30% higher unit costs (A+C1) | 10% decreased death risk, 30% higher unit costs and 3% annual increase in incidence (A+B+C1) |
|-------------------------------|------|--------------------------------------------------|-------------------------------------------|-----------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| All cancers                   | 1255 | 1911 (2.4%)                                      | 2039 (2.7%)                               | 2139 (3.0%)                       | 2485 (3.9%)                                   | 2238 (3.3%)                                   | 1976 (2.6%)                                   | 2092 (2.9%)                                   | 2651 (4.2%)                                      | 2967 (4.9%)                                      |
| Mouth, pharynx                | 42   | 67 (2.5%)                                        | 70 (2.8%)                                 | 72 (3.0%)                         | 87 (4.0%)                                     | 79 (3.5%)                                     | 68 (2.7%)                                     | 73 (3.1%)                                     | 91 (4.3%)                                       | 98 (4.8%)                                       |
| Colon, rectum, rectosigmoid   | 249  | 386 (2.5%)                                       | 413 (2.9%)                                | 424 (3.0%)                        | 502 (4.0%)                                     | 461 (3.5%)                                     | 396 (2.6%)                                     | 417 (2.9%)                                     | 537 (4.4%)                                       | 590 (4.9%)                                       |
| Pancreas                      | 34   | 57 (2.9%)                                        | 62 (3.4%)                                 | 58 (3.0%)                         | 75 (4.4%)                                     | 68 (3.9%)                                     | 58 (3.0%)                                     | 64 (3.5%)                                     | 81 (4.9%)                                       | 82 (5.0%)                                       |
| Lung, trachea                 | 149  | 179 (1.0%)                                       | 194 (1.5%)                                | 255 (3.0%)                        | 232 (2.5%)                                     | 210 (1.9%)                                     | 182 (1.1%)                                     | 198 (1.6%)                                     | 252 (2.9%)                                       | 359 (5.0%)                                       |
| Melanoma                      | 53   | 94 (3.2%)                                        | 94 (3.3%)                                 | 90 (3.0%)                         | 122 (4.8%)                                     | 106 (4.0%)                                     | 99 (3.6%)                                     | 104 (3.8%)                                     | 122 (4.8%)                                       | 117 (4.5%)                                       |
| Breast                        | 198  | 275 (1.8%)                                       | 280 (1.9%)                                | 338 (3.0%)                        | 358 (3.3%)                                     | 333 (2.9%)                                     | 265 (2.0%)                                     | 292 (2.2%)                                     | 365 (3.4%)                                       | 447 (4.6%)                                       |
| Oesophagus uteri              | 13   | 16 (1.1%)                                        | 16 (1.2%)                                 | 22 (3.0%)                         | 21 (2.6%)                                     | 18 (1.9%)                                     | 16 (1.2%)                                     | 18 (1.7%)                                     | 21 (2.7%)                                       | 30 (4.6%)                                       |
| Prostate                      | 270  | 452 (2.9%)                                       | 463 (3.0%)                                | 461 (3.0%)                        | 588 (4.4%)                                     | 556 (4.1%)                                     | 463 (3.0%)                                     | 472 (3.1%)                                     | 602 (4.5%)                                       | 613 (4.7%)                                       |
| Kidney (excl. renal pelvis)   | 34   | 57 (2.9%)                                        | 61 (3.2%)                                 | 59 (3.0%)                         | 75 (4.4%)                                     | 67 (3.8%)                                     | 60 (3.1%)                                     | 62 (3.4%)                                     | 79 (4.7%)                                       | 81 (4.8%)                                       |
| Urinary tract                 | 60   | 90 (2.3%)                                        | 95 (2.6%)                                 | 101 (3.0%)                        | 117 (3.8%)                                     | 104 (3.2%)                                     | 94 (2.6%)                                     | 97 (2.8%)                                     | 123 (4.1%)                                       | 139 (4.8%)                                       |
| Non-Hodgkin lymphoma          | 67   | 85 (1.4%)                                        | 91 (1.7%)                                 | 113 (3.0%)                        | 110 (2.8%)                                     | 99 (2.2%)                                     | 90 (1.7%)                                     | 91 (1.8%)                                     | 118 (3.2%)                                       | 158 (4.9%)                                       |
| Leukemia                      | 40   | 58 (2.2%)                                        | 63 (2.6%)                                 | 68 (3.0%)                         | 76 (3.7%)                                     | 68 (3.0%)                                     | 60 (2.4%)                                     | 64 (2.7%)                                     | 81 (4.1%)                                       | 95 (4.9%)                                       |
| Multiple myeloma              | 38   | 58 (2.4%)                                        | 63 (2.8%)                                 | 66 (3.0%)                         | 76 (3.9%)                                     | 66 (3.1%)                                     | 63 (2.8%)                                     | 63 (2.8%)                                     | 82 (4.3%)                                       | 92 (5.0%)                                       |

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A. Annual growth in the number of new cases from NORCAN: 10% decrease in monthly death risk, and no changes in monthly unit costs (costs as reported in Fig. 1).

B. Assuming a 3% increase in the number of new cases (compared with 2.4% reported by NORCAN). Lifetime costs per new cancer case assumed to be equal to 2017 numbers (as reported in Table 1).

C. Annual growth in the number of new cases from NORCAN: 30% increase in monthly unit costs (reported in Fig. 1) in all phases (C1), initial phase (C2), continuing phase (C3), and terminal phase (C4) and no changes in death risk (prognosis).
Canada,\textsuperscript{[6]} and New Zealand\textsuperscript{[16]} our results suggest that there is an association between 5-year relative survival and cancer-related lifetime costs. Cancers with very poor prognosis and cancers with a relatively good prognosis tend to have low costs compared with those with a 5-year relative survival of 50% to 70%. Previous research also finds differences in costs between genders and these findings suggest that males may have higher treatment costs than females for the majority of cancer types.\textsuperscript{[5,6]}

In our study, estimated lifetime costs were higher for males in 9 out of 10 non-gender-specific cancers. Only urinary tract had higher costs for females (lifetime costs were marginally higher for females), a cancer which males tend to have better survival when compared with females.\textsuperscript{[30,31]} Differences in cancer stage and age at the time of diagnosis and prognosis may explain some or all of the differences in costs. However, even for cancers with almost equal stage distribution at the time of diagnosis (colon, lung, and pancreatic cancer), males had higher lifetime costs when compared with females.

In contrast to other studies, we use gender and cancer-specific lifetime costs to develop scenarios for future treatment costs. Our results suggest that melanoma, kidney, pancreatic, and prostate cancer is expected to have a relatively high growth in coming years, while the growth in lung and cervical cancer costs is expected to be modest. The introduction of new costly treatment options (better overall survival) and screening programs may be of great importance for the future costs of some cancers (e.g., lung cancer).

Our findings may be important for policymakers for several reasons. First, timely gender- and cancer-specific estimates of cancer treatment costs are important for assessing equity of care and to better understand resource consumption associated with different cancers. For example, our results may indicate that cancer-related lifetime costs in Norway are higher for males when compared with females. Additionally, our results suggest a relationship between 5-year relative survival and treatment costs. Second, few studies of lifetime costs in public health care systems compared with females.

The remaining 35% include primary care (2.7%), institutional care and home nursing services (16.7%), out-patient diagnostics imaging and laboratory services (6.6%), pharmacy dispensed drugs (7.8%), and other non-patient-related costs in hospitals (research and development , capital costs, ambulance services, etc) (1.9%).\textsuperscript{[34]} We did not have long-term data to estimate costs in the continuing phase, and estimates were based on years 4, 5, 6, and 7 after diagnosis for patients diagnosed in 2010. The treatment intensity may be higher in these years as compared with longer follow-up and costs in the continuing phase may be slightly overestimated. To ensure comparability we employed the same length for all phases. However, for some cancers, the initial treatment phase may extend beyond the first year (e.g., hormonal therapy for breast cancer). Finally, predictions of future costs are by nature associated with much uncertainty. Structural changes over time in technology and medical practice will likely affect future lifetime costs as survival and unit costs change.

In conclusion, cancers with an intermediate prognosis (50%–70% 5-year relative survival) are associated with higher direct medical costs than those with relatively good or poor prognosis. Additionally, our results suggest that costs of treating male patients are higher compared with females. Future research should investigate possible explanations of these differences.

**Author contributions**

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