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

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 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.ancr.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[5] 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.[5,6]

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.[24] 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.[25,26] 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).[27] 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.[27] 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 $Lifetime\ costs\ (t_T) = \sum_{t=1}^{T} \hat{S}(t) C_t$ where $\hat{S}(t)$ 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.[11]

Lifetime costs were expressed in 2017 Euros using a 4% real (inflation-adjusted) discount rate according to national guidelines.[28]

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 $L(I) = \min(12, t_T - t_0 - L[T])$, 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.[5,6,15,29]

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.[3] 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).
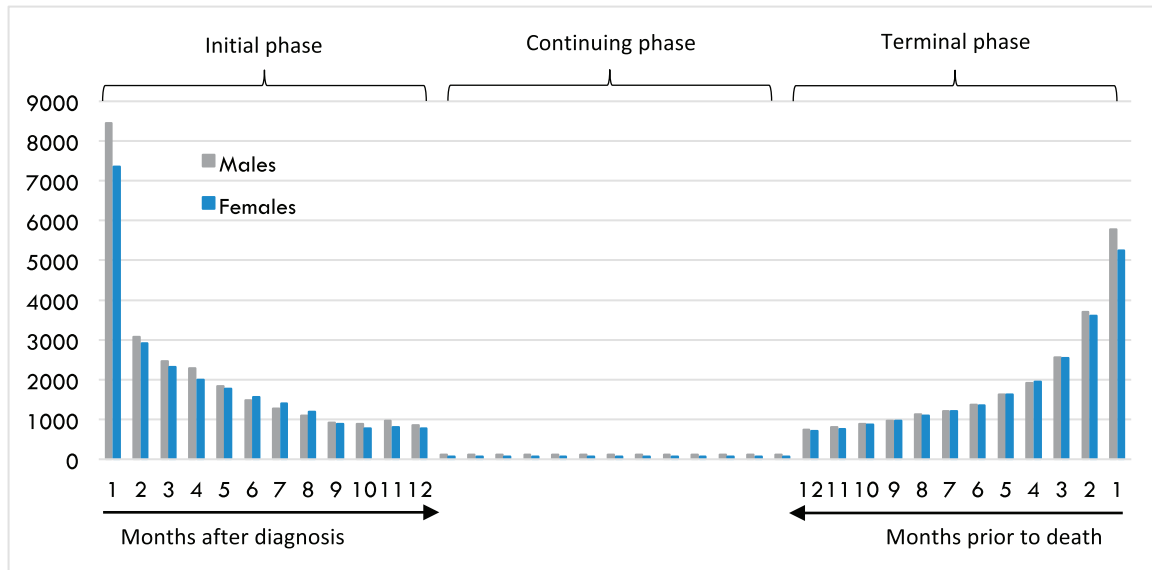
Figure 1. Mean monthly undiscounted direct medical costs in hospitals after diagnosis per patient 2017-EUR (1 EUR = 9.8 NOK).

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).

Estimates of lifetime costs varied widely across cancers, reflecting differences in survival and phase-specific unit costs. Discounted mean lifetime costs for all cancers combined were EUR 40,608 for males and EUR 36,921 for females (48,967 and 45,427 undiscounted). For all patients combined, costs were

highest in the initial phase (EUR 21,808), followed by the terminal phase (EUR 12,085), and the continuing care phase (EUR 4347). Cancers with the highest lifetime costs per patient were myeloma (EUR 89,686), mouth/pharynx (EUR 66,619), non-Hodgkin lymphoma (EUR 65,528), and colon cancer (EUR 57,303), while melanoma of the skin (EUR 25,363), urinary tract (EUR 33,839), cervical cancer (EUR 38,294), and kidney cancer (EUR 39,561) were associated with the lowest lifetime costs.

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),

Table 1

Lifetime direct medical costs in hospitals and cost by phase per patient 2017-EUR (1 EUR = 9.8 NOK), 2017.

	Months in phase			Discounted (EUR)				Undiscounted (EUR)			
	Initial	Cont.	Terminal	Initial	Cont.	Terminal	Total	Initial	Cont.	Terminal	Total
All cancers											
All patients	10.2	96.9	7.7	21,808	4347	12,085	38,241	22,018	8757	15,274	46,049
Males	10.1	87.4	8.2	22,565	4952	13,091	40,608	22,776	9700	16,490	48,967
Females	10.3	106.8	7.3	21,137	3898	11,887	36,921	21,344	8038	16,045	45,427
mouth, pharynx											
All patients	10.6	89.7	8.5	40,303	4892	21,424	66,619	40,581	9616	26,940	77,137
Males	10.5	85.8	8.7	41,681	4807	23,977	70,465	41,960	9390	30,020	81,370
Females	10.7	96.7	8.2	37,838	5095	17,863	60,796	38,114	10,114	23,271	71,499
colon, rectum, rectosigmoid											
All patients	10.2	81.0	8.7	37,070	4960	15,273	57,303	37,388	9503	19,308	66,199
Males	10.2	77.1	8.9	38,277	5656	16,742	60,675	38,617	10,738	21,069	70,424
Females	10.3	84.8	8.6	35,725	4241	14,050	54,016	36,019	8191	18,150	62,359
Pancreas											
All patients	5.0	8.6	5.6	28,663	1294	18,100	48,057	28,865	2370	18,974	50,209
Males	5.0	8.2	5.6	29,464	1809	18,964	50,238	29,672	3201	19,930	52,803
Females	4.9	8.8	5.5	27,828	887	17,324	46,039	28,025	1674	18,210	47,909
lung, trachea											
All patients	7.0	20.6	7.3	28,243	2816	17,451	48,510	28,452	5028	19,116	52,596
Males	6.7	16.4	7.1	28,499	2519	17,921	48,940	28,709	4405	19,428	52,542
Females	7.5	26.8	7.6	28,105	3161	17,059	48,324	28,316	5764	19,218	53,299
melanoma											
All patients	11.5	147.2	6.4	11,260	5057	9045	25,363	11,409	10,832	12,101	34,342
Males	11.4	130.7	7.2	12,512	5805	11,380	29,698	12,678	12,184	14,970	39,832
Females	11.7	162.8	5.6	9913	4301	8091	22,305	10,041	9353	12,325	31,720
breast											
Females	11.7	148.2	7.0	40,775	6537	11,514	58,826	41,188	13,742	19,234	74,163
cervix uteri											
Females	11.3	155.5	5.1	20,002	3223	15,068	38,294	20,138	7158	25,687	52,983
prostate											
Males	11.5	109.0	9.7	40,526	4417	7871	52,815	40,934	8340	10,898	60,172
kidney (excl. renal pelvis)											
All patients	10.2	96.0	8.2	22,691	5175	11,695	39,561	22,822	10,213	15,130	48,165
Males	10.3	93.9	8.4	23,341	6349	12,773	42,464	23,477	12,439	16,532	52,448
Females	10.1	99.4	7.9	21,416	3379	9861	34,655	21,539	6739	13,053	41,331
urinary tract											
All patients	10.7	88.6	9.0	18,516	5699	9624	33,839	18,679	10,843	12,392	41,915
Males	10.8	88.7	9.1	18,420	6086	9317	33,823	18,583	11,514	11,998	42,095
Females	10.3	88.2	8.7	18,782	4822	10,376	33,979	18,942	9319	13,354	41,616
non-Hodgkin lymphoma											
All patients	10.3	104.6	7.4	35,738	12,942	16,848	65,528	36,038	26,290	21,534	83,861
Males	10.3	101.2	7.4	38,015	13,014	19,044	70,073	38,337	26,466	24,040	88,843
Females	10.4	108.8	7.4	32,795	12,796	14,322	59,913	33,065	25,974	18,675	77,714
leukemia											
All patients	10.0	91.0	7.3	30,902	6962	16,845	54,709	31,250	14,065	20,482	65,797
Males	10.1	87.9	7.2	33,416	6257	18,043	57,717	33,803	12,601	22,411	68,815
Females	10.0	94.8	7.4	27,890	7760	15,329	50,978	28,192	15,733	18,502	62,427
multiple myeloma											
All patients	10.0	45.2	9.7	40,045	25,632	24,009	89,686	40,472	42,590	28,653	111,715
Males	10.1	46.7	9.7	42,167	26,908	24,652	93,728	42,603	45,206	29,474	117,283
Females	10.0	43.4	9.8	37,355	24,195	23,063	84,614	37,771	39,628	27,326	104,725

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,[5]

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).

	2016	2034* (Annual growth %)								
		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%)	285 (2.0%)	292 (2.2%)	365 (3.4%)	447 (4.6%)
Cervix 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 (3.99%)	66 (3.1%)	63 (2.8%)	63 (2.8%)	82 (4.3%)	92 (5.0%)

* NORCAN reports average yearly incidence for the period 2032 to 2036. As a simplification the predicted incidence was assumed to occur in 2034.
† Assuming changes in the number of new cancer cases as reported by NORCAN. Lifetime costs per new cancer case assumed to be equal to 2017 numbers (as reported in Table 1).
A. Annual growth in the number of new cases from NORDCAN, 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 NORDCAN). Lifetime costs per new cancer case assumed to be equal to 2017 (as reported in Table 1).
C. Annual growth in the number of new cases from NORDCAN, 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,[6] and New Zealand[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.[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.[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 in Europe have been published, and current estimates found in the literature need to be updated. Incidence-based cost estimates are particularly relevant when policymakers evaluate different prevention and screening strategies, as lifetime costs give information on the potential resources the health care sector could save by preventing a new cancer case.[32] Third, scenarios for future treatment costs can aid policymakers in planning of future health care and increase understanding of how key factors such as incidence, survival, and unit costs influence the total health care costs. Policymakers must decide whether to increase capacity within all areas of oncology, or if some specialties should be prioritized. Projections of future costs by cancer site are useful for identifying future growth areas and to evaluate possible measures for cost containment.

There are several advantages of using registry data from a national health care system to estimate cancer-related treatment costs. Frist, the data cover the entire Norwegian population as cancer treatment in private hospitals is negligible. Additionally, the use of individual personal identification numbers allows patients to be followed over time after diagnosis. Second, all episodes of care are assigned a diagnostic code which enables us to estimate attributable costs because we know which treatment episodes are related to cancer. Third, DRG-weights and DRG-unit price used to estimate costs include all patient-related costs and are based on cost per patient calculation from reported accounting figures from Norwegian hospitals. This enables us to estimate the actual resource use (economic costs), and we avoid problems that arise when the market price differs from the actual resource use needed to produce the service (e.g., out of pocket payments).

Despite the strength of a large national sample, our study has several limitations. Due to legal restrictions, we were not able to link NPR and CRN data. However, previous studies indicate that the diagnostic codes in NPR are valid when compared with data from CRN and misclassification of patients is unlikely to influence our results.[33] Our data did not allow for a net cost strategy (differences in costs between cancer patients and matched non-cancer patients) due to lack of information about non-cancer patients. Although the attributable cost strategy is fairly straightforward, we may run the risk of underestimating cancer-related costs because some costs are attributed to other diseases (e.g., costs associated with heart problems arising downstream from the cardiotoxicity associated with chemotherapy may not show up in the data as a cancer-related episode if the ICD-10 coding indicates cardiovascular disease).

Cancer stage at the time of diagnosis is presumably of great importance for the treatment intensity and thereby the costs. For melanoma, several patients with local disease undergo relatively simple treatment (surgical excision of the primary melanoma) and are associated with low costs compared with patients with distant metastases, thus contributing to a low average cost. We only included patient-related hospital costs which account for approximately 65% of the direct health care costs in Norway.[34] 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%).[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.

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