ACTA ONCOLOGICA
2019, VOL. 58, NO. 5, 737–744
https://doi.org/10.1080/0284186X.2019.1566772

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE



# Socioeconomic inequality in cancer survival – changes over time. A population-based study, Denmark, 1987–2013

Susanne Oksbjerg Dalton[a,b], Maja Halgren Olsen[a], Christoffer Johansen[a,c], Jørgen H. Olsen[a] and Kaae Klaus Andersen[a]

[a]Danish Cancer Society Research Center, Survivorship, Copenhagen, Denmark; [b]Department of Oncology, Zealand University Hospital, Naestved, Denmark; [c]Department of Oncology, Copenhagen University Hospital, Copenhagen, Denmark

**ABSTRACT**

**Background:** Socioeconomic inequality in survival after cancer have been reported in several countries and also in Denmark. Changes in cancer diagnostics and treatment may have changed the gap in survival between affluent and deprived patients and we investigated if the differences in relative survival by income has changed in Danish cancer patients over the past 25 years.

**Methods:** The 1- and 5-year relative survival by income quintile is computed by comparing survival among cancer patients diagnosed 1987–2009 to the survival of a cancer-free matched sample of the background population. The comparison is done within the 15 most common cancers and all cancers combined. The gap in relative survival due to socioeconomic inequality for the period 1987–1991 is compared the period 2005–2009.

**Results:** The relative 5-year survival increased for all 15 cancer sites investigated in the study period. In general, low-income patients diagnosed in 1987–1991 had between 0% and 11% units lower 5-year relative survival compared with high-income patients; however, only four sites (breast, prostate, bladder and head & neck) were statistically different. In patients diagnosed 2005–2009, the gap in 5-year RS was ranging from 2% to 22% units and statistically significantly different for 9 out of 15 sites. The results for 1-year relative survival were similar to the 5-year survival gap. An estimated 22% of all deaths at five years after diagnosis could be avoided had patients in all income groups had same survival as the high-income group.

**Conclusion:** In this nationwide population-based study, we observed that the large improvements in both short- and long-term cancer survival among patients diagnosed 1987–2009. The improvements have been most pronounced for high-income cancer patients, leading to stable or even increasing survival differences between richest and poorest patients. Improving survival among low-income patients would improve survival rates among Danish cancer patients overall and reduce differences in survival when compared to other Western European countries.

**ARTICLE HISTORY**
Received 25 October 2018
Accepted 21 December 2018

## Background

Survival is a key measure of the overall effectiveness of health care services in the management of cancer and fortunately, survival is increasing for most cancer sites in all countries [1]. However, it has been consistently reported that cancer patients from socioeconomically disadvantaged groups have poorer survival than patients from socioeconomically advantaged groups [2–4]. We have previously demonstrated a marked social inequality in relative survival for almost all major cancer sites in Denmark, even though the Danish health care system ensures tax-funded and equal access to health care at all levels from the GP to the highly specialized oncologist [5].

Socioeconomic position, for example, measured by education, income or a deprivation index is a proxy for health behavior, symptom perception, communication with health care professionals and adherence to health services, that is, participation in screening programs or to treatment recommendations [6,7].

Only few studies that have investigated socioeconomic inequality on cancer survival over time. These studies have either shown no change in disparities or a widening of disparities for several major cancers [8–13]. In Denmark, cancer survival rates have been lower than many other Western countries through several decades. Improving survival among disadvantaged cancer patients would narrow the difference in survival between the most advantaged and disadvantaged cancer patients and improve overall survival rates significantly in the population. The purpose of this study is to investigate to what extent socioeconomic inequality, as measured by income at the individual level, is associated with trends in 1-year and 5-year relative

CONTACT Susanne Oksbjerg Dalton sanne@cancer.dk Survivorship, Danish Cancer Society Research Center, Strandboulevarden 49, Copenhagen DK 2100, Denmark

Supplemental data for this article can be accessed here.

survival after cancer in Denmark over a period of the past 25 years.

## Material and methods

The study is based on a nationwide sample of cancer patients and cancer-free comparisons persons embedded in the total of 5.6 million persons living in Denmark in 1987–2009 and for whom there is information available in the nationwide administrative and health registries. The analyses are based on a registry-based linkage by means of the unique person identification number which since 1968 has been assigned to all residents of Denmark [14]. Individual information on income was obtained from the Income Statistics Register [15]. Information on date of cancer diagnosis and diagnosis code according to the WHO International Classification of Diseases, 10th revision (IDC-10), was obtained from the Danish Cancer Registry [16]. Updated information on vital status and emigration was obtained from the Central Population Registry [14].

### Cancer cohort

We identified all ($N = 142{,}430$) persons $\geq$20 years of age who were diagnosed with a first, invasive, primary, malignant neoplasm (except non-melanoma skin cancer) in Denmark from 1987 through 2009. We analyzed the 15 most common cancers in Denmark covering about 85% of all cancers, including cancers of the breast (ICD-10, C50), lung (C33-C34;C39), prostate (C61), colon (C18-C19), melanoma (C43), bladder (C67), head and neck (C00-C15;C32), CNS (C71-C72), rectum (C20), non-Hodgkin lymphoma (NHL) (C82-C85), pancreas (C25), endometrium (C54), kidney (C64), ovary (C56) and stomach (C16), as well as all cancers combined (except non-melanoma skin cancer).

### Matched cancer-free comparison cohort

For each cancer case, we sampled at random with replacement 100 population comparisons matched on age (born same month and year), gender and disposable income, and without cancer on index date, that is, date of diagnosis of the cancer patient.

### Socioeconomic position

Individual disposable income in the year prior to diagnosis was used as the indicator for socioeconomic position. For each person, the disposable income was calculated as the percentile in the age and gender-specific distribution. For modeling the percentiles were divided into quintiles. Thus, the first quintile denotes the 20% with lowest income and the 5th quintile denotes the 20% with highest income. Persons for whom information on income was missing were excluded (<1%).

### Vital status

We obtained information on vital status and emigration through 2014 for all persons in the study population using death of all causes as outcome.

## Methods

For the comparison of incidence over time, we compared standardized incidence rates for the two time periods 1987–1991 and 2005–2009.

We estimated 1-year and 5-year relative survival (RS) for cancers diagnosed between 1987–1991 and 2005–2009, that is, survival of cancer patients relative to that of the matched background population sample. This was done for each income quintile separately. To adjust for age-, gender- and period-related differences between income quintiles and to allow for a comparison of relative survival we applied age and gender-specific weights derived from the entire cancer cohort, that is, direct standardization.

The survival gap for a given cancer site and period was defined as the difference in 1- and 5-year relative survival, respectively, between the lowest and highest income quintile. All estimates were given with 95% confidence intervals. Intervals not including zero where taken as statistical evidence for a survival gap. We estimated the number of 5-year survivors potentially gained by calculating the hypothetical total number of 5-years survivors assuming that everybody had a RS corresponding to that of the highest income quintile. The potentially gained number of 5-year survivors is then the difference from the actual number of 5-year survivors compared to the hypothetical number. The uncertainty in both the number of cases (assumed Poisson distributed) and the estimated 5-year relative survival was taken into account when bootstrapping the 95% confidence interval for the number of potentially extended lives. All analysis was performed using the statistical software R (R Core Team 2013).

## Results

In the period between 1987–1991 and 2005–2009, the Danish age-standardized incidence rates (IR) (except for ovary and stomach cancer) and 1- and 5-year RS increased for all considered cancer sites (Table 1 for IR and 5-year RS; results for 1-year survival not shown). Five-year RS increased considerably for many cancers with a medium or good prognosis as breast, colon, rectum, NHL, and kidney cancer with increases in 5-year RS ranging from 15% to 25% units. The largest increase in age-standardized IR and 5-year RS was observed for prostate cancer (change in age-standardized IR, 123; 95% CI 119–126 per 100,000 and change in 5-year RS, 48%; 95% CI 47–50%, respectively) (Table 1).

Figure 1 (showing the five most frequent cancers) and 1S (depicting the remaining 10 cancers analyzed) illustrate the increase in observed survival by cancer type over the period, with a clear stepwise improved observed survival between quintiles of income (for the sake of clarity, we show only

**Table 1.** Age-standardized incidence rates and 5-years observed and relative survival for the 15 most common cancers and all sites combined among persons aged above 20 diagnosed in Denmark 1987–1991 and 2005–2009.

| Cancer site | Incident cases 2005–2009 | Age standardized IR 2005–2009 | Change in age standardized IR from 1987–1991 to 2005–2009 | 5-yr OS in patients diagnosed 2005–2009 | 5-yr RS in patients diagnosed 2005–2009 | Change in 5-yr RS (%-units) from patients diagnosed in 1987–1991 to 2005–2009 |
|---|---|---|---|---|---|---|
| | N | per 100 000 | per 100 000 (95% CI) | % | % | % (95% CI) |
| Breast | 22 389 | 211.6 | 69.3 (65.7–72.9) | 80.0 | 88.1 | 16.8 (16.0–17.7) |
| Lung | 20 730 | 99.4 | 17.1 (15.3–19.0) | 10.9 | 12.7 | 6.8 (1.7–11.8) |
| Prostate | 20 474 | 199.5 | 122.5 (119.2–125.7) | 68.3 | 91.1 | 48.4 (47.2–49.6) |
| Colon | 13 161 | 63.1 | 11.1 (9.7–12.6) | 46.0 | 58.0 | 15.3 (13.1–17.6) |
| Bladder | 8695 | 41.7 | 2.6 (1.4–3.9) | 58.4 | 72.4 | 10.4 (8.4–12.5) |
| Melanoma | 7660 | 36.7 | 18.5 (17.5–19.5) | 81.3 | 89.2 | 10.9 (9.4–12.3) |
| Rectum | 6861 | 32.9 | 5.6 (4.5–6.6) | 51.4 | 63.5 | 23.2 (20.3–26.0) |
| Pancreas | 4436 | 21.3 | 3.8 (3.0–4.7) | 4.1 | 5.2 | 3.6 (−16.0–22.8) |
| NHL | 4434 | 21.2 | 6.0 (5.2–6.9) | 59.8 | 69.2 | 24.0 (20.7–27.3) |
| Head and Neck | 3928 | 18.8 | 4.6 (3.9–5.4) | 48.7 | 55.9 | 8.4 (4.7–12.2) |
| CNS | 3593 | 17.2 | 4.3 (3.5–5.0) | 39.8 | 42.2 | 13.9 (8.8–19.2) |
| Endometrium | 3417 | 32.3 | 1.2 (−0.3–2.7) | 73.5 | 83.0 | 6.8 (4.6–9.1) |
| Kidney | 3113 | 14.9 | 2.0 (1.3–2.7) | 47.6 | 56.8 | 24.6 (19.8–29.3) |
| Ovary | 2825 | 26.7 | −2.0 (−3.4–0.6) | 37.7 | 41.5 | 12.0 (6.5–17.4) |
| Stomach | 2733 | 13.1 | −3.8 (−4.6–3.1) | 16.3 | 20.6 | 8.5 (−1.0–18.0) |
| All sites | 142 430 | 686.1 | 123.4 (118.5–128.2) | 52.2 | 61.8 | 19.3 (18.3–20.0) |

CI: confidence intervals; CNS: central nervous system; IR: incidence rate; NHL: non-Hodgkin lymphoma; OS: observed unweighted survival; RS: relative survival; All sites excluding nonmelanoma skin cancer.

quintiles 1, 3 and 5). Both among prostate cancer and breast cancer patients, the survival among patients in income quintile 5 is approaching that of the cancer-free population with time. Among lung cancer patients, survival also increased for all income groups, and the differences in survival by income seem smaller than that of the background population. In contrast, for colon cancer patients the difference seem to widen over time, while the survival differences by income in the background population survival were stable. For bladder cancer patients, survival differences by income seem stable in both the background and cancer population (Figure 1).

The largest increases in the survival gap were observed among patients with colon, rectum and head and neck cancers (Figure 2(S) and Table 1S for 1-year survival and Figure 2 and Table 2 for 5-year survival. Starting with no difference in survival, colon cancer patients with the highest income increased their 5-year RS by 19% units (from 43% to 62%), while the lowest income patients increased 5-year RS by 11% units (from 42% to 53%). For rectum cancer patients, corresponding increases in 5-year RS were 26% units among highest income patients (from 41% to 67%) and 20% units in lowest income patients (from 36% to 56%). For head and neck cancer patients, the highest income patients increased 5-year RS by 13% units (from 52% to 65%), while lowest income patients hardly increased 5-year RS at all (from 41% to 44%), respectively. For bladder cancer and melanoma, there was considerable increasing survival differences through the study period with a statistically significant gap in 5-year RS by income among patients diagnosed in 2005–2009. For cancer of the breast, lung and kidney, inequalities by income in 5-year RS remained stable during the study period. Conversely, for example, prostate cancer and non-Hodgkin lymphoma, inequality remained but actually decreased by time, indicating slightly reducing differences over the period although confidence intervals of the gap estimates overlap (Table 2 and Figure 2(B)).

Among those cancers with a statistically significant gap in 5-year RS, the number of potential 5-year survivors that could be gained ranged from 102 (95% CI, 10–198) among non-Hodgkin lymphoma patients to 729 (95% CI, 528–954) among colon cancer patients, had all patients diagnosed in 2005–2009 had the same survival as patients in the highest income quintile (Table 3). In total, had all Danish cancer patients in income quintiles 1–4 who were diagnosed in 2005–2009 had the same survival as those patients in income quintile 5, more than 11,000 5-year survivors would have been gained, corresponding to 22% of all patients who died before 5 years (Table 3).

## Discussion

Our study suggests that although relative survival of the 15 most common cancers has improved in Denmark over the past 20 years, cancer patients with the highest income seem to have benefited more from advances in cancer diagnostics and treatment, widening the socioeconomic inequality in survival. The magnitude of this inequality is not trivial as a substantial number of lives could potentially be extended if these survival disparities could be eliminated through improving outcomes of patients with lower income.

Population-based studies from England/Wales [13] and Scotland [12] support our findings, observing that differences in 5-year relative survival between patients living in affluent vs. deprived areas widened significantly between patients diagnosed in the late 1980s vs. late 1990s. A later population study from England including 21 common cancers found that the deprivation gap in relative survival slightly decreased for 1-year survival but not for 3-year survival from 1996 to 2006 [11]. Another English population-based study found that inequality in relative survival after breast cancer decreased between 1973–2004 narrowing the gap from 10% to 6% difference, while, like in the present study, inequalities in rectal cancer survival, doubled over the period from a

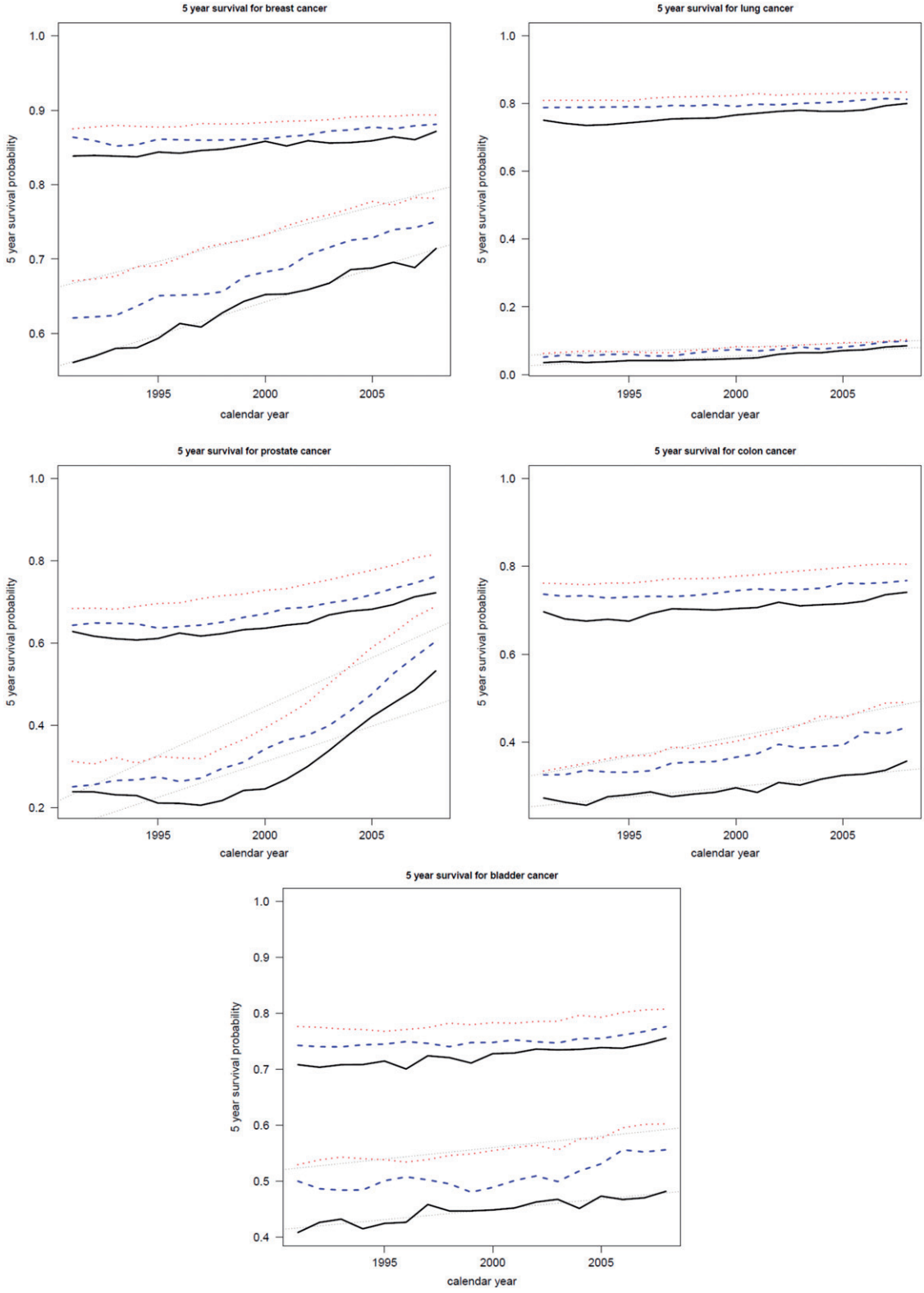


**Figure 1.** 5-year survival in patients with cancer of the breast, prostate, lung, colon and bladder diagnosed from 1987 to 2009 and corresponding 5-year survival in cancer-free matched controls by 1 (red-dotted line), 3 (blue-dashed line) and 5 (black line) income quintile, Denmark 1987–2013. Upper three lines reflect survival in cancer-free matched controls and lower three lines survival in cancer patients. Please note that y-axes differ by cancer site.

relative survival gap of 5% to 10% units [10]. A population-based study from Osaka, Japan found no obvious changes in five-year net survival between patients living in affluent vs. deprived areas in the period 1993–2004, except for a modest increase in inequality for lung cancer survival among men [9]. In a recent population-based study from New South Wales, Australia, inequality in relative survival by area-based deprivation was either stable or increasing in the 10 most common cancers between 1996 and 2008 [8]. Our study, based on individual-level measure and hence more precise

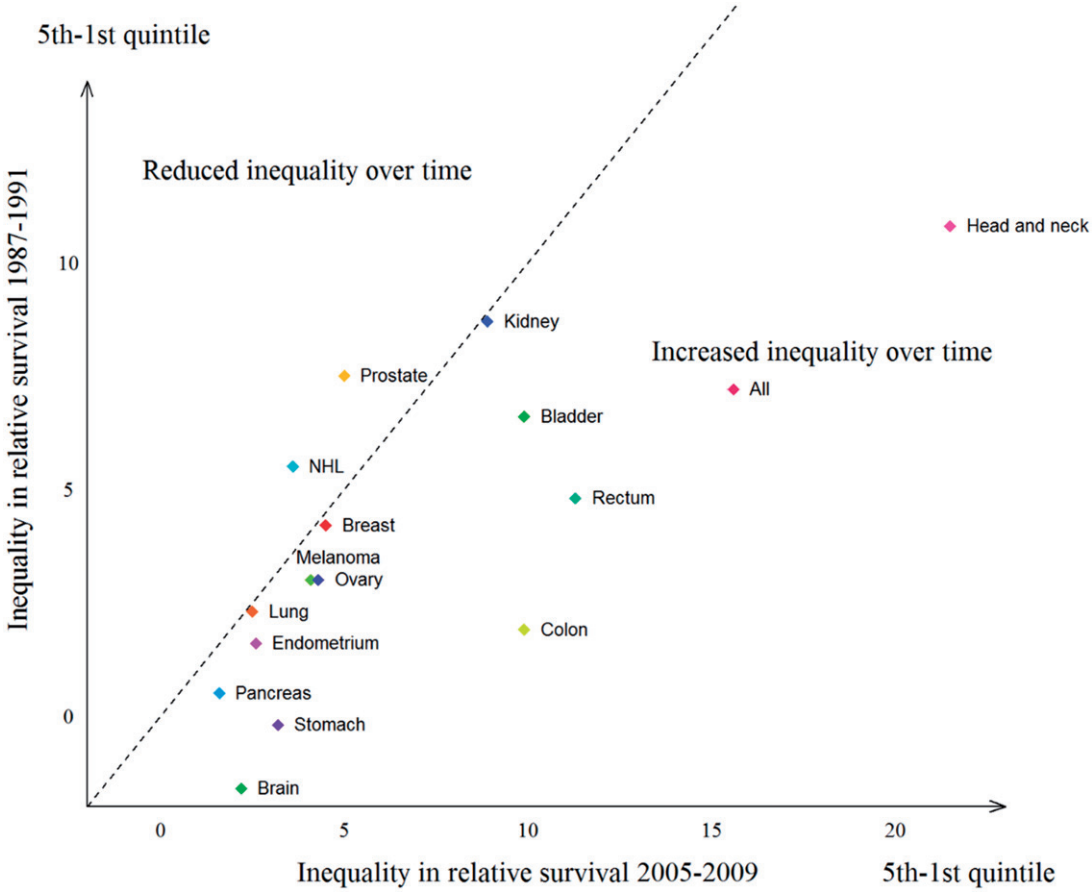


**Figure 2.** Differences in 5-year relative survival between high (5 quintile) and low income (1 quintile) patients in %-units for the 15 most common cancer sites and all cancer combined diagnosed 1987–1991 vs. 2005–2009, respectively.

measurement of socioeconomic position, reveal a rather stable survival gap between richest and poorest, that is, breast, lung or kidney cancer patients in Denmark and even a tendency to a slight decrease in survival gap among prostate cancer and NHL patients; however, we still observe that for many common cancers the gap has widened considerably over the past decades.

Among patients with colon and rectum cancers, the improvement in survival of the poorest patients was much less than that observed amongst the richest patients – leading to the largest widening in survival gap over the period and to some of the largest gaps by income among the examined cancers. In a study among Danish colorectal cancer patients diagnosed 2001–2004, differences in survival by socioeconomic position were partly mediated by comorbidity and to a lesser extent lifestyle, but not by differential access to surgical treatment [17]. Adjuvant treatment of colorectal cancer has gradually been introduced over the past decades and is currently offered to about a third of patients. Further studies of early diagnostics, access to treatment and comorbidity in the setting of more complex treatments are called for to point to possible interventions targeting the rapidly increasing inequality in Danish colorectal cancer survival.

The large increase in inequality in survival for head and neck cancer was observed despite only a minor increase in incidence. Changes in the incidence of head and neck cancer sub-sites over the period [18] may have led to a larger proportion of patients being diagnosed with HPV-positive oropharynx cancer, which are characterized by better prognosis and higher socioeconomic position [19] thus potentially increasing inequality over time. In line with this, a population-based study from Canada reported a widening difference in survival between highest and lowest income quintiles between 1992 and 2005 for oropharynx cancer, but not for oral cavity cancer or other head and neck cancers [20].

The pronounced increase in prostate cancer incidence and survival probably reflects increased use of PSA-testing, which has enabled detection of asymptomatic prostatic cancers, and thus, in and of itself, increased incidence and improved survival [21,22]. Improvements in treatment of this cancer may, however, override any socioeconomic differences in PSA-testing in the period and thus contribute to the observed indication of an actual decrease in socioeconomic inequality in survival over time. The survival of the most affluent patients with prostate cancer and breast cancer patients is approaching that of the cancer-free population, reflecting that while observed survival for cancer patients might be changing over time, similar changes affect the background population without cancer.

Statistically significant inequality persistently exist in survival after nine of the 15 most common cancers in Denmark. The %-unit difference in RS between poorest and richest patients of all sites were, however, larger than that observed

**Table 2.** 5-year relative survival (proportion) among patients with highest income (5th quintile) and the difference in 5-year relative survival between patients in 5th quintile and in 1st quintile of income (%-units) for the 15 most common cancers and all sites combined, Denmark 1987–1991 and 2005–2009.

| Cancer site | 5-yr RS 1987–1991 5th quintile % (95% CI) | Difference in 5-yr RS 1st-5th quintile 1987–1991 % (95% CI) | 5-yr RS 2005–2009 5th quintile % (95% CI) | Difference in 5-yr RS 1st-5th quintile 2005–2009 % (95% CI) |
|---|---|---|---|---|
| Breast | 74.9 (74.0–75.9) | −4.2 (−6.0 to −2.5) | 90.1 (89.5–90.7) | −4.5 (−5.5 to −3.6) |
| Lung | 7.7 (7.2–8.2) | −2.3 (−11.6–6.8) | 13.6 (13.1–14.2) | −2.5 (−8.4–3.4) |
| Prostate | 44.8 (43.2–46.5) | −7.5 (−12.7 to −2.7) | 87.5 (86.7–88.4) | −5.0 (−6.4 to −3.7) |
| Colon | 43.4 (42.2–44.6) | −1.9 (−6.0–2.1) | 62.4 (61.2–63.6) | −9.9 (−12.5 to −7.2) |
| Bladder | 66.9 (65.4–68.5) | −6.6 (−9.9 to −3.3) | 75.7 (74.3–77.2) | −9.9 (−12.5 to −7.2) |
| Melanoma | 80.1 (78.3–81.8) | −3.0 (−6.1–0.0) | 91.1 (90.1–9.1) | −4.1 (−5.6 −2.6) |
| Rectum | 41.3 (39.6–43.0) | −4.8 (−10.8–0.9) | 67.0 (65.4–68.6) | −11.3 (−14.7 to −3.4) |
| Pancreas | 1.9 (1.4–2.5) | −0.5 (−44.1–40.4) | 5.7 (4.9–6.6) | −1.6 (−22.6-19.3) |
| NHL | 48.0 (45.8–50.3) | −5.5 (−12.1–0.9) | 71.0 (69.2–72.8) | −3.6 (−7.1 to −0.1) |
| Head and Neck | 52.2 (49.9–54.7) | −10.8 (−17.4 to −4.1) | 65.3 (63.1–67.5) | −21.5 (−26.3 to −16.8) |
| CNS | 32.4 (30.5–34.4) | 1.6 (−7.0–10.0) | 44.2 (42.4–46.1) | −2.2 (−8.2–3.7) |
| Endometrium | 78.6 (76.7–80.6) | −1.6 (−5.1–2.0) | 82.3 (80.6–84.0) | −2.6 (−5.5–0.4) |
| Kidney | 38.5 (36.0–41.1) | −8.7 (−18.0–0.5) | 58.1 (56.0–60.4) | −8.9 (−14.1 to −3.4) |
| Ovary | 34.6 (32.6–36.7) | −3.0 (−11.4−5.5) | 40.6 (38.7–42.6) | −4.3 (−11.1–2.5) |
| Stomach | 12.2 (11.0–13.5) | 0.2 (−14.4–14.3) | 19.7 (17.9–21.6) | −3.2 (−16.2–9.9) |
| All sites | 46.2 (45.9–46.6) | −7.2 (−8.4 to −6.0) | 68.5 (68.2–68.9) | −15.6 (−16.3 to −14.8) |

CI: confidence interval; CNS: central nervous system; NHL: non-Hodgkin lymphoma; RS: relative survival; All sites excluding non-melanoma skin cancer.

**Table 3.** Number of cancer-related early deaths (<5 years) and estimated increase in number and proportion of 5-year survivors among cancer patients diagnosed in Denmark 2005–2009, had patients in income quintile 1–4 had the same 5-year relative survival as patients in income quintile 5.

| Cancer site | Number of cancer-related early deaths (<5 years) *N* | Estimated gain in 5-year survivors among patients diagnosed 2005-9 *N* (95% CI) | Proportion of early deaths potentially converted to 5-year survivors excess among patients diagnosed 2005-9 % |
|---|---|---|---|
| Breast | 2664 | 557 (435–698) | 20.9 (16.3–26.2) |
| Lung | 18105 | 304 (−505–1187) | 1.7 (−2.8–6.6) |
| Prostate | 1822 | 640 (486–802) | 35.1 (26.7–44.0) |
| Colon | 5528 | 729 (528–954) | 13.2 (9.6–17.3) |
| Bladder | 2400 | 491 (333–639) | 20.5 (13.9–26.7) |
| Melanoma | 827 | 112 (42–180) | 13.5 (5.1–21.8) |
| Rectum | 2329 | 384 (234–531) | 16.5 (10.0–22.8) |
| Pancreas | 4205 | 61 (−544–658) | 1.5 (−10.5–15.6) |
| NHL | 1366 | 102 (10–198) | 7.1 (0.7–14.5) |
| Head and Neck | 1732 | 488 (362–629) | 28.2 (20.9–36.3) |
| CNS | 2077 | 42 (−93–172) | 2.0 (−4.5–8.3) |
| Endometrium | 581 | −8 (−70–52) | 0 |
| Kidney | 1345 | 120 (3–231) | 8.9 (2.2–17.2) |
| Ovary | 1653 | −23 (−141–97) | 0 |
| Stomach | 2170 | 61 (181–292) | 2.8 (−8.3–13.5) |
| All sites | 54,408 | 11,737 (11,104–12,370) | 21.6 (20.4–22.7) |

Cancer-related early deaths, observed minus expected number of deaths prior to 5 years from cancer diagnosis; Potentially postponed deaths, if patients in all income quintiles had had same 5-year RS as patients in the 5th quintile of income.
CI: confidence interval; CNS: central nervous system; NHL: non-Hodgkin lymphoma. All sites excluding non-melanoma skin cancer.

in most of the investigated 15 cancer sites. This may be due to even larger differences in survival by income in cancers outside the 15 most frequent disease groups but may also reflect that more cancers with an overall poor prognosis and poorer relative survival affect persons with low income [5]. The lower survival among Danish cancer patients with low social position can in part be attributed to more advanced stage at diagnoses [23–28] and more comorbidity while little or no differences in access to adequate and timely treatment were seen according to socioeconomic position [29–31] except for lung cancer treatment and some forms of NHL treatment [32–34]. This is in line with data from other Western countries such as Sweden [35–37], UK [38–40] and Canada and Australia [41–43], although few studies included stage, treatment and comorbidity in the same analyses.

More than 1 out of 5 cancer deaths among Danish cancer patients could potentially be postponed if survival level of the most advantaged cancer patients could be achieved for all patients across the income span. This is higher than the expected weighted average across the cancer sites, and is due to the fact that the actual number of potentially extendable lives depends not only on the survival gap but also on the incidence rate of that cancer and the relative survival for each cancer type. The proportion of early deaths potentially converted to 5-year survivors among Danish cancer patients is however, also higher than proportions reported in other countries. In Finland, 10% avoidable deaths at 5 years overall were estimated among cancer patients aged 65–89 years diagnosed 1996–2005 if all had had cancer mortality as those with highest education [44], whereas the overall proportion of avoidable deaths after 5 years based on survival of the least deprived group was 11% for patients diagnosed 2004–2006 in England [45] and 13% for patients diagnosed 2004–2008 in New South Wales, although based on only 10

cancer sites [8]. The English and Australian studies used area-based socioeconomic indicators which may underestimate differences as compared to using individual level indicators. The Finnish study, like ours used an individual marker for socioeconomic position; thus, why Denmark has a larger inequality in cancer survival and why this disparity seems to widen is not clear, although more patients diagnosed with advanced stage disease and high proportion of patients with severe comorbidity may contribute [46,47].

Strengths of this study include the use of individual income to measure socioeconomic position ensuring a precise estimation of the association of a person's socioeconomic position with relative survival. Further, all information on cancer incidence and socioeconomic status was collected prospectively and consistently for administrative purposes, independently of this study, thus minimizing selection bias and misclassification of disease-related and socioeconomic information. To provide an overview of the absolute socioeconomic differences in 1- and 5-year cancer survival, we accounted for socioeconomic differences in background mortality and estimate the differences between income-specific mortality attributable to cancer. Although we estimate the survival gap between the patients with highest and lowest income, our study demonstrates that the association between income and survival after cancer is stepwise across the full income spectrum. In the estimation of number of potentially gained 5-year survivors, we use information from all 5 income quintiles and highlight the potential public health benefit from improving survival rates among patients with lower income. A limitation to our study is that we were not able to include information on stage and treatment in our analyses. Further studies are needed in order to figure out the mechanisms behind the widening survival gap by income over time, taking into account the impact of differences in stage at diagnosis, other tumor-specific factors, comorbidity, and treatment as well as behavioral factors such as smoking, alcohol consumption, and patient related or professional diagnostic delays.

Documentation of a generally low survival after cancer in Denmark and long waiting times before initiation of cancer treatment, led to the introduction of a national policy, the 'Integrated Cancer Pathways' in 2007 [48]. These pathways were designed to integrate the cancer patient's care process through the different sectors of the health care system, with clinical standards for referral, diagnostics, treatment, and maximum waiting-time for all steps in the clinical care processing. In the United Kingdom, the NHS Cancer plan was introduced in 2000 to address the deficit in cancer survival compared to other European countries. The NHS Cancer plan had a strong focus on tackling inequalities in cancer survival (The NHS Cancer plan 2000) but so far, although overall UK cancer survival rates improve still no convincing narrowing of the gap in survival after cancer between the richest and the poorest can be observed [12,45]. Narrowing the gap between the rich and poor patients could contribute significantly to reducing the gap in survival between Denmark and the rest of Europe but available data did only allow inclusion of cancer-patients diagnosed in the first years after implementation of the Danish 'Integrated Cancer Pathways' in the present study. Future analyses will reveal whether this more systematic care approach continuously improves survival and reduces the socioeconomic inequality in survival. The results of this study, however, emphasize the potential and importance of this policy.

In conclusion, in this nationwide, population-based study, we found that socioeconomic differences in 5-year overall survival have increased over the past 25 years and that potentially avoidable deaths at five years currently amount to 22% of all cancer deaths. Greater attention and interventions targeting socioeconomically deprived patients through diagnostics, treatment, follow-up and rehabilitation is necessary in order to improve cancer outcomes.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## References


[1] Coleman MP, Forman D, Bryant H, et al. Cancer survival in Australia, Canada, Denmark, Norway, Sweden, and the UK, 1995-2007 (the International Cancer Benchmarking Partnership): an analysis of population-based cancer registry data. Lancet. 2011; 377:127–138.

[2] Rachet B, Woods LM, Mitry E, et al. Cancer survival in England and Wales at the end of the 20th century. Br J Cancer. 2008;99:S2–S10.

[3] Woods LM, Rachet B, Coleman MP. Origins of socio-economic inequalities in cancer survival: a review. Annals Oncol. 2006;17: 5–19.

[4] Kogevinas M, Porta M. Socioeconomic differences in cancer survival: a review of the evidence. In Kogevinas M, Pearce M, Susser M, Boffetta M (eds): Social inequalities and cancer. IARC Scientific Publications No. 138. Lyon: International Agency for Research on Cancer 1997; 177–206.

[5] Dalton SO, Schüz J, Engholm G, et al. Social inequality in incidence of and survival from cancer in a population-based study in Denmark, 1994-2003: summary of findings. Eur J Cancer. 2008;44: 2074–2085.

[6] Galobardes B, Shaw M, Lawlor DA, et al. Indicators of socioeconomic position (part 1). J Epidemiol Community Health. 2006;60: 7–12.

[7] Andersen AM, Bach E, Baadsgaard M, et al. Health inequality–determinants and policies. Scand J Public Health. 2012; 40:12–105.

[8] Stanbury JF, Baade PD, Yu Y, et al. Cancer survival in New South Wales, Australia: socioeconomic disparities remain despite overall improvements. BMC Cancer. 2016;16:48.

[9] Ito Y, Nakaya T, Nakayama T, et al. Socioeconomic inequalities in cancer survival: a population-based study of adult patients diagnosed in Osaka, Japan, during the period 1993–2004. Acta Oncol. 2014;53:1423–1433.

[10] Lyratzopoulos G, Barbiere JM, Rachet B, et al. Changes over time in socioeconomic inequalities in breast and rectal cancer survival in England and Wales during a 32-year period (1973-2004): the potential role of health care. Ann Oncol. 2011;22:1661–1666.

[11] Rachet B, Ellis L, Maringe C, et al. Socioeconomic inequalities in cancer survival in England after the NHS cancer plan. Br J Cancer. 2010;103:446–453.

[12] Shack LG, Rachet B, Brewster DH, et al. Socioeconomic inequalities in cancer survival in Scotland 1986–2000. Br J Cancer. 2007; 97:999–1004.

[13] Coleman MP, Rachet B, Woods LM, et al. Trends and socioeconomic inequalities in cancer survival in England and Wales up to 2001. Br J Cancer. 2004;90:1367–1373.

[14] Pedersen CB. The Danish Civil Registration System. Scand J Public Health. 2011;39:22–25.
[15] Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. Scand J Public Health. 2011;39:103–105.
[16] Gjerstorff ML. The Danish Cancer Registry. Scand J Public Health. 2011;39:42–45.
[17] Frederiksen BL, Osler M, Harling H, et al. Do patient characteristics, disease, or treatment explain social inequality in survival from colorectal cancer? Soc Sci Med. 2009;69:1107–1115.
[18] Blomberg M, Nielsen A, Munk C, et al. Trends in head and neck cancer incidence in Denmark, 1978-2007: focus on human papillomavirus associated sites. Int J Cancer. 2011;129:733–741.
[19] Dahlstrom KR, Bell D, Hanby D, et al. Socioeconomic characteristics of patients with oropharyngeal carcinoma according to tumor HPV status, patient smoking status, and sexual behavior. Oral Oncol. 2015;51:832–838.
[20] McDonald JT, Johnson-Obaseki S, Hwang E, et al. The relationship between survival and socio-economic status for head and neck cancer in Canada. J Otolaryngol - Head Neck Surg. 2014;43:2.
[21] Outzen M, Brasso K, Martinussen N, et al. Prostate cancer in Denmark 1978–2009–trends in incidence and mortality. Acta Oncol. 2013;52:831–836.
[22] Karlsen RV, Larsen SB, Christensen J, et al. PSA testing without clinical indication for prostate cancer in relation to socio-demographic and clinical characteristics in the Danish Diet, Cancer and Health Study. Acta Oncol. 2013;52:1609–1614.
[23] Olsen MH, Bøje CR, Kjaer TK, et al. Socioeconomic position and stage at diagnosis of head and neck cancer - a nationwide study from DAHANCA. Acta Oncol. 2015;54:759–766.
[24] Ibfelt E, Kjaer SK, Johansen C, et al. Socioeconomic position and stage of cervical cancer in Danish women diagnosed 2005 to 2009. Cancer. Epidemiol Biomarkers Prev. 2012;21:835–842.
[25] Frederiksen BL, Osler M, Harling H, et al. Social inequalities in stage at diagnosis of rectal but not in colonic cancer: a nationwide study. Br J Cancer. 2008;98:668–673.
[26] Frederiksen BL, Brown P. d N, Dalton SO, et al. Socioeconomic inequalities in prognostic markers of non-Hodgkin lymphoma: analysis of a national clinical database. Eur J Cancer. 2011;47:910–917.
[27] Dalton SO, Frederiksen BL, Jacobsen E, et al. Socioeconomic position, stage of lung cancer and time between referral and diagnosis in Denmark, 2001–2008. Br J Cancer. 2011;105:1042–1048.
[28] Dalton SO, Düring M, Ross L, et al. The relation between socioeconomic and demographic factors and tumour stage in women diagnosed with breast cancer in Denmark, 1983–1999. Br J Cancer. 2006;95:653–659.
[29] Ibfelt EH, Dalton SO, Høgdall C, et al. Do stage of disease, comorbidity or access to treatment explain socioeconomic differences in survival after ovarian cancer? - a cohort study among Danish women diagnosed 2005–2010. Cancer Epidemiol. 2015;39:353–359.
[30] Ibfelt EH, Kjaer SK, Høgdall C, et al. Socioeconomic position and survival after cervical cancer: influence of cancer stage, comorbidity and smoking among Danish women diagnosed between 2005 and 2010. Br J Cancer. 2013;109:2489–2495.
[31] Dalton SO, Ross L, Düring M, et al. Influence of socioeconomic factors on survival after breast cancer-a nationwide cohort study of women diagnosed with breast cancer in Denmark 1983–1999. Int J Cancer. 2007;121:2524–2531.
[32] Starr LK, Osler M, Steding-Jessen M, et al. Socioeconomic position and surgery for early-stage non-small-cell lung cancer: a population-based study in Denmark. Lung Cancer. 2013;79:262–269.
[33] Dalton SO, Steding-Jessen M, Jakobsen E, et al. Socioeconomic position and survival after lung cancer: influence of stage, treatment and comorbidity among Danish patients with lung cancer diagnosed in 2004–2010. Acta Oncol. 2015;54:797–804.
[34] Frederiksen BL, Dalton SO, Osler M, et al. Socioeconomic position, treatment, and survival of non-Hodgkin lymphoma in Denmark–a nationwide study. *Br J Cancer*. 2012;106:988–995.
[35] Eriksson H, Lyth J, Månsson-Brahme E, et al. Low level of education is associated with later stage at diagnosis and reduced survival in cutaneous malignant melanoma: a nationwide population-based study in Sweden. Eur J Cancer. 2013;49:2705–2716.
[36] Cavalli-Björkman N, Lambe M, Eaker S, et al. Differences according to educational level in the management and survival of colorectal cancer in Sweden. Eur J Cancer. 2011;47:1398–1406.
[37] Berglund A, Holmberg L, Tishelman C, et al. Social inequalities in non-small cell lung cancer management and survival: a population-based study in central Sweden. Thorax. 2010;65:327–333.
[38] Smith A, Crouch S, Howell D, et al. Impact of age and socioeconomic status on treatment and survival from aggressive lymphoma: a UK population-based study of diffuse large B-cell lymphoma. Cancer Epidemiol. 2015;39:1103–1112.
[39] Forrest LF, Adams J, Rubin G, et al. The role of receipt and timeliness of treatment in socioeconomic inequalities in lung cancer survival: population-based, data-linkage study. Thorax. 2015;70:138–145.
[40] Rutherford MJ, Hinchliffe SR, Abel GA, et al. How much of the deprivation gap in cancer survival can be explained by variation in stage at diagnosis: an example from breast cancer in the East of England. Int J Cancer. 2013;133:2192–2200.
[41] Gorey KM, Luginaah IN, Holowaty EJ, et al. Effects of being uninsured or underinsured and living in extremely poor neighborhoods on colon cancer care and survival in California: historical cohort analysis, 1996–2011. BMC Public Health. 2012;12:897.
[42] Jembere N, Campitelli MA, Sherman M, et al. Influence of socioeconomic status on survival of hepatocellular carcinoma in the Ontario population; a population-based study, 1990–2009. PLoS One. 2012;7:e40917.
[43] Booth CM, Li G, Zhang-Salomons J, et al. The impact of socioeconomic status on stage of cancer at diagnosis and survival: a population-based study in Ontario, Canada. Cancer. 2010;116:4160–4167.
[44] Pokhrel A, Martikainen P, Pukkala E, et al. Education, survival and avoidable deaths in cancer patients in Finland. Br J Cancer. 2010;103:1109–1114.
[45] Ellis L, Coleman MP, Rachet B. How many deaths would be avoidable if socioeconomic inequalities in cancer survival in England were eliminated? A national population-based study, 1996–2006. Eur J Cancer. 2012;48:270–278.
[46] Storm HH, Dickman PW, Engeland A, et al. Do morphology and stage explain the inferior lung cancer survival in Denmark? Eur Respir J. 1999;13:430–435.
[47] Sant M, Chirlaque Lopez MD, Agresti R, et al. Survival of women with cancers of breast and genital organs in Europe 1999–2007: results of the EUROCARE-5 study. Eur J Cancer. 2015;51:2191–2205.
[48] Probst HB, Hussain ZB, Andersen O. Cancer patient pathways in Denmark as a joint effort between bureaucrats, health professionals and politicians-A national Danish project. Health Policy. 2012;105:65–70.