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Small-area analysis on socioeconomic inequalities in cancer survival for 25 cancer sites in Germany

Isabelle Finke[1,2] | Gundula Behrens[1] | Werner Maier[3] | Lars Schwettmann[3,4] | Ron Pritzkuleit[5] | Bernd Holleczek[6] | Hiltraud Kajüter[7] | Michael Gerken[8] | Johann Mattutat[5] | Katharina Emrich[9] | Lina Jansen[1] | Hermann Brenner[1,10,11] | for the German Cancer Survival Working Group

[1]Division of Clinical Epidemiology and Aging Research, German Cancer Research Center (DKFZ), Heidelberg, Germany

[2]Medical Faculty Heidelberg, University of Heidelberg, Heidelberg, Germany

[3]Helmholtz Zentrum München - German Research Center for Environmental Health (GmbH), Institute of Health Economics and Health Care Management, Neuherberg, Germany

[4]Department of Economics, Martin Luther University Halle-Wittenberg, Halle (Saale), Germany

[5]Institute for Cancer Epidemiology at the University of Lübeck, Cancer Registry Schleswig-Holstein, Lübeck, Germany

[6]Saarland Cancer Registry, Saarbrücken, Germany

[7]Cancer Registry of North Rhine-Westphalia, Bochum, Germany

[8]Tumor Center - Institute for Quality Management and Health Services Research, University of Regensburg, Regensburg, Germany

[9]Cancer Registry of Rhineland-Palatinate gGmbH, Mainz, Germany

[10]Division of Preventive Oncology, German Cancer Research Center (DKFZ) and National Center for Tumor Diseases (NCT), Heidelberg, Germany

[11]German Cancer Consortium (DKTK), German Cancer Research Center (DKFZ), Heidelberg, Germany

Correspondence
Lina Jansen, Division of Clinical Epidemiology and Aging Research, German Cancer Research Center (DKFZ), Im Neuenheimer Feld 581, 69120 Heidelberg, Germany.
Email: l.jansen@dkfz.de

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Abstract

Socioeconomic inequalities in cancer survival have been reported in various countries but it is uncertain to what extent they persist in countries with relatively comprehensive health insurance coverage such as Germany. We investigated the association between area-based socioeconomic deprivation on municipality level and cancer survival for 25 cancer sites in Germany. We used data from seven population-based cancer registries (covering 32 million inhabitants). Patients diagnosed in 1998 to 2014 with one of 25 most common cancer sites were included. Area-based socioeconomic deprivation was assessed using the categorized German Index of Multiple Deprivation (GIMD) on municipality level. We estimated 3-month, 1-year, 5-year and 5-year conditional on 1-year age-standardized relative survival using period approach for 2012 to 2014. Trend analyses were conducted for periods between 2003-2005 and 2012-2014. Model-based period analysis was used to calculate relative excess risks (RER) adjusted for age and stage. In total, 2 333 547 cases were included. For all

Abbreviations: CD, Census Collection District; CI, confidence interval; CRC, colorectal cancer; DCO, death certificate only; GIMD, German Index of Multiple Deprivation; ICD-10, International Classification of Diseases, Version 10; N, number; Q, quintile; RER, relative excess risk; RS, relative survival; SLA, Statistical Local Area.

Lina Jansen and Hermann Brenner contributed equally to this study.

cancers combined, 5-year survival rates by GIMD quintile were 61.6% in Q1 (least deprived), 61.2% in Q2, 60.4% in Q3, 59.9% in Q4 and 59.0% in Q5 (most deprived). For most cancer sites, the most deprived quintile had lower 5-year survival compared to the least deprived quintile even after adjusting for stage (all cancer sites combined, RER 1.16, 95% confidence interval 1.14-1.19). For some cancer sites, this association was stronger during short-term follow-up. Trend analyses showed improved survival from earlier to recent periods but persisting deprivation differences. The underlying reasons for these persisting survival inequalities and strategies to overcome them should be further investigated.

KEYWORDS
area-based socioeconomic deprivation, cancer registry, Germany, survival

1 | INTRODUCTION

Socioeconomic inequalities in cancer survival have been reported in a number of countries and studies revealed for different cancer sites that patients living in affluent regions have better survival than those living in deprived regions.[1-7] Such associations have even been reported in countries with rather comprehensive access to health care for all population groups, such as Australia,[8] England[9] and France.[10]

Measurements such as deprivation indices can be used to investigate area effects on population health independent of the individual socioeconomic status by considering local material and social disparities.[11] As interventions aimed to reduce social inequalities might be implemented on regional level, it is reasonable to examine health effects of area-based measurements.

Previous studies have shown that the strength of association might depend on the resolution of the area-based deprivation index.[12-14] For example, an Australian study investigating deprivation differences in cancer survival reported stronger effects when using the smaller area level of Census Collection Districts (CD, 200 households) instead of Statistical Local Areas (SLA, median population: 21 000 residents).[12] Hazard ratios for death for the most deprived regions compared to the least deprived regions were 1.25 (95% confidence interval [CI] 1.22-1.29) for CD level and 1.16 (95% CI 1.13-1.20) for SLA level, both adjusted for age, sex, year of diagnosis, remoteness, country of birth, cancer site and stage.[12] A study conducted in the United States showed less or even reverse social gradients for most investigated health outcomes (eg, cause-specific mortality rates, cancer incidence rates) when using socioeconomic measures on the larger zip code level (average population: 30 000) compared to smaller census block group (average population: 1000) or census tract (average population: 4000) measures.[13]

In a previous study from Germany, the associations between area-based socioeconomic deprivation and cancer survival was analyzed for 25 cancer sites using data from population-based cancer registries covering 200 of 439 districts (median population: 126 000 residents in 2006) in Germany.[15] Results of our study showed that survival in the period 2002 to 2006 was comparable among deprivation groups except lower relative survival (RS) for patients living in the most deprived districts. These survival differences persisted after adjustment for stage and were strongest for cancer sites with good prognosis and in the first months after diagnosis.

What's new

Socioeconomic inequality is known to affect cancer survival rates, even in countries with universal health-care coverage. This large German study analyzed smaller-scale population areas (~1200 residents each), and found that survival rates for most common cancers were lower among patients from lower-income areas than among those from more affluent areas. The underlying causes of this association between socioeconomic deprivation and decreased cancer survival should be further investigated, as should strategies to correct these causal factors.

The objective of the present analysis was to investigate the association between area-based socioeconomic deprivation on municipality level (ie, small scale population level with median population of included areas: 1194 residents in 2006)[16] and cancer survival for 25 cancer sites by using data from German population-based cancer registries. In trend analysis, we aimed to investigate whether deprivation-associated inequalities changed over time. Furthermore, we intended to examine whether the association between area-based socioeconomic deprivation and cancer survival depends on the factors age, sex and stage at diagnosis of the cancer patients.

2 | MATERIALS AND METHODS

For our register-based cohort study, data were used from seven population-based cancer registries in Germany covering 10 of 16 German federal states (Schleswig-Holstein, Lower Saxony, North Rhine-Westphalia, Rhineland-Palatinate, Bavaria, Saarland,

Brandenburg, Mecklenburg-Western Pomerania, Saxony and Thuringia). A common record layout was used to collect the data, which were checked for plausibility and pooled for analysis. Data of districts with a proportion of death certificate only (DCO) cases of less than 13% from 2002 to 2014 were used covering a population of about 31.9 million residents in 2006 (Supplementary Table S1).[16] Patients aged ≥15 years with invasive malignant tumors of 25 most common cancer sites (which account for approximately 94% of all cancers; codes of the International Classification of Diseases and Related Health Problems, 10th Revision [ICD-10]: C00-C14, C15, C16, C18-21, C22, C23-C24, C25, C32, C33-C34, C43, C49, C50 [females], C53, C54, C56, C61, C62, C64, C67, C71-C72, C73, C81, C82-C85, C90, C91-C96) who has been diagnosed between 1998 and 2014 were included into the analyses. DCO or autopsy only cases were excluded from the survival analyses.

Area-based socioeconomic deprivation status on municipality level was assessed using the German Index of Multiple Deprivation (GIMD) 2006.[11,17] The GIMD 2006 is based on data of official statistics mainly from 2006 and consists of seven single deprivation domains (income, employment, education, municipality revenue, social capital, environment and security), and a composite index comprising all seven domains. Scores of the composite index were assigned to all included municipalities of our study area and new deprivation quintiles were computed over these municipalities so that the underlying population was distributed evenly over the quintiles. These deprivation quintiles were assigned to each patient according to the municipality of residence at the time of diagnosis. In the catchment areas of included registries, there were 6524 municipalities with a median population of 1194 residents (range: 8-1 294 608, interquartile range: 517-3494 residents) in 2006.[16] Supplementary Figure S1 shows a map of Germany displaying the distribution of GIMD quintiles across all municipalities included.

Period analysis was used to calculate RS for each of the 25 most common cancer sites.[18] RS quantifies survival of cancer patients relative to expected survival in the overall population. Expected survival was estimated using the Ederer II method[19] and life tables stratified by age, sex, calendar period and area-based socioeconomic deprivation. Life tables were derived from population and mortality data on municipality level.[20,21] Population and mortality data were aggregated according to GIMD quintiles from which life tables were calculated.

For each cancer site and GIMD quintile, 5-year age-standardized RS was estimated for the period 2012 to 2014. Age-standardization was conducted after the International Cancer Survival Standards.[22] For colorectal, lung, breast and prostate cancer, age-, sex- and stage-specific survival was calculated additionally. In analyses including all cancer sites combined, we adjusted for case mix.[23] Furthermore, trend analyses of age-standardized 5-year RS for the time periods 2003-2005, 2006-2008, 2009-2011 and 2012-2014 were conducted. Additional analyses comprised short-term survival (3-month and 1-year) as well as 5-year survival conditional on 1-year survival. Differences in cancer survival with respect to quintiles of the composite index of area-based socioeconomic deprivation were tested for statistical significance by model-based period analysis adjusted for follow-up time, age and stage.[24] Models adjusting for stage included only patients with available stage information, all other models included the total study population. All analyses were carried out with SAS software (version 9.4), using the same macros for period analysis as in a previous study.[15,24,25]

Due to data protection provisions, the cancer registry North Rhine-Westphalia could not provide individual record data of the cancer patients. Therefore, SAS scripts for analyses were provided to the registry to sum up person years and number of deaths by GIMD quintile, year of diagnosis, year of follow-up, age, sex and stage at diagnosis. These data were then incorporated in the respective analysis.

In sensitivity analyses, age- and sex-specific survival was calculated only for patients with available stage information of their tumors. To consider that some registries provided data only for years of diagnosis starting after 1998, trend analysis were repeated as sensitivity analyses by including only registries which provided data for all years of diagnosis. In an additional sensitivity analysis, the main analysis was repeated adjusting for either federal state or East/West-Germany, respectively.

3 | RESULTS

In total, records of 2 333 547 cases were included in the present study (Supplementary Figure S2). Table 1 shows characteristics of the study population according to the area-based socioeconomic deprivation of their municipalities. The proportion of DCO cases was similar across area-based socioeconomic deprivation quintiles. Patients resident in the least deprived municipalities were slightly younger (median 67 years) and showed a marginally higher proportion of microscopically confirmed cases (97.3%) compared to all other patients.

For all cancer sites combined, there was a gradient across area-based socioeconomic deprivation quintiles in 5-year age-standardized RS (Table 2; Supplementary Table S2). This clear survival gradient was also present for stomach, colorectal and prostate cancer. Compared to the least deprived GIMD quintile (Q1), the most deprived quintile (Q5) had a lower 5-year RS for 17 of 25 cancer sites and for all cancer sites combined (relative excess risk [RER] 1.16, 95% CI 1.14-1.18). Adjusting for stage at diagnosis attenuated the association for eight out of 17 cancer sites, but increased the effect for cancers of the oral cavity, lung, breast, ovary, testis and bladder.

Table 3 shows subgroup analyses of 5-year RS for female breast, prostate, colorectal and lung cancer stratified by age group, stage and sex (where applicable). The association of a lower survival in the most deprived group was stronger for younger patients for breast and prostate cancer but comparable across age groups for colorectal and lung cancer. However, after adjustment for stage, the age difference resolved for prostate cancer but became apparent for colorectal cancer (CRC). In general, adjusting for stage attenuated the associations in prostate and CRC but increased effect estimates for breast cancer. In colorectal and lung cancer, associations were stronger in male patients. Associations were weakest in advanced stage in prostate, colorectal and lung cancer but not in breast cancer. Restricting the

TABLE 1 Number of patients with 25 common forms of cancer according to their area-based socioeconomic deprivation (in quintiles) assigned by their residence at diagnosis

GIMD quintile	GIMD score, mean (range)	Underlying population in 2006 (million)	Cases diagnosed in 1998-2014[a]	% DCO cases[b]	Cases in the analysis, N (%)[c]	Median age at diagnosis	Microscopically confirmed cases (%)[d]
Q1, least deprived	9 (2-13)	6.33	423 114	9.0	384 883 (16.5)	67	97.3
Q2	15 (13-18)	6.52	494 740	9.8	446 372 (19.1)	68	96.0
Q3	20 (18-24)	6.32	504 691	10.8	450 300 (19.3)	68	95.7
Q4	26 (24-30)	6.42	559 118	9.1	508 430 (21.8)	68	95.7
Q5, most deprived	39 (30-70)	6.37	596 391	8.9	543 562 (23.3)	68	95.7
Total	22 (2-70)	31.95	2 578 054	9.5	2 333 547 (100.0)	68	96.0

Abbreviations: DCO, death certificate only; GIMD, German Index of Multiple Deprivation; N, number.
[a]Due to different coverage of years of diagnosis across GIMD quintiles, case numbers across GIMD quintiles are not directly comparable.
[b]DCO or autopsy only cases among included cancer sites.
[c]Exclusions are shown in the flow chart (Figure S2).
[d]DCO cases and cases with missing information on confirmation were excluded.

analyses to patients with available stage information attenuated the association in prostate, colorectal and lung cancer but increased effect estimates in younger breast cancer patients (Table S3).

Table 4 shows RERs estimates for 3-month, 1-year and 5-year conditional on 1-year survival for the most deprived compared to the least deprived quintile adjusted for age and for age and stage. Supplementary Tables S4, S5 and S6 show the corresponding RS rates. With adjustment for age, association strengths weakened continuously from 3-month to 1-year to 5-year conditional on 1-year survival for 16 of 25 cancer sites. For all cancer sites combined, the RER decreased from 1.31 to 1.19 to 1.12. With additional adjustment for stage, this pattern was observed for 14 out of 20 cancer sites with RERs decreasing for all cancers combined from 1.36 to 1.18 to 1.14.

Table 5 compares 5-year RS rates and RER for the most and the least deprived quintiles between the periods 2003-2005 and 2012-2014. The association was slightly attenuated from the earlier to the most recent period for most cancer sites and all cancer sites combined (2003-2005: RER 1.20, 95% CI 1.18-1.23; 2012-2014: RER 1.16, 95% CI 1.14-1.18). In Figure 1, differences in 5-year RS rates across GIMD quintiles are shown for lung (A), breast (B), colorectal (C) and prostate (D) cancer for the periods from 2003-2005 to 2012-2014. In general, survival improved from the earliest to the most recent period but survival differences across GIMD quintiles remained.

In sensitivity analyses, associations were attenuated when adjusting for federal state and to a lesser extent when adjusting for East-/West-Germany (Supplementary Tables S7 and S8). RERs for all cancer sites combined for Q5 vs Q1 were 1.11 (95% CI 1.09-1.13) and 1.13 (95% CI 1.11-1.15) with these adjustments compared to 1.16 (95% CI 1.14-1.18) without such adjustments. Restricting the trend analysis to registries providing data for all years of diagnosis 1998 to 2014 slightly decreased effect estimates in 2003 to 2005 and slightly increased estimates in 2012 to 2014 for most cancer sites. This resulted in a slight increase rather than decrease of the RER estimate over time for all cancer sites combined which was 1.14 (95% CI 1.11-1.17) in 2003 to 2005 and 1.18 (95% CI 1.15-1.22) in 2012 to 2014 (Table S9).

4 | DISCUSSION

This is the first population-based study to investigate the association of area-based socioeconomic deprivation on municipality level and survival in 25 most common cancers in Germany. Our results show a survival gradient from least to most deprived municipalities in the included study regions for all cancers combined. Overall, patterns were different across cancer sites. However, for most cancer sites, patients living in municipalities belonging to the most deprived quintile had significantly lower survival compared to patients from the least deprived quintile, and these differences persisted after adjusting for stage. Furthermore, the survival disadvantage of patients from the most deprived quintile was generally more pronounced in the first year after diagnosis, especially in the first 3 months after diagnosis, than in the longer run. Trend analyses showed increasing survival rates from earlier to more recent periods but also remaining inequalities.

Our results are in line with findings from previous studies revealing lower cancer survival in most deprived areas,[1-10,15] even in countries with comprehensive health insurance coverage.[8-10] In most countries, a gradual decrease of cancer survival with increasing area-based deprivation has been shown, in line with our observations for several individual cancer sites and all cancers combined.[1-10] The previous study by Jansen et al[15] using deprivation quintiles on district level (median 126 000 residents) reported no gradient across deprivation quintiles. The authors of the study discussed a higher heterogeneity within the units when using a larger area-level as possible reason for the previous findings.[15,26,27] This could still be true for the absence of a survival gradient for some cancer sites in the current study despite using a

TABLE 2 Five-year age-standardized relative survival in 2012 to 2014 by GIMD quintile and cancer site for cancer patients in Germany

			GIMD quintiles (Q)							
			5-year relative survival rate (SE)						Relative excess risk (95% confidence interval)	
Cancer site	ICD-10 code	Number of cases	Q1 (least deprived)	Q2	Q3	Q4	Q5 (most deprived)	Q1-Q5[a]	Q5 (most deprived)[b] adjusted for age	Q5 (most deprived)[c] adjusted for age and stage
Oral	C00-C14	40 971	52.0 (1.1)	52.9 (1.1)	50.2 (1.0)	48.5 (1.0)	46.0 (1.0)	6.0	**1.36 (1.25-1.48)**	**1.45 (1.32-1.59)**
Esophagus	C15	18 629	25.3 (1.2)	23.9 (1.2)	26.1 (1.1)	22.7 (1.1)	21.0 (1.0)	4.3	**1.16 (1.06-1.27)**	1.12 (1.00-1.25)
Stomach	C16	48 850	34.2 (0.8)	34.1 (0.8)	33.9 (0.8)	33.3 (0.7)	30.8 (0.7)	3.4	**1.11 (1.04-1.18)**	**1.11 (1.02-1.20)**
Colon and rectum	C18-C21	190 434	65.7 (0.4)	64.2 (0.4)	63.4 (0.4)	63.0 (0.4)	62.0 (0.4)	3.7	**1.23 (1.18-1.29)**	**1.18 (1.12-1.24)**
Liver	C22	22 069	19.7 (1.1)	18.2 (1.1)	17.5 (1.0)	15.0 (0.9)	15.5 (0.9)	4.2	**1.21 (1.11-1.31)**	1.11 (0.97-1.28)
Gallbladder	C23-C24	14 645	25.4 (1.6)	24.6 (1.6)	22.4 (1.5)	24.7 (1.4)	22.0 (1.4)	3.4	**1.15 (1.04-1.28)**	**1.15 (1.00-1.32)**
Pancreas	C25	42 841	13.3 (0.7)	13.3 (0.7)	11.2 (0.6)	13.1 (0.7)	11.3 (0.6)	2.0	**1.12 (1.06-1.18)**	**1.09 (1.02-1.16)**
Larynx	C32	11 021	65.7 (2.0)	63.0 (1.9)	64.2 (1.8)	58.1 (1.8)	60.2 (1.7)	5.5	**1.24 (1.02-1.50)**	1.10 (0.88-1.37)
Lung	C33-C34	143 935	19.5 (0.4)	19.5 (0.4)	18.3 (0.4)	18.3 (0.4)	17.7 (0.4)	1.8	**1.08 (1.05-1.12)**	**1.10 (1.06-1.14)**
Melanoma	C43	60 379	93.2 (0.4)	93.5 (0.4)	93.2 (0.4)	91.2 (0.5)	91.9 (0.5)	1.3	**1.34 (1.10-1.63)**	1.00 (0.82-1.23)
Soft tissue	C49	8024	67.4 (2.0)	68.2 (2.0)	68.1 (1.9)	67.8 (2.0)	68.0 (2.0)	−0.6	1.05 (0.85-1.29)	1.16 (0.83-1.63)
Breast	C50	205 897	85.1 (0.4)	84.8 (0.4)	83.9 (0.4)	84.2 (0.4)	83.5 (0.4)	1.6	**1.20 (1.11-1.29)**	**1.58 (1.45-1.71)**
Cervix	C53	14 538	66.0 (1.4)	66.5 (1.4)	66.6 (1.4)	64.4 (1.2)	64.0 (1.4)	2.0	1.13 (0.96-1.32)	1.19 (0.98-1.43)
Corpus uteri	C54	33 449	79.1 (0.9)	80.3 (0.9)	78.8 (0.9)	78.4 (0.8)	78.6 (0.8)	0.5	1.05 (0.91-1.21)	1.08 (0.91-1.30)
Ovary	C56	21 945	44.8 (1.1)	41.3 (1.1)	41.5 (1.1)	40.6 (1.1)	37.9 (1.1)	6.9	**1.36 (1.23-1.50)**	**1.37 (1.21-1.56)**
Prostate	C61	194 052	90.4 (0.6)	89.7 (0.6)	89.0 (0.5)	88.4 (0.8)	87.7 (0.7)	2.7	**1.61 (1.41-1.84)**	1.12 (0.99-1.26)
Testis	C62	12 700	92.2 (2.3)	92.7 (2.1)	93.2 (2.1)	92.7 (2.2)	90.9 (2.6)	1.3	**2.28 (1.23-4.21)**	—[e]
Kidney	C64	47 578	76.5 (0.9)	76.2 (0.8)	75.8 (0.8)	74.3 (0.7)	74.9 (0.7)	1.6	1.11 (0.99-1.25)	1.04 (0.90-1.20)
Bladder	C67	46 880	56.6 (1.0)	56.3 (0.9)	57.1 (0.9)	54.9 (0.9)	55.0 (0.9)	1.6	1.02 (0.94-1.11)	**1.12 (1.00-1.24)**
Brain	C71-C72	18 710	30.1 (1.0)	28.1 (1.0)	27.6 (1.0)	29.4 (1.0)	30.5 (1.0)	−0.4	1.06 (0.97-1.15)	n/a[f]
Thyroid	C73	17 869	91.9 (0.9)	92.0 (1.0)	90.4 (1.0)	89.8 (0.9)	87.8 (1.0)	4.1	**2.06 (1.45-2.93)**	**1.64 (1.12-2.40)**
Hodgkin lymphoma	C81	6078	86.4 (1.3)	86.9 (1.4)	86.4 (1.3)	85.4 (1.3)	85.3 (1.4)	1.1	0.98 (0.68-1.43)	n/a[f]
Non-Hodgkin lymphoma	C82-C85	43 743	69.7 (0.8)	70.0 (0.8)	67.7 (0.8)	68.7 (0.8)	66.1 (0.8)	3.6	**1.21 (1.09-1.34)**	n/a[f]
Multiple myeloma	C90	18 157	54.5 (1.4)	54.0 (1.3)	50.9 (1.3)	53.3 (1.2)	52.0 (1.3)	2.5	**1.21 (1.07-1.37)**	n/a[f]
Leukemia	C91-C96	34 506	57.0 (1.0)	59.1 (1.0)	58.7 (0.9)	59.1 (0.9)	57.7 (0.9)	−0.7	1.00 (0.91-1.10)	n/a[f]
All cancer sites[d]		1 317 900	61.6 (0.2)	61.2 (0.2)	60.4 (0.2)	59.9 (0.2)	59.0 (0.2)	2.6	**1.16 (1.14-1.18)**	**1.16 (1.14-1.19)**

Abbreviations: GIMD, German Index of Multiple Deprivation, ICD-10, International Classification of Diseases Version 10; n/a, not applicable; Q, quintile.
[a]Difference of GIMD quintiles.
[b]Reference: Q1 (least deprived), adjusted for age at diagnosis. Significant relative excess risks ($p < 0.05$) are printed in bold.
[c]Reference: Q1 (least deprived), adjusted for age at diagnosis and stage at diagnosis. Significant relative excess risks ($p < 0.05$) are printed in bold.
[d]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix.
[e]Results not shown due to low number of cases of death.
[f]No adjustment for stage as no stage information was available (mostly not applicable) for these cancer sites.

TABLE 3 Subgroup analysis of 5-year relative survival in 2012 to 2014 across GIMD quintiles by age, sex and stage for the four most common cancer sites

Cancer site, subgroup	Number of cases	5-year relative survival rate (SE)[a]						Relative excess risk (95% confidence interval)	
		Q1	Q2	Q3	Q4	Q5	Q1-Q5[b]	Q5[c]	Q5[d]
Breast cancer									
Age ≤65 years	112 839	66.0 (0.4)	64.7 (0.5)	65.0 (0.5)	65.6 (0.4)	64.7 (0.5)	1.3	**1.26 (1.14-1.41)**	**1.86 (1.65-2.10)**
Age >65 years	90 721	46.4 (0.4)	46.3 (0.3)	45.5 (0.3)	45.7 (0.3)	45.4 (0.3)	1.0	**1.14 (1.03-1.27)**	**1.34 (1.19-1.51)**
Local stage	105 045	96.3 (0.5)	96.1 (0.5)	95.6 (0.5)	96.5 (0.4)	95.1 (0.5)	1.2	**1.49 (1.12-1.97)**	n/a
Regional stage	55 271	85.0 (0.7)	84.0 (0.7)	83.8 (0.7)	82.8 (0.7)	83.1 (0.7)	1.9	**1.24 (1.07-1.43)**	n/a
Advanced stage	26 508	65.9 (1.0)	60.7 (1.1)	60.3 (1.1)	56.3 (1.1)	55.9 (1.1)	10.0	**1.60 (1.44-1.78)**	n/a
Prostate cancer									
Age ≤65 years	53 614	68.2 (0.6)	67.3 (0.6)	67.3 (0.6)	66.5 (0.8)	65.8 (0.8)	2.4	**2.11 (1.60-2.79)**	1.11 (0.88-1.40)
Age >65 years	129 589	51.1 (0.3)	50.6 (0.3)	49.7 (0.3)	50.0 (0.3)	49.5 (0.3)	1.6	**1.47 (1.27-1.70)**	1.11 (0.96-1.29)
Local stage	93 560	100.3 (0.7)	99.9 (0.5)	99.5 (0.5)	98.9 (0.5)	97.8 (0.5)	2.5	1.82 (0.81-4.09)	n/a
Regional stage	6282	84.1 (2.8)	78.3 (3.3)	80.0 (3.2)	76.3 (2.9)	82.8 (2.9)	1.3	1.30 (0.69-2.47)	n/a
Advanced stage	11 136	26.0 (1.7)	30.8 (2.5)	23.3 (1.5)	25.4 (1.6)	28.6 (2.9)	−2.6	1.08 (0.95-1.22)	n/a
Colorectal cancer									
Men	105 330	64.6 (0.6)	63.2 (0.6)	62.0 (0.6)	61.8 (0.6)	60.1 (0.6)	4.5	**1.28 (1.21-1.37)**	**1.24 (1.15-1.32)**
Women	85 104	67.0 (0.6)	65.5 (0.6)	64.9 (0.6)	64.7 (0.6)	64.5 (0.6)	2.5	**1.17 (1.09-1.25)**	**1.10 (1.02-1.19)**
Age ≤65 years	56 468	49.9 (0.8)	47.8 (0.8)	48.8 (0.8)	48.9 (0.8)	47.2 (0.8)	2.7	**1.24 (1.14-1.35)**	**1.23 (1.13-1.35)**
Age >65 years	130 617	35.1 (0.3)	34.4 (0.3)	33.6 (0.3)	33.3 (0.3)	32.9 (0.3)	2.2	**1.23 (1.17-1.30)**	**1.16 (1.09-1.23)**
Local stage	60 578	87.9 (0.6)	86.9 (0.6)	85.3 (0.6)	86.1 (0.6)	85.1 (0.6)	2.8	**1.45 (1.23-1.70)**	n/a
Regional stage	36 577	70.2 (1.0)	69.5 (0.9)	69.1 (0.9)	68.6 (0.9)	67.0 (0.9)	3.2	**1.19 (1.06-1.33)**	n/a
Advanced stage	60 716	42.0 (0.8)	41.9 (0.7)	43.1 (0.7)	37.7 (0.7)	38.6 (0.7)	3.4	**1.12 (1.05-1.19)**	n/a
Lung cancer									
Men	98 875	18.5 (0.6)	18.0 (0.5)	16.5 (0.5)	16.6 (0.4)	15.8 (0.4)	2.7	**1.09 (1.05-1.14)**	**1.11 (1.06-1.16)**
Women	45 060	21.5 (0.7)	22.3 (0.7)	21.3 (0.6)	21.4 (0.6)	21.3 (0.7)	0.2	1.04 (0.98-1.09)	1.04 (0.98-1.11)
Age ≤65 years	53 999	15.2 (0.7)	16.0 (0.7)	15.4 (0.7)	15.1 (0.6)	15.6 (0.7)	−0.4	**1.07 (1.02-1.12)**	**1.09 (1.03-1.15)**
Age >65 years	84 383	9.6 (0.3)	9.4 (0.3)	8.3 (0.2)	8.9 (0.2)	8.3 (0.2)	1.3	**1.09 (1.05-1.14)**	**1.11 (1.06-1.16)**
Local stage	18 776	57.2 (1.5)	57.0 (1.5)	54.7 (1.4)	54.7 (1.3)	55.2 (1.2)	2.0	1.12 (0.99-1.27)	n/a
Regional stage	24 481	23.5 (1.2)	23.6 (1.1)	21.8 (1.0)	20.9 (0.9)	20.2 (0.9)	3.3	**1.16 (1.07-1.25)**	n/a
Advanced stage	60 748	9.6 (0.5)	10.8 (0.5)	10.5 (0.5)	9.0 (0.4)	8.4 (0.4)	1.2	**1.07 (1.02-1.12)**	n/a

Abbreviations: GIMD, German Index of Multiple Deprivation; n/a, not applicable; Q, quintile.
[a]Age-standardized.
[b]Difference of GIMD quintiles.
[c]Reference: Q1 (least deprived), adjusted for age at diagnosis, including patients with missing stage information. Significant relative excess risks ($p < 0.05$) are printed in bold.
[d]Reference: Q1 (least deprived), adjusted for age at diagnosis and stage at diagnosis, excluding patients with missing stage information. Significant relative excess risks ($p < 0.05$) are printed in bold.

much smaller area-level (median 1194 residents). As the previous study compared the most deprived area with all other areas combined, a direct comparison of effect sizes with our study is not possible.[15] However, our study supports previous findings of stronger associations between RS and area-based socioeconomic deprivation during short term follow-up and that stage at diagnosis only partly explained the associations.[15]

Adjusting for stage at diagnosis affected derived survival estimates differently, depending on the cancer site. In prostate cancer, the association between lower RS and area-based socioeconomic deprivation was only present when not adjusting for or stratifying by stage at diagnosis. This might reflect overdiagnosis of lower stage tumors in least deprived municipalities as a result of opportunistic PSA (prostate-specific antigen) screening.[28] This pattern was reversed for breast cancer survival, which showed stronger associations with area-based socioeconomic deprivation after stage adjustment or stratification. Studies from the United States,[29,30] England[31] and the Netherlands[32] analyzing overall, cancer-specific or RS reported lower survival in breast cancer patients resident in more-deprived areas but attenuated associations when adjusting for stage at diagnosis. One

TABLE 4 Comparison of 3-month, 1-year and 5-year conditional on 1-year age-standardized relative survival in 2012 to 2014 for the most deprived quintile (Q5) by cancer site

	Relative excess risk (95% confidence interval) for Q5 vs Q1					
	Without stage adjustment[a]			With stage adjustment[b]		
Cancer site	3-month RS	1-year RS	5-year conditional on 1-year RS	3-month RS	1-year RS	5-year conditional on 1-year RS
Oral	**1.46 (1.11-1.93)**	**1.41 (1.24-1.60)**	**1.33 (1.19-1.48)**	**1.74 (1.21-2.49)**	**1.60 (1.37-1.86)**	**1.34 (1.19-1.51)**
Esophagus	1.16 (0.92-1.45)	**1.20 (1.07-1.35)**	1.10 (0.95-1.26)	**1.55 (1.09-2.18)**	**1.27 (1.09-1.48)**	0.95 (0.81-1.12)
Stomach	**1.27 (1.09-1.47)**	**1.08 (1.00-1.18)**	**1.14 (1.03-1.26)**	**1.40 (1.13-1.74)**	1.11 (1.00-1.23)	1.08 (0.96-1.21)
Colon and rectum	**1.35 (1.21-1.51)**	**1.32 (1.24-1.41)**	**1.16 (1.09-1.23)**	**1.30 (1.14-1.49)**	**1.23 (1.14-1.33)**	**1.14 (1.06-1.22)**
Liver	**1.28 (1.08-1.52)**	**1.19 (1.08-1.31)**	**1.24 (1.07-1.43)**	1.21 (0.89-1.64)	1.14 (0.96-1.36)	1.07 (0.85-1.33)
Gallbladder	1.21 (0.96-1.51)	**1.19 (1.04-1.36)**	1.11 (0.94-1.32)	1.29 (0.93-1.80)	**1.21 (1.01-1.45)**	1.07 (0.87-1.32)
Pancreas	**1.32 (1.18-1.48)**	**1.16 (1.09-1.24)**	1.03 (0.93-1.14)	**1.39 (1.20-1.61)**	**1.13 (1.04-1.22)**	0.99 (0.89-1.11)
Larynx	**3.00 (1.26-7.12)**	1.27 (0.91-1.76)	1.23 (0.97-1.55)	5.22 (0.89-30.65)	1.45 (0.94-2.24)	0.98 (0.76-1.27)
Lung	**1.25 (1.16-1.34)**	**1.11 (1.07-1.16)**	1.03 (0.98-1.09)	**1.31 (1.19-1.43)**	**1.12 (1.07-1.17)**	1.05 (0.99-1.11)
Melanoma	—[d]	**2.11 (1.32-3.36)**	1.18 (0.95-1.47)	**2.25 (1.03-4.89)**	1.01 (0.70-1.45)	0.98 (0.77-1.24)
Soft tissue	**2.23 (1.18-4.23)**	1.12 (0.83-1.52)	0.97 (0.72-1.30)	1.58 (0.60-4.19)	1.44 (0.85-2.45)	0.92 (0.58-1.45)
Breast	**1.53 (1.05-2.23)**	**1.43 (1.22-1.68)**	**1.14 (1.05-1.24)**	1.31 (0.93-1.86)	**1.27 (1.07-1.50)**	**1.57 (1.43-1.73)**
Cervix	1.77 (0.95-3.31)	1.17 (0.92-1.48)	1.11 (0.90-1.37)	2.15 (0.85-5.45)	1.21 (0.90-1.64)	1.15 (0.90-1.46)
Corpus uteri	1.28 (0.79-2.06)	1.09 (0.87-1.38)	1.01 (0.84-1.22)	1.10 (0.63-1.92)	1.02 (0.76-1.36)	1.06 (0.85-1.33)
Ovary	**1.44 (1.10-1.89)**	**1.45 (1.24-1.70)**	**1.28 (1.12-1.45)**	1.20 (0.78-1.83)	**1.36 (1.09-1.71)**	**1.35 (1.16-1.57)**
Prostate	**2.17 (1.14-4.15)**	**1.97 (1.52-2.55)**	**1.48 (1.27-1.72)**	1.28 (0.66-2.49)	**1.43 (1.10-1.85)**	1.02 (0.89-1.18)
Testis	1.98 (0.49-8.00)	**2.78 (1.20-6.47)**	2.21 (0.84-5.84)	—[e]	—[d]	—[d]
Kidney	**1.42 (1.05-1.91)**	1.03 (0.88-1.20)	**1.23 (1.03-1.48)**	1.14 (0.75-1.71)	0.86 (0.70-1.04)	**1.28 (1.03-1.58)**
Bladder	1.16 (0.92-1.47)	1.09 (0.98-1.21)	0.94 (0.84-1.06)	**2.12 (1.37-3.27)**	**1.21 (1.05-1.41)**	0.98 (0.85-1.14)
Brain	1.23 (0.97-1.55)	**1.14 (1.02-1.28)**	0.95 (0.83-1.09)	n/a[f]	n/a[f]	n/a[f]
Thyroid	1.68 (0.85-3.32)	**2.15 (1.41-3.26)**	**1.90 (1.02-3.52)**	1.06 (0.49-2.32)	1.58 (0.97-2.57)	1.77 (0.98-3.21)
Hodgkin lymphoma	1.28 (0.47-3.51)	0.83 (0.51-1.36)	1.32 (0.75-2.31)	n/a[f]	n/a[f]	n/a[f]
Non-Hodgkin lymphoma	**1.31 (1.04-1.66)**	**1.17 (1.03-1.33)**	**1.28 (1.09-1.50)**	n/a[f]	n/a[f]	n/a[f]
Multiple myeloma	**1.76 (1.17-2.65)**	**1.58 (1.28-1.94)**	1.04 (0.89-1.21)	n/a[f]	n/a[f]	n/a[f]
Leukemia	1.10 (0.87-1.40)	1.08 (0.96-1.23)	0.89 (0.77-1.04)	n/a[f]	n/a[f]	n/a[f]
All cancer sites[c]	**1.31 (1.25-1.36)**	**1.19 (1.16-1.21)**	**1.12 (1.09-1.15)**	**1.36 (1.28-1.44)**	**1.18 (1.15-1.20)**	**1.14 (1.11-1.18)**

Abbreviations: Q, quintile; RS, relative survival.

[a]Reference: Q1 (least deprived), adjusted for age at diagnosis, total population. Significant relative excess risks ($p < 0.05$) are printed in bold

[b]Reference: Q1 (least deprived), adjusted for age at diagnosis and stage at diagnosis, excluding patients with missing stage information. Significant relative excess risks ($p < 0.05$) are printed in bold.

[c]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix.

[d]Results not shown due to low number of cases of death.

[e]Model did not converge.

[f]No adjustment for stage as no stage information was available for these cancer sites.

Dutch study[32] reported decreased effect estimates in interval and non–screen-detected breast cancer cases but a slightly increased effect estimates in screening attendees after stage adjustment. In Germany, an organized mammography screening has been implemented starting in 2005 and being fully implemented in 2009.[33] In the age group invited for screening, late-stage breast cancer incidence and disease-specific mortality were reduced at the cost of moderate occurrence of overdiagnosis.[33] To explain increasing survival inequalities between area-based socioeconomic deprivation groups when adjusting for stage, more detailed analyses on breast cancer patients including information on screening attendance would be desirable.

Two recent studies from Germany investigated the association between area-based socioeconomic deprivation and cancer survival in colorectal[34] and lung cancer[35] patients using data from three clinical cancer registries. In contrast to our study, Jansen et al[34] reported stronger disparities in longer follow-up periods for CRC patients. However, it has to be considered that only overall survival has been calculated while the present study used RS.[34] Both the present and

TABLE 5 Trend analysis for 5-year age-standardized relative survival by GIMD quintile and cancer site for German cancer patients, period 2003-2005 and 2012-2014

	Period 2003-2005				Period 2012-2014			
	5-year relative survival rate (SE)			Relative excess risk (95% confidence interval)[a]	5-year relative survival rate (SE)			Relative excess risk (95% confidence interval)[a]
Cancer site	Q1	Q5	Q1-Q5[b]	Q5 (most deprived)	Q1	Q5	Q1-Q5[b]	Q5 (most deprived)
Oral	46.6 (1.7)	43.7 (1.3)	2.9	**1.19 (1.09-1.29)**	52.0 (1.1)	46.0 (1.0)	6.0	**1.36 (1.25-1.48)**
Esophagus	20.8 (1.6)	16.3 (1.1)	4.5	**1.19 (1.08-1.31)**	25.3 (1.2)	21.0 (1.0)	4.3	**1.16 (1.06-1.27)**
Stomach	31.3 (1.0)	27.4 (0.7)	3.9	**1.19 (1.12-1.26)**	34.2 (0.8)	30.8 (0.7)	3.4	**1.11 (1.04-1.18)**
Colon and rectum	61.1 (0.6)	57.6 (0.4)	3.5	**1.28 (1.22-1.34)**	65.7 (0.4)	62.0 (0.4)	3.7	**1.23 (1.18-1.29)**
Liver	15.7 (1.4)	10.3 (0.9)	5.4	**1.33 (1.20-1.46)**	19.7 (1.1)	15.5 (0.9)	4.2	**1.21 (1.11-1.31)**
Gallbladder	20.2 (1.8)	16.5 (1.2)	3.7	**1.26 (1.13-1.40)**	25.4 (1.6)	22.0 (1.4)	3.4	**1.15 (1.04-1.28)**
Pancreas	10.0 (0.8)	7.7 (0.6)	2.3	**1.19 (1.11-1.26)**	13.3 (0.7)	11.3 (0.6)	2.0	**1.12 (1.06-1.18)**
Larynx	67.0 (2.9)	58.6 (2.2)	8.4	**1.51 (1.21-1.88)**	65.7 (2.0)	60.2 (1.7)	5.5	**1.24 (1.02-1.50)**
Lung	15.9 (0.5)	13.8 (0.4)	2.1	**1.12 (1.08-1.16)**	19.5 (0.4)	17.7 (0.4)	1.8	**1.08 (1.05-1.12)**
Melanoma	88.3 (0.9)	85.3 (0.8)	3.0	**1.79 (1.45-2.22)**	93.2 (0.4)	91.9 (0.5)	1.3	**1.34 (1.10-1.63)**
Soft tissue	61.1 (2.5)	56.8 (2.2)	4.3	1.22 (0.97-1.54)	67.4 (2.0)	68.0 (2.0)	−0.6	1.05 (0.85-1.29)
Breast	80.9 (0.6)	79.8 (0.4)	1.1	**1.19 (1.10-1.30)**	85.1 (0.4)	83.5 (0.4)	1.6	**1.20 (1.11-1.29)**
Cervix	63.3 (1.8)	61.5 (1.3)	1.8	1.12 (0.94-1.32)	66.0 (1.4)	64.0 (1.4)	2.0	1.13 (0.96-1.32)
Corpus uteri	78.4 (1.2)	79.0 (0.9)	−0.6	0.98 (0.84-1.16)	79.1 (0.9)	78.6 (0.8)	0.5	1.05 (0.91-1.21)
Ovary	37.1 (1.3)	37.3 (1.0)	−0.2	**1.14 (1.03-1.26)**	44.8 (1.1)	37.9 (1.1)	6.9	**1.36 (1.23-1.50)**
Prostate	85.5 (0.9)	82.7 (0.7)	2.8	**2.07 (1.76-2.43)**	90.4 (0.6)	87.7 (0.7)	2.7	**1.61 (1.41-1.84)**
Testis	85.1 (1.3)	85.2 (2.7)	−0.1	**2.10 (1.27-3.44)**	92.2 (2.3)	90.9 (2.6)	1.3	**2.28 (1.23-4.21)**
Kidney	73.1 (1.3)	68.2 (0.9)	4.9	**1.29 (1.14-1.47)**	76.5 (0.9)	74.9 (0.7)	1.6	1.11 (0.99-1.25)
Bladder	57.3 (1.2)	56.1 (0.9)	1.2	1.07 (0.98-1.17)	56.6 (1.0)	55.0 (0.9)	1.6	1.02 (0.94-1.11)
Brain	27.8 (1.4)	25.9 (1.1)	1.9	**1.11 (1.01-1.22)**	30.1 (1.0)	30.5 (1.0)	−0.4	1.06 (0.97-1.15)
Thyroid	87.9 (1.5)	86.8 (1.2)	1.1	**1.52 (1.05-2.20)**	91.9 (0.9)	87.8 (1.0)	4.1	**2.06 (1.45-2.93)**
Hodgkin lymphoma	83.5 (2.0)	81.5 (1.5)	2.0	**1.82 (1.15-2.88)**	86.4 (1.3)	85.3 (1.4)	1.1	0.98 (0.68-1.43)
Non-Hodgkin lymphoma	59.3 (1.3)	56.8 (1.0)	2.5	**1.23 (1.10-1.37)**	69.7 (0.8)	66.1 (0.8)	3.6	**1.21 (1.09-1.34)**
Multiple myeloma	42.6 (1.9)	38.2 (1.5)	4.4	**1.27 (1.10-1.46)**	54.5 (1.4)	52.0 (1.3)	2.5	**1.21 (1.07-1.37)**
Leukemia	47.4 (1.4)	48.8 (1.1)	−1.4	1.10 (0.99-1.23)	57.0 (1.0)	57.7 (0.9)	−0.7	1.00 (0.91-1.10)
All cancer sites[c]	57.0 (0.2)	54.5 (0.2)	2.5	**1.20 (1.18-1.23)**	61.6 (0.2)	59.0 (0.2)	2.6	**1.16 (1.14-1.18)**

Abbreviations: GIMD, German Index of Multiple Deprivation; ICD-10, International Classification of Diseases Version 10; Q, quintile.
[a]Reference: Q1 (least deprived), adjusted for age at diagnosis. Significant relative excess risks ($p < 0.05$) are printed in bold.
[b]Difference of GIMD quintiles.
[c]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix.

the previous study reported stronger associations in younger patients and in lower stages.[34] In general, our results for CRC are in line with results from other countries such as the United Kingdom,[9,36,37] the Netherlands[38] and France[10] reporting differences in 5-year RS between area-based deprivation groups. In lung cancer, adjusting for stage at diagnosis led to larger effect estimates but the association was weaker in advanced stage. The association was stronger in older patients and attenuated in the subgroup of women. The previous study investigating overall survival including a smaller underlying population showed no impact of stage on the association but similar results for older patients and sex subgroups.[35] In line with our results, studies from other countries using area-based index measures showed lower lung cancer survival in most-deprived areas.[4]

Analyses on trends of area-based socioeconomic deprivation inequalities in RS over time showed inconsistent results across cancer sites. Although inequalities seemed to slightly decrease over time for all cancer sites combined in analyses including all cancer registries, this could not be confirmed by our sensitivity analyses restricted to cancer registries providing data for all years of diagnosis (1998-2014). In sensitivity analyses, the association for the period 2003 to 2005 was not as strong as in the main analyses. It is not possible to finally assess the changes from early to recent periods because first, cases numbers were too low for the rather small strength of association and second,

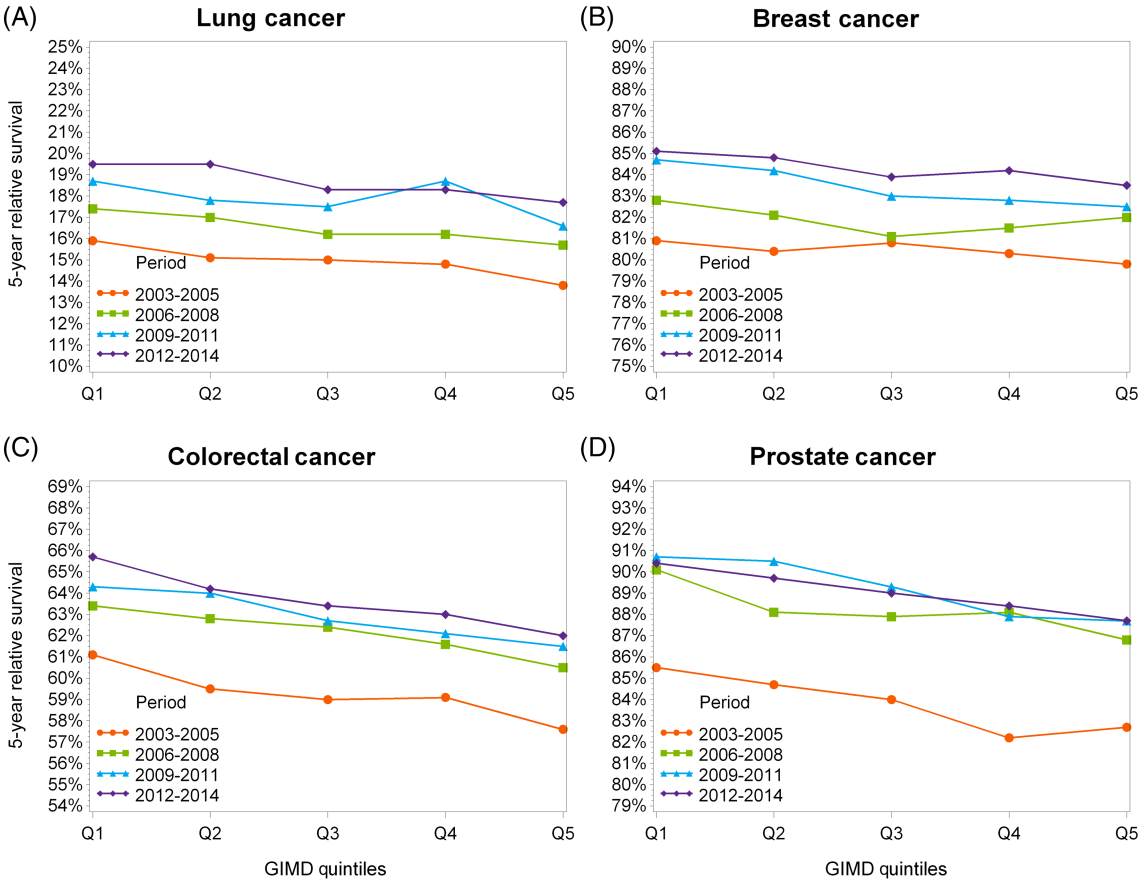

FIGURE 1 Differences in 5-year age-standardized relative survival rates across German Index of Multiple Deprivation (GIMD) quintiles for the four most common cancer sites (A-D) stratified by the calendar period. Ordinate scales are equally reduced to a range of 15% points [Color figure can be viewed at wileyonlinelibrary.com]

some registries could only provide data for some years of diagnosis and when we included only registries providing all years of diagnosis, the results were different. Therefore, trends of area-based socioeconomic deprivation inequalities could depend on the region in our study. Increasing or persistent survival disparities by area-based socioeconomic deprivation have been reported previously[39] but evidence on underlying reasons and contributing factors regarding the patient, diagnosis and treatment is limited.[1,26]

Hypothesized reasons for social inequalities in cancer survival comprise insurance status, tumor characteristics, stage, treatment, life style factors and comorbidity.[26] As all German residents have access to a comprehensive health insurance program, lack of insurance is unlikely to be the reason for social inequalities. To account for variations in background mortality due to differences in life style factors and comorbidity, we calculated RS using life tables stratified by area-based socioeconomic deprivation quintiles, sex, age and calendar year. However, it was not possible to adjust for life style factors and comorbidity beyond their impact on overall mortality. Adjusting for stage at diagnosis had only marginal effects on survival differences between area-based socioeconomic deprivation groups. It was not possible to account for differences in treatment or access to treatment. Two recent studies from Germany investigated the impact of treatment on lung[35] and CRC[34] survival differences between area-based socioeconomic deprivation groups by using more comprehensive clinical cancer registry data, but they included less regions and calculated overall survival.[34,35] Restricting the analyses to lung cancer patients receiving a certain treatment attenuated the association for chemotherapy and radiotherapy subgroups and increased effect estimates for the surgery subgroup.[35] For CRC, survival disparities between area-based socioeconomic deprivation groups persisted after adjustment for utilization of surgery as well as in subgroups receiving treatment according to guidelines.[34]

A limitation of our study was that we could not include Germany as a whole in our analyses as no small-area level was available in federal states comprising only one city and data quality for other excluded regions was not yet sufficient for survival analyses. In total, we excluded 61% of the German population; however, the included 39% comprised an underlying population of about 32 million residents. The distribution of the GIMD quintiles were comparable between included and excluded areas.[15] A previous study investigating a similar study region showed that the included areas were in general representative for whole Germany regarding socioeconomic deprivation.[40] Since the previous study, data quality of German cancer registries has improved; therefore, a lower cut-off value for DCO cases as inclusion criterion could be used in the present study.[15] As the proportion of DCO cases was not different across area-based socioeconomic deprivation quintiles, DCO cases should not have

affected the observed gradients in survival. Another limitation was that we used the GIMD based on data mainly from 2006 and therefore cannot consider changes in the distribution of area-based socioeconomic deprivation across municipalities, especially in our trend analyses. Due to data protection restrictions, it was not possible to link more than one area-based index to the cancer registry data, although the GIMD was also available for 2010. However, there were only minor changes between the GIMD 2006 and the GIMD 2010 in the distribution across municipalities. Furthermore, only the GIMD for the municipality of residence at the time of diagnosis could be considered in our analysis. However, the time period right after diagnosis is the most critical time regarding cancer survival. Additionally, residence at time of diagnosis might represent best a patients' access to resources for cancer early detection, diagnosis and treatment. Also, our study intended to investigate municipality-level deprivation but due to the lack of individual socioeconomic status data, we could neither conclude about the impact of individual socioeconomic status on cancer survival nor the interaction of individual and area-based socioeconomic deprivation. Studies examining both measures showed that they are independently associated with cancer survival.[41-43] Interventions to reduce social inequalities in cancer survival would mostly be implemented on area-level and not on individual-level; hence, it is reasonable to investigate area-based socioeconomic deprivation. Currently, the information on stage at diagnosis is missing for more than 35% of the patients and the stage-groups were rather crude (localized/regional/distant). However, the completeness of stage information has strongly increased since the previous study[15] in which missing information on stage was present for 48% of the patients. Hence, data quality of German cancer registries has improved and is going to improve through the implementation of clinical cancer registries.[44,45]

A strength of our study was the large cohort of the cancer patients of a population of 32 million German residents. Furthermore, we used data from population-based cancer registries with a completeness of more than 90% in 2014.[44] It was possible to investigate survival differences in the 25 most common cancer sites. Area-based socioeconomic deprivation in our study region was assessed on a relatively small area-level (median population for included municipalities: 1194 residents)[16] which is comparable to studies from England (mean 1500 residents)[9] although the range of residents is a lot larger in the German administrative areas (interquartile range: 517-3494 residents) which were not explicitly created for statistical purposes. We accounted for general mortality by computing RS using life tables stratified by sex, age, calendar year and GIMD on municipality level.

Overall, we found similar gradients in cancer patient survival across area-based socioeconomic indicators as in our previous study from Germany,[15] despite using a smaller area level for quantifying area-based socioeconomic deprivation. Trend analyses revealed increasing survival in recent years, with inconsistent patterns regarding decreases or increases in socioeconomic gradients over time between cancer sites. To further explore the underlying reasons for persistent social disparities in cancer survival, more detailed analyses including complete information on tumor and treatment factors are essential. Completeness of German epidemiological cancer registries has already improved since the previous study[15] and clinical cancer registries including more information about the tumor and treatment are currently established in all federal states. Future research should use these emerging data resources to further investigate underlying reasons for social inequalities in cancer survival in Germany.

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CONFLICT OF INTEREST

The authors declared no potential conflicts of interest.

ETHICS APPROVAL

The study was approved by ethics committee of the University of Heidelberg. Data collection within the Cancer Registries has been carried out according to state legislation of cancer registration. The study was conducted in accordance with the recommendations of the Declaration of Helsinki by the World Medical Association.

DATA AVAILABILITY STATEMENT

The data analyzed in this study were provided by epidemiological cancer registries. Restrictions apply to the usage of these data, which were used under the provisions for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the cancer registries.

ORCID

Isabelle Finke https://orcid.org/0000-0002-0620-4819

Lina Jansen https://orcid.org/0000-0001-8004-4940

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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