Cancer Control
Volume 28: 1-33

Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/10732748211011956
journals.sagepub.com/home/ccx
SAGE

Factors Explaining Socio-Economic Inequalities in Cancer Survival: A Systematic Review

Nina Afshar, PhD[1,2], Dallas R. English, PhD[1,3], and Roger L. Milne, PhD[1,3,4]

Abstract

Background: There is strong and well-documented evidence that socio-economic inequality in cancer survival exists within and between countries, but the underlying causes of these differences are not well understood.

Methods: We systematically searched the Ovid Medline, EMBASE, and CINAHL databases up to 31 May 2020. Observational studies exploring pathways by which socio-economic position (SEP) might causally influence cancer survival were included.

Results: We found 74 eligible articles published between 2005 and 2020. Cancer stage, other tumor characteristics, health-related lifestyle behaviors, co-morbidities and treatment were reported as key contributing factors, although the potential mediating effect of these factors varied across cancer sites. For common cancers such as breast and prostate cancer, stage of disease was generally cited as the primary explanatory factor, while co-morbid conditions and treatment were also reported to contribute to lower survival for more disadvantaged cases. In contrast, for colorectal cancer, most studies found that stage did not explain the observed differences in survival by SEP. For lung cancer, inequalities in survival appear to be partly explained by receipt of treatment and co-morbidities.

Conclusions: Most studies compared regression models with and without adjusting for potential mediators; this method has several limitations in the presence of multiple mediators that could result in biased estimates of mediating effects and invalid conclusions. It is therefore essential that future studies apply modern methods of causal mediation analysis to accurately estimate the contribution of potential explanatory factors for these inequalities, which may translate into effective interventions to improve survival for disadvantaged cancer patients.

Keywords

cancer survival, socio-economic position, deprivation, disadvantage, inequality, disparity

Received November 04, 2019. Received revised March 06, 2021. Accepted for publication March 31, 2021.

Introduction

Socio-economic position (SEP) is a complex construct of several aspects of a person's social, financial and occupation position.[1] Cancer patients with lower SEP consistently show worse survival than those with higher SEP, regardless of whether individual-level SEP or area-based measures are used.[2,3] Comprehensive reviews conducted by the International Agency for Research on Cancer (IARC) in 1997[2] and Woods et al, in 2005[3] found solid evidence for socio-economic inequalities in cancer survival for most malignancies and in many countries. The extent of the survival differences by SEP

[1] Cancer Epidemiology Division, Cancer Council Victoria, Melbourne, Victoria, Australia
[2] Cancer Health Services Research Unit, Centre for Health Policy, School of Population and Global Health, The University of Melbourne, Melbourne, Victoria, Australia
[3] Centre for Epidemiology and Biostatistics, School of Population and Global Health, The University of Melbourne, Melbourne, Victoria, Australia
[4] Precision Medicine, School of Clinical Sciences at Monash Health, Monash University, Melbourne, Victoria, Australia

Corresponding Author:
Nina Afshar, Cancer Epidemiology Division, Cancer Council Victoria, 615 St Kilda Road, Melbourne, Victoria 3004, Australia.
Email: nina.afshar@cancervic.org.au

is moderate for most cancer sites, but substantial for cancers of the breast, colon, bladder and corpus uteri, which all have relatively good prognosis.[2] Stage at diagnosis was reported to be the primary explanatory factor, but its estimated mediating effect has differed by cancer site and between countries and studies.[3,4] Few studies have assessed the contribution of treatment to survival differences among socio-economic groups.[3,4] The degree to which patient characteristics such as the presence of co-morbid conditions and health-related behaviors explain socio-economic differences in cancer survival also remains unclear.

In this systematic review, we assessed studies exploring underlying reasons for socio-economic inequalities in cancer survival, with the aim of identifying potential contributing factors and determining the validity of published estimates of their mediating effects.

Methods

This systematic review was planned, conducted and reported in adherence to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P).[5] The review protocol was registered with the International Prospective Register of Systematic Reviews–PROSPERO (registration number CRD42016039227).

Search Strategy

A systematic search of studies published in English from 1 January 2005 to 31 May 2020 was conducted in Ovid Medline, EMBASE and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases to identify those that investigated the underlying reasons for socio-economic inequalities in cancer survival (Supplementary Table 1). The bibliographies of selected studies were reviewed to locate eligible articles that might not have been detected through the above process. Finally, we carried out a further manual search using Google Scholar and reviewed the first 3 pages to ensure that potentially relevant studies were not missed.

Eligibility Criteria

Eligible studies met all of the following criteria: (1) observational study of adults (men or women diagnosed with cancer at age $\geq$15 years); (2) written in English and published in a peer-reviewed journal since 2005; (3) investigated the underlying causes of socio-economic inequalities in cancer survival; (4) assessed death from any cause or death from a specific type of cancer; and (5) reported an estimate of a hazard ratio (HR), odds ratio (OR), or excess mortality rate ratio (EMRR), with a corresponding 95% confidence interval (CI) or standard error. The EMRR is the ratio of the excess mortality rate due to cancer diagnosis in one group of people (e.g., people with low SEP) versus the excess mortality rate in another group (e.g., people with high SEP). We excluded eligible abstracts if full text was not available.

Study Screening and Data Extraction

N.A. performed the literature search and excluded irrelevant or ineligible studies based on the titles and abstracts. Full reports of selected articles were imported to *Covidence*, a web-based program for conducting systematic reviews, for independent screening by N.A. and R.L.M. Any disagreements were resolved after consulting D.R.E. Data from the selected studies were extracted by N.A. with assistance from R.L.M. For each study, we extracted the following information: the first author's last name, year of publication, country where the study was conducted, sources of data, diagnosis years, range of age at cancer diagnosis, cancer types studied, measures and categories of socio-economic position, factors considered as potentially contributing to socio-economic inequalities in cancer patient survival, statistical methods and covariates included in the analyses.

Assessment of Risk of Bias

N.A. and R.L.M independently assessed the risk of bias of eligible studies using the domains of bias from the ROBINS-E (Risk of Bias In Non-Randomized Studies-of Exposures) tool [http://www.bristol.ac.uk/population-health-sciences/centres/cresyda/barr/riskofbias/robins-e/]. The following domains were reviewed: confounding, selection of participants into the study, classification of the exposure, adjustment for mediators, level of missing data, measurement of the outcome, and reporting of results.

Results

Study Selection

The electronic database search identified 9,245 articles; 2,069 duplicate citations were removed, and an additional 7,026 articles were excluded based on their title and abstract, leaving 150 articles for further assessment. We excluded 76 studies after full-text screening; therefore, 74 articles met the eligibility criteria for inclusion in the review (Figure 1).

Study Characteristics

Table 1 summarizes the characteristics of the included studies and factors considered as potentially contributing to socio-economic inequalities in cancer-specific and overall survival. Forty-four studies were conducted in Europe[6-48] (1 study used data from England and Australia),[49] 19 in the United States of America (US),[50-68] 4 in Canada,[69-72] 3 in Australia,[73-75] 2 in New Zealand,[76,77] and 2 in Asia.[78,79] These studies assessed the following cancers: female breast,[8,9,13,17,18,26,29,30,32,36,44,49,53,59-61,65,67,77] male breast,[58] cervix,[24,50] ovary,[23,42,45] endometrium,[33] prostate,[7,34,43,64] penis,[47] colorectum,[12,15,22,28,40,48,55,57,66,73]

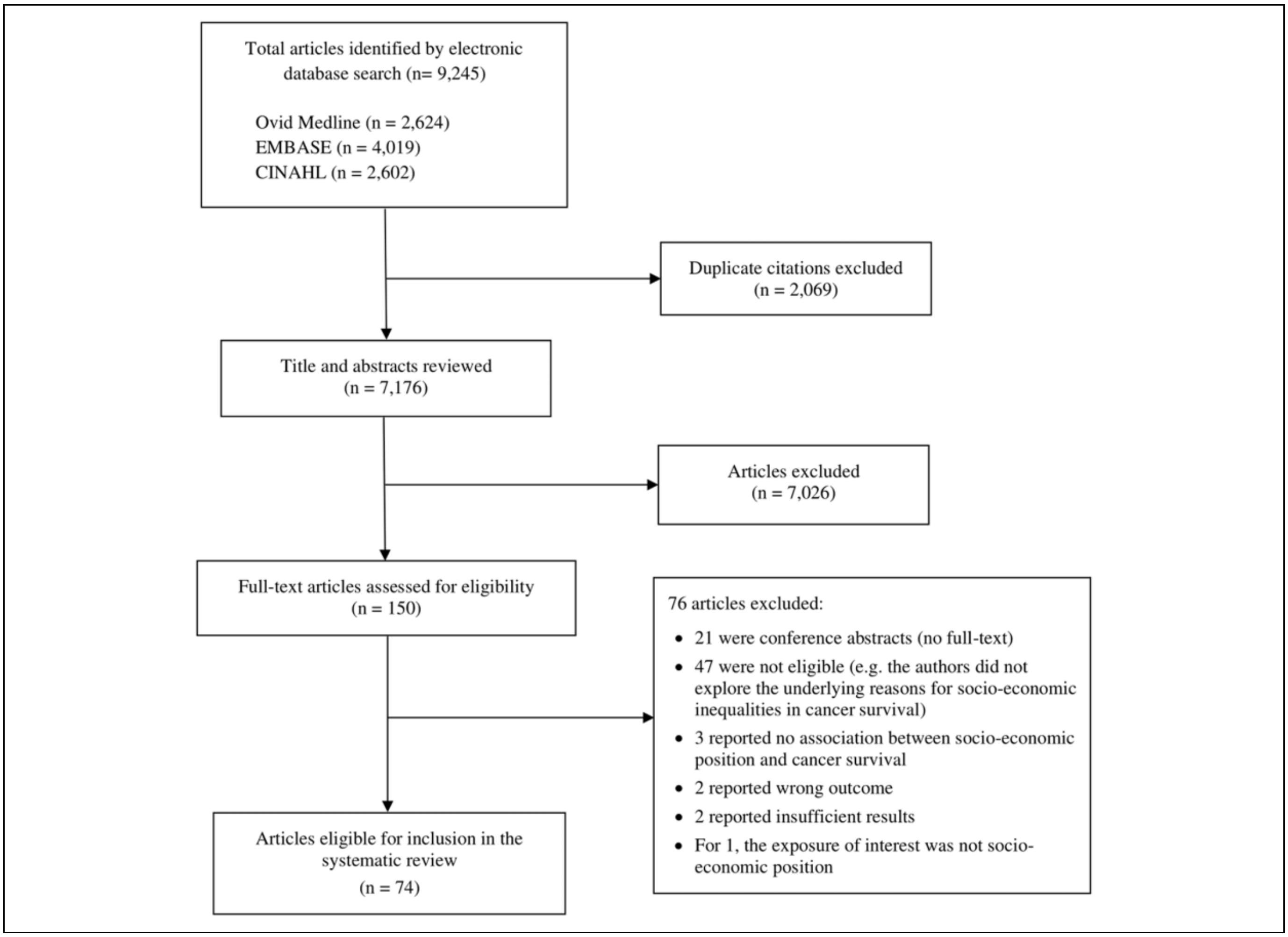

Figure 1. Flow diagram describing selection of studies for inclusion in the systematic review of factors explaining socio-economic inequalities in cancer survival. CINAHL, Cumulative Index to Nursing and Allied Health Literature.

lung,[10,11,16,20,25,41,56] head and neck,[31,54,70,71] brain and central nervous system (glioma),[62,63] esophagus,[27] pancreas,[39,79] liver,[72] kidney,[52] melanoma,[19,35] acute myeloid leukemia[37] and non-Hodgkin lymphoma,[21,38] as well as selected groups of malignancies.[6,14,46,51,68,69,74-76,78] The majority of the studies used population-based cancer registry data,[7-11,13,16-20,25,27-30,34-36,38-41,44,49,50,52,54-56,58,60-63,66,68,69,71-79], some linking these with healthcare administration, public and private hospital, screening and treatment datasets.[8,20,38,50,54,71,73] The remaining studies used data from a variety of sources including cohort and case-control studies,[6,12,14,26,43,59,64] hospitals,[31,37,46,70] cancer surveillance programs,[57] national cancer audit[48] or other cancer databases.[15,21-24,32,33,42,45,47,51,53,65,67] Twenty-three studies reported cancer-specific survival, or relative or net survival, where the cancer under study was considered as the cause of death,[10,13,18,19,27,28,30,32,34-36,44,49,52,60,61,66,71,73-77] while 36 studies presented overall survival (*i.e.*, death from any cause).[6-8,11,14,16,17,20-26,33,37-39,41,42,45,46,48,50,51,53,55-58,62,63,70,72,78,79] Other studies reported both overall and cancer-specific or relative/net survival.[9,12,15,29,31,40,43,47,54,59,64,65,67-69]

The measurement of SEP of cancer patients at diagnosis varied across studies. Several studies used composite measures or indices of SEP or deprivation such as census tracts socio-economic status,[38,51-56,58,61-63,65,66,68,70,71] Townsend index,[17,27,28] the index of multiple deprivation,[12,20,25,29,32,34,41,44,45,48] the index of relative socio-economic advantage and disadvantage or the index of relative socio-economic disadvantage,[73-75] the New Zealand deprivation index,[76,77] the Scottish Index of multiple deprivation, deprivation index,[30,37,42] socio-economic index[11] or the Small Area Health Research Unit index of social deprivation.[36] Other studies defined SEP using measures such as educational level, income, unemployment rate, poverty-level, median house-hold income or median property value across aggregated or geographical areas based on address, postal code or neighborhood.[7-9,31,49,50,59,60,64,67,69,72,78] The remaining studies used individual measures including education, gross household or disposable income, last occupation and housing status (rental or owner occupied).[6,10,13-16,18,19,21-24,26,33,35,39,40,43,46,47,57,59,64,67,79]

Table 1. Characteristics of Included Observational Studies on Potential Explanations for Socio-Economic Inequalities and Cancer Survival, 2005-2020.

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Aarts et al, 2013	Netherlands	GLOBE, prospective cohort study	Eindhoven and Surroundings	1991-2008	NA (15-75 at baseline)	All malignancies with focus on colon, lung (non-small cell), prostate and female breast	Education level (individual level)	4	Kaplan-Meier method (crude survival), Cox proportional hazards regression (overall 5-year survival)	For all cancers combined, 5-year crude survival was superior in highly educated patients compared with low educated cancer patients. Educational inequalities in overall 5-year survival were observed in prostate cancer comparing low educated patients with highly educated, while no associations were found for breast, colon and non-small cell lung cancer after adjusting for age, year of diagnosis and stage at diagnosis. Comorbidities and lifestyle behaviors did not explain educational inequalities in overall survival after prostate cancer.	Age, year of diagnosis, stage at diagnosis and sex (colon and non-small cell lung cancer) Additionally, adjusted for comorbidity, alcohol consumption, physical activity and smoking status
Aarts et al, 2013	Netherlands	Eindhoven Cancer Registry	South-eastern Netherlands	1998-2008	All ages	Prostate	Socio-economic status (SES) defined at neighborhood level based on the postal code of the residence area derived from individual tax data provided at an aggregated level	3	Cox proportional hazard regression (overall 10-year survival)	Overall 10-year survival was superior in high-SES patients compared with low-SES (both localized and advanced stages). Treatment had a larger impact on the risk of death comparing patients living in low and high socio-economic status areas, except for men aged 75 years and older. Presence of comorbidities partly contributed to inequalities in overall survival following prostate cancer diagnosis.	Stratified by age and stage at diagnosis Additionally, adjusted for year of diagnosis, comorbidity and treatment

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Aarts et al, 2011	Netherlands	BoBZ database (population-based screening program) linked with Eindhoven Cancer Registry	Southern Netherlands	1998-2005	All ages	Breast	Socio-economic status (SES) defined at an aggregated level for each postal code	3	Life test method (crude survival), Cox proportional hazards regression (overall 5-year survival)	Women with low SES had lower overall 5-year survival compared with women with high SES, whether screen-detected, interval carcinoma or not attended screening at all. Among non-attendees and interval cancers, the differences in survival were largely explained by stage (48% and 35%) and to a lesser degree by treatment, and comorbidities (16% and 16%), respectively. Presence of comorbidities explained 23% of survival inequalities among screen-detected patients; it had less impact on interval cancers or non-attendees.	Age Stratified by screening attendance Additionally, adjusted for stage at diagnosis, comorbidity, and treatment
Abdel-Rahman et al, 2019	United States	Surveillance, Epidemiology, and End Results (SEER)	United States	2010-2015	All ages	Breast (non-metastatic)	Census tract-level socioeconomic Status (SES)	3	Cox proportional hazard regression (cancer-specific survival)	Lower SES index is associated with worse breast cancer-specific survival, which was not explained by stage at diagnosis or breast cancer subtype (triple negative, luminal and HER 2).	Model 1: Adjusted for age, race, stage at diagnosis, and Stratified by breast cancer subtype Model 2: Adjusted for age, race, breast cancer subtype, and Stratified by stage
Bastiaannet et al, 2011	Netherlands	Netherlands Cancer Registry	Netherlands	1995-2005	All ages	Breast	Socio-economic status (SES) Area-based measure according to place of residence at the time of diagnosis	5	Cox proportional hazard regression (overall 10-year survival), 10-year relative survival (Hakulinen method), Relative Excess Risk of death using generalized linear model with Poisson distribution	Patients with a very low SES had lower overall and cancer-specific 10-year survival compared to very high SES group. Cancer stage only partly explains observed socio-economic differences in breast cancer survival. Socio-economic status remained a significant independent prognostic factor of survival.	Age, year of diagnosis, histology, grade, T-stage, nodal status, distant metastases, surgery, and adjuvant treatment

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Beckmann et al, 2015	Australia	South Australia Cancer Registry linked with public/private hospital separation data, public/private radiotherapy and clinical cancer registries (teaching hospitals)	South Australia	2003-2008	50-79	Colorectum	Index of relative Socioeconomic Advantage and Disadvantaged (IRSAD) 2006 (area-based measure of socio-economic position)	5	Kaplan-Meier method (1-, 3- and 5-year crude cancer-specific survival), Competing risk regression (Fine and Gray method)	Patients from the most advantaged areas had better survival compared with patients from disadvantaged areas. Survival inequalities were not explained by differential stage at diagnosis, patient factors, other tumor characteristics, comorbidity, and treatment modalities.	Age, sex, year of diagnosis, place of residence, cancer site, stage, grade, comorbidity, primary treatments
Berger et al, 2019	France	The leukemia unit of the Toulouse University Hospital	South-west of France	2009-2014	$\geq$60	Acute Myeloid Leukemia (AML)	European deprivation index (ecological)	5	Cox proportional hazard regression (Overall survival)	Cases living in the most deprived areas had a higher risk of dying from all causes, which was not explained by differential initial treatment.	Age, sex, and comorbidity Additional adjustment for AML ontogeny, cytogenetic prognosis, performance status, white blood cells count, and treatment
Berglund et al, 2010	Sweden	Regional Lung Cancer Registry	Central Sweden	1996-2004	30-94	Lung (Non-small cell)	Education level (individual level measure, main indicator of socio-economic position) Socioeconomic index (SEI) based on the occupation of the household	3 3	Kaplan-Meier method, Cox proportional hazards regression (1- and 3-year crude cancer-specific survival)	Cancer-specific survival was higher among patients from high education level. Stage at diagnosis was not different between educational groups. The authors observed social inequalities in 1- and 3-year survival for all patients, but after adjustment for known prognostic factors and treatment, a social gradient in survival remained only among women with early-stage disease. In men with stage III disease, the reverse pattern was observed, with higher risk of death in patients with high education level.	Cancer-specific survival (both SES indicators): Sex, age, stage at diagnosis Cancer-specific hazard models (Educational level): Sex, age, histopathology, performance status, smoking status, treatment (stratified by stage)

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Berglund et al, 2012	England	Thames Cancer Registry	Southeast England	2006-2008	≤59-≥80	Lung	Socioeconomic Index (SEI) based on the income domain of the 2007 Indices of deprivation and postcode	5	Logistic regression, Cox proportional hazards regression (Overall survival), Mortality rates modeled with flexible parametric survival models using a restricted cubic spline (overall 5-year survival)	Overall survival was higher in the most affluent group, especially for early stages. While survival in advanced stage was poor in all socioeconomic quintiles with minimal difference between affluent and deprived patients. Inequalities in survival from lung cancer could not be fully explained by differences in stage at diagnosis, comorbidity and type of treatment.	Sex, age at diagnosis, comorbidity, treatment
Bharathan et al, 2011	England	Northern Region Colorectal Cancer Audit Group	Northern England	1998–2002	≤60->80	Colorectum	Indices of Multiple Deprivation (IMD) 2004 (area-based measure)	5	Logistic regression, Kaplan-Meier method (crude overall 5-year survival), Cox proportional hazards regression, 5-year relative survival (Hakulinen-Tenkanen method)	Overall and relative 5-year survival was higher among affluent patients. The difference was partly explained by variation in comorbidity, urgency of surgery and curative resection status. Deprivation remained as a significant independent predictor of overall survival.	Age, sex, grade, tumor site and differentiation, stage, operative urgency and resection
Booth et al, 2010	Canada	Ontario Cancer Registry	Ontario	2003-2007	NA	Breast, colon, rectum, non-small cell lung, cervix, and larynx	Socio-economic status (based on community median household income, census 2001)	5	Kaplan-Meier method, Cox proportional hazards regression (overall and cancer-specific 5-year survival)	Overall survival was different across socio-economic groups for all cancers. Socio-economic disparities were found in cancers of breast, colon, and larynx. Differences in stage at diagnosis partially explained socio-economic inequalities in breast cancer survival, but no other cancers.	Age, stage at diagnosis

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Bouchardy et al, 2006	Switzerland	Geneva cancer registry	Geneva	1980-2000	<70	Breast	Socio-economic status (based on individual-level occupation)	4	Cox proportional hazards regression (5- and 10-year overall and cancer-specific survival)	Women from low socio-economic status had higher risk of dying due to breast cancer. Socio-economic inequalities are partly explained by stage at diagnosis, tumor characteristics, method of detection (screening, symptom, other), sector of care (public, private) and treatment.	Age, period of diagnosis, country of birth, marital status, method of detection, stage, histology, tumor characteristics, sector of care and treatment
Braaten et al, 2009	Norway	NOWAC (Norwegian Women and Cancer Study)	Norway	1996-2005	34-69	Colon and rectum, lung, breast, ovary and other malignancies	Years of Education (individual level) Gross household Income (individual level)	4 5	Cox proportional hazards regression (overall 5-year survival)	Both years of education and gross household income were inversely associated with all-cause cancer mortality. Higher-educated women with ovarian cancer had lower risk of dying, while mortality risk among colorectal cancer patients increased with years of education (not with income). Educational inequality in overall survival from colon and rectal cancer is partially explained by stage at diagnosis, and although less so, by smoking and alcohol drinking. For ovarian cancer, stage at diagnosis and smoking status prior to diagnosis did not explain the observed differences across education groups.	Age, household size, marital status, stage, smoking, BMI, physical activity, parity, hormone replacement therapy, contraceptives, alcohol, diet, region of living

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Brookfield et al, 2009	United States	Florida Cancer Data System (FCDS) linked to Agency for Healthcare Administration (AHCA)	Florida	1998-2003	All ages	Cervix	Community poverty level (based on post code)	4	Kaplan-Meier method (median survival), Cox proportional hazards regression (overall survival)	Survival was significantly lower among disadvantaged patients as compared with affluent patients. Tumor characteristics and treatment explained some of the observed socio-economic disparities in survival.	Age, race, ethnicity, comorbidities, insurance status, tumor stage, grade, histology, and treatments
Byers et al, 2008	Unite States	Patterns of Care (POC) Study of the National Program of Cancer Registries (NPCR)	California, Colorado, Illinois, Louisiana, New York, Rhode Island, and South Carolina	1997	$\geq$25	Breast, colorectum, prostate	Socio-economic status (based on the education and income levels of the census tract of residence)	3	Cox proportional hazards regression (overall 5-year survival)	Survival was lower among individuals with breast cancer living in low-SES areas compared with those in affluent areas. Socioeconomic inequalities in overall 5-year survival after breast cancer was explained by later stage at diagnosis and comorbidity, while treatment had no mediating effect.	Age, race/ethnicity, comorbidity, stage, treatment (colorectum and breast), sex and subsite (colorectum)
Cavalli-Björkman et al, 2011	Sweden	Two Swedish Clinical Quality Registers on colon and rectal cancer	Central Sweden (Stockholm–Gotland and Uppsala–Örebro regions)	1995-2006 (rectal) 1997-2006 (colon)	<75	Colon and rectum	Education (individual level)	3	Kaplan-Meier method (overall 3- and 5-year survival), Cox proportional hazards regression, Relative Survival, Excess mortality rates modeled using Poisson regression	Highly educated patients with colon or rectal cancer had higher survival. Differences in elective or emergency surgery and type of hospital or preoperative radiotherapy for rectal cancer did not contribute to higher excess risk of death due to colon or rectal cancer in patients with low education.	Age, sex Stratified by stage
Chu et al, 2016	Canada	Princess Margaret Hospital/cancer center	Toronto	2003-2010	All ages	Head and neck (squamous cell carcinoma)	Socio-economic status (neighborhood-level based on postcode derived from 2006 Canada Census)	5	Cox proportional hazards regression, logistic regression (overall survival)	Overall survival was worse among patients with lower socio-economic status which may be due to differences in smoking, alcohol consumptions and stage at diagnosis.	Age, sex, stage, Alcohol consumption, smoking status

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Comber et al, 2016	Ireland	Irish National Cancer Registry linked to public hospital discharge data (Hospital Inpatient Enquiry data)	Ireland	2004-2008	All ages	Non-Hodgkin's lymphoma	Census-based deprivation score (area-based)	Not applicable	Discrete-time survival using structural equation modeling (overall survival)	Lower survival among disadvantaged patients was partly explained by probability of late stage at diagnosis and emergency presentation.	Age
Cote et al, 2019	United States	Surveillance, Epidemiology, and End Results (SEER)	United States	2000-2015	$\geq$18	Glioma	Socioeconomic Status (County level, census based)	5	Cox proportional hazards regression (overall survival)	Survival was higher for people living in higher SES counties, which was not explained by differences in receiving radiotherapy and chemotherapy.	Age at diagnosis, extent of surgical resection Additional adjustment for radiation and chemotherapy
Dalton et al, 2015	Denmark	Danish Lung Cancer Register	Denmark	2004-2010	30-84	Lung	Education (individual level) Income (household)	3 3	Logistic regression, Cox proportional hazards regression (overall survival)	Lung cancer survival was different by all socioeconomic status indicators. Educational inequality in survival partly explained by differential stage, first-line treatment, comorbidity and performance status.	Age, sex, period of diagnosis, treatment, comorbidity, performance status Income was adjusted for education
Danzing et al, 2014	United States	SEER (Survival, Epidemiology and End Results) registry	United States	2004-2010	$\geq$18	Kidney	Socioeconomic Status (County level, census based)	4	Kaplan-Meier method, Cox proportional hazards regression (cancer-specific survival)	Low socio-economic status was independently associated with poorer survival from renal cancer. Authors suggested that the observed difference may be explained by late stage at diagnosis.	Age, sex, race, grade, histology, year of surgery, procedure type, place of residence, and marital status
Deb et al, 2017	United States	SEER (Survival, Epidemiology and End Results) registry	United States	2003-2012	All ages	Glioma	Socioeconomic Status (County level, census-based)	3 5	Logistic regression, Cox proportional hazards regression (overall 5-year survival)	The observed lower survival in cases living in disadvantaged areas was only partly explained by differences in the treatment received (surgery and radiation therapy).	Age at diagnosis, sex, race, tumor type, and tumor grade Additional adjustment for surgery and radiation therapy

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
DeRouen et, 2018	United States	Prostate Cancer Study (population-based case-control study)	San Francisco Bay Area and Los Angeles County	1997-2003	40-79	Prostate	Education (individual level/self-reported) Neighborhood-level socio-economic status (SES)	3 5	Cox proportional hazards regression (overall and cancer-specific survival)	Education and SES were jointly associated with overall and prostate cancer-specific survival such that men with the lowest levels of education and living in low SES areas had the greatest risk of death compared to college graduates living in high SES areas. Co-morbidities, health behaviors, hospital SES and environmental factors did not explain the observed gap in prostate cancer-specific survival by education, although the gap in survival by SES decreased after adjusting for these variables.	Age, race/ethnicity, study site, census-block-group Stratified by stage Additional adjustment for nativity (US-born or foreign-born, co-morbidities, health behaviors and environmental factors
Downing et al, 2007	England	Northern and Yorkshire Cancer Registry	Northern and Yorkshire regions	1998-2000	All ages	Breast	Townsend Index for area of residence	4	Logistic regression, Cox proportional hazards regression (overall 5-year survival)	Women from more deprived areas had increased risk of death which could be partly explained by stage at diagnosis	Age, stage
Eaker et al, 2009	Sweden	Regional Breast Cancer Register of the Uppsala/ Örebro Region	Central Sweden	1993-2003	20-79	Breast	Level of education (individual-level)	4	Cox proportional hazards regression (5-year cancer-specific survival), relative survival	Survival was lower among disadvantaged patients. Differences in diagnostic intensity, tumor characteristics and primary treatments did not explain educational inequalities in breast cancer survival.	Age, year of diagnosis, diagnostic intensity, tumor characteristics and treatments. Stratified by stage at diagnosis

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Engberg et al, 2020	Denmark	Danish Pancreatic Cancer Database	Denmark	2012–2017	All ages	Pancreas	Household income	4	Cox proportional hazards regression (overall survival)	The overall survival was higher for cases with higher household income. Differences in surgical resection and chemotherapy explained very little of the observed gap in survival across household incomes.	Age group, year of diagnosis and comorbidity (stratified by sex) Additional adjustment for civil status, education, region of residence, stage, surgical resection and chemotherapy
Eriksson et al, 2013	Sweden	Swedish Melanoma Register	Sweden	1990-2007	All ages	Melanoma	Level of education (individual-level)	3	Kaplan-Meier method, Cox proportional hazards regression (cancer-specific survival)	Cancer-specific survival was lower among low educated patients which is partially explained by advanced-stage presentation.	Age, sex, clinical stage at diagnosis, tumor site, histogenetic type, tumor ulceration, tumor thickness, Clark's level of invasion, living area, period of diagnosis (all models were stratified by healthcare region)
Feinglass et al, 2015	United States	National Cancer Data Base (NCBD) hospital-based cancer registry	United States	1998-2006	All ages	Breast	Socioeconomic status (from patients' combined ZIP code quartiles of census-based median income and educational attainment at the time of diagnosis)	6	Cox proportional hazards regression (5- and 10-year overall survival), Kaplan-Meier method	The highest SES group had better survival compared with the lowest. Disparities in disease stage, insurance status and treatment explained some of survival inequalities. Comorbidity explained only a very small proportion of the observed survival gap.	Age, hospital characteristics, time period, insurance status, race / ethnicity, stage, type of treatment
Feller et al, 2018	Switzerland	Swiss National Cohort (SNC) - National Institute for Cancer Epidemiology and Registration (NICER) cancer registry network	Switzerland	2001-2008	30-84	Colorectum	Socio-economic position (SEP) based on individual-level of education	3	Competing risk regressions (Fine and Gray's method), Cox proportional hazards regression (overall and cancer-specific survival)	Survival was lower in patients with colorectal cancer with low level of SEP/ education, which was only partly explained by rurality of residence and stage at diagnosis.	Age at diagnosis, sex, civil status, and nationality Additional adjusted for urbanity, language region of residence, tumor localization, stage at diagnosis and canton of residence
Finke et al, 2020	Germany	Population-based clinical cancer registries	South and East Germany	2000-2015	$\geq$15	Lung	German Index of Multiple Deprivation (area-based)	5	Cox proportional hazards regression (overall 5-year survival)	Cases living in the most deprived areas had lower overall survival compared with those living in the least deprived regions, which were not explain by tumor grade and stage at diagnosis.	Age, sex, year of diagnosis Additional adjustment for cancer subtype, grading and stage

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Forrest et al, 2015	England	Linked dataset of the Northern and Yorkshire Cancer registry and Hospital Episode Statistics and lung cancer audit data	Northern and Yorkshire regions	2006-2009	All ages	Lung	Index of Multiple Deprivation (area-based)	5	Logistic regression (overall 2-year survival)	Survival was significantly lower in the most deprived patients. Inequalities in survival from lung cancer were partly explained by differences in receipt of the treatment. Stage of disease and performance status did not contribute to the observed differences.	Age, sex, histology, year of diagnosis, comorbidity, timely GP referral, stage, performance status, type of treatment, timely 1st treatment
Frederiksen et al, 2012	Denmark	Danish national lymphoma database (LYFO)	Denmark	2000-2008	≥25	Non-Hodgkin Lymphoma	Education (individual-level, used in multivariable analysis) Household income	3 4	Cox proportional hazards regression (overall survival), Kaplan-Meier method	Patients with low socioeconomic position had lower survival. Comorbidity slightly contributed to survival differences. Other clinical prognostic factors such as stage at diagnosis, performance status, extranodal involvement and level of LDH partly explained differences in survival.	Age, sex, year of operation, clustering at the department level, comorbidity, performance status, stage, extranodal involvement, level of LDH, IPI score
Frederiksen et al, 2009	Denmark	National clinical database of the Danish Colorectal Cancer Group (DCCG)	Denmark	2001-2004	61-76	Colon and rectum	Income (individual-level) Education (individual-level) Housing status (individual-level)	1 3 2	Cox proportional hazards regression (overall survival)	Survival was superior in patients with higher SES compared with those with low SES. The observed association was partly explained by comorbidity and to a lesser extent by lifestyle, while stage at diagnosis, mode of admittance, type of surgery and specialization of surgeon did not contribute to survival differences.	Age, sex, year of operation, alcohol, tobacco, BMI, comorbidity, stage, mode of admittance, specialist surgeon, type or radicality of operation Income was adjusted for education. Housing status was adjusted for income and education

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Grady et al, 2019	France	François Baclesse regional cancer care center	North-West France (Caen)	2011-2015	≥18	Ovary	European Deprivation Index (area-based)	2	Cox proportional hazards regression (3-year overall survival)	Women living in more socio-economically disadvantaged areas had lower survival than those living in less disadvantaged reasons. The observed gap in survival was partly explained by differences in stage and the treatment received i.e. chemotherapy, and surgical resection	Age Additional adjustment for performance status, grade, stage, chemotherapy, surgical resection
Groome et al, 2006	Canada	Linked cancer research database (Ontario Cancer Registry, hospital discharged data, and radiotherapy data)	Ontario	1982-1995	All ages	Larynx	Socio-economic status (area-based measure based on adjusted median household income from the Canadian Census)	5	Conditional Cox proportional hazards regression (cancer-specific survival)	Socio-economic status was associated with laryngeal cancer outcomes; survival disparity was only observed for glottic cases. The anatomic extent of the tumor explained some of differences in survival from glottic cancer.	T-category (the anatomic extent of the tumor)
Guo et al, 2015	United States	Florida Cancer Data System (FCDS)	Florida	1996-2010	≥20	Oral and pharynx	Socio-economic status (using census tract-level poverty information from the 2000 U.S. census data)	3	Cox proportional hazards regression, mediation analysis (overall and cancer-specific survival)	Low socio-economic status was associated with poorer survival. Higher rate of individual smoking was the major contributor to poorer survival in disadvantaged patients. The mediation effect of individual smoking was larger in the middle SES group than in the low SES group.	Age, sex, race/ ethnicity, marital status, health insurance, year of diagnosis, anatomic site, stage, treatment, smoking
Hines et al, 2014	United States	Georgia Comprehensive Cancer Registry (GCCR)	Georgia	2000-2007	45-85	Colorectum	Census Tract Socioeconomic Status	3	Kaplan-Meier method, Cox proportional hazards regression (overall survival)	Patients from low socio-economic position had higher risk of death after colorectal cancer. Survival inequality was not explained by tumor grade, stage and treatment.	Age, sex, race, disease stage, tumor grade, geography, treatment (surgery, chemotherapy, or radiation)

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Ibfelt et al, 2015	Denmark	Danish Gynaecological Cancer Database (DGCD)	Denmark	2005-2010	≥25	Ovary	Education (individual-level) Disposable income (individual-level)	3 3	Logistic regression, Cox proportional hazards regression (overall survival)	There were socio-economic inequalities in survival after ovarian cancer that were not fully explained by disease stage, histology and co-morbidities.	Age, comorbidity, ASA score, cancer stage, tumor histological subtype Income was adjusted for education and cohabitation status
Ibfelt et al, 2013	Denmark	Danish Gynaecological Cancer Database (DGCD)	Denmark	2005-2010	≥25	Cervix	Education (individual-level) Disposable income (individual-level)	3 3	Cox proportional hazards regression (overall survival)	Survival was lower among women with minimum education and lower income. Socioeconomic disparities in survival partly explained by stage at diagnosis and less by comorbidity and smoking status.	Age, comorbidity, cancer stage, smoking status Cohabitation status was adjusted for education. Income was adjusted for education and cohabitation status
Jack et al, 2006	England	Thames Cancer Registry	South-east London	1998	All ages	Lung	Index of Multiple Deprivation (area-based)	5	Logistic regression (overall 1-year survival)	Variation in treatment partly explained differences in overall survival.	Age, sex, histology, stage and basis of diagnosis, treatment
Jeffreys et al, 2009	New Zealand	New Zealand Cancer Registry	New Zealand	1994-2003	15-99	All malignancies	New Zealand deprivation index (area-based)	4	5-year relative survival, weighted linear regression	Socioeconomic inequalities in cancer survival were evident for all major cancers. Extent of disease explained some of the differences in survival from breast (33.8%), colorectal cancer (12.2%) and melanoma (50%) and it explained all socio-economic inequalities in survival of cervical cancer.	Deprivation- and ethnic-specific life table by age, sex, year
Jembere et al, 2012	Canada	Ontario Cancer Registry	Ontario	1990-2009	All ages	Liver (Hepatocellular Carcinoma)	Neighborhood Income	5	Kaplan-Meier method (1-, 2- and 5-year overall survival), Cox proportional hazards regression	Patients with higher SES had superior survival compared with those with low SES. Survival disparity was mostly explained by receiving curative treatment and less by comorbidity.	Age, sex, comorbidity, ultrasound screening, and curative treatment

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Johnson et al, 2014	United States	Georgia Comprehensive Cancer Registry (GCCR)	Georgia	2000-2009	50-85	Lung (non-small cell)	Census Tracts Socioeconomic Status (SES)	4	Cox proportional hazards regression (overall 5-year survival)	Patients living in deprived areas with lowest level of education and highest level of deprivation had poorer survival. Stage at diagnosis, tumor grade and treatment partly explained survival differences.	Age, sex, race, stage, tumor grade, and treatment (surgery, chemotherapy, radiation)
Keegan et al, 2015	United States	Electronic medical records data from Kaiser Permanente Northern California linked to data from the California Cancer Registry	Northern California	2004-2007	45-64	Breast	Census Tracts Socioeconomic status (SES)	2	Cox proportional hazards regression (overall and cancer-specific survival)	Women living in low-SES neighborhoods had worse breast cancer-specific survival than those living in high-SES neighborhood, which were not explained by differences in treatment and co-morbid conditions.	Age, marital status, subtype, tumor size, lymph node involvement, tumor grade and stage (stratified by race/ ethnicity) Additional adjustment for co-morbidities, and treatment modalities
Kim et al, 2011	United States	Cancer Surveillance Program (CSP)	Los Angeles	1988-2006	All ages	Rectum	Household income	3	Kaplan-Meier method, Cox proportional hazards regression (overall survival)	Affluent patients had higher survival after rectal cancer compare to underprivileged patients. Socio-economic inequity in survival was not fully explained by differential access to treatment, tumor grade and extent of disease.	Age, sex, race/ ethnicity, immigration status, tumor grade, extent of disease, time period, chemotherapy, radiotherapy, surgery
Larsen et al, 2015	Denmark	Danish Diet, Cancer and Health Study	Denmark	1993-2008	54-74	Breast	Educational level (individual-level) Income (individual-level)	3 3	Cox proportional hazards regression (overall survival)	Lower education was associated with higher risk of death. Educational differences in survival were partly explained by metabolic indicators, smoking status, alcohol intake and less by disease-related prognostic factors and comorbidity.	Age, tumor size, lymph node status, no. of positive lymph nodes, grade and receptor status, comorbidity, metabolic indicators (BMI, waist circumference, diabetes, smoking and alcohol at baseline and at time of diagnosis)

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Larsen et al, 2016	Denmark	Danish Diet, Cancer and Health study linked to Danish Cancer Registry and other population-based registries	Copenhagen or Aarhus area	1993-2008	$\geq$50	Prostate	Education (individual-level) Income (individual-level)	3 3	Cox proportional hazards regression (overall and cancer-specific survival)	Cases with lowest education and income had lower prostate cancer-specific and overall survival than their counterparts with highest education and income. The observed lower survival for cases with lowest education partly explained by treatment and metabolic indicators. For patients with lowest income, lower survival was not explained by tumor aggressiveness, comorbidity, treatment or metabolic indicators.	Age Additional adjustment for tumor aggressiveness, comorbidity, treatment and metabolic indicators (BMI, waist circumference and diabetes at baseline, and BMI and diabetes at time of diagnosis).
Launay et al, 2012	France	Calvados digestive cancer registry	Calvados	1997-2004	All ages	Esophagus	Townsend index (area-based)	5	Relative 1- and 5-year survival, Excess hazard model based on maximum likelihood estimation (Esteve model)	Deprived patients had poorer survival compared with affluent patients. Survival disparities not explained by differences in cancer extension or morphology at diagnosis, surgery, radiotherapy and chemotherapy.	Age, sex, year of diagnosis, morphology, stage, treatments (surgery, radiotherapy, chemotherapy)
Lejeune et al, 2010	England	Thames Cancer Registry Eastern Cancer Registration and information center Northern and Yorkshire Cancer Registry and information service	England	1997-2000	$\geq$15	Colorectum	Townsend index (area-based)	5	Relative 3-year survival, generalized linear model with Poisson	Affluent patients had better survival compared with disadvantaged patients. Tumor stage partly explained socio-economic inequalities in survival after colorectal cancer. Early treatment (within the first month following diagnosis) greatly reduced socio-economic differences in survival.	Age, receipt of treatment and time-to-treatment, and stage at diagnosis

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Li et al, 2016	England	Northern and Yorkshire Cancer Registry	North East England, Yorkshire and Humber regions	2000-2007	15-99	Breast	Index of Multiple Deprivation (area-based)	5	6-months, 1-, 3- and 5-year net survival), mediation analysis (overall survival)	Socioeconomic inequalities in breast cancer survival were partly explained by differences in stage at diagnosis, surgical treatment.	Year and regions at diagnosis, tumor stage, treatment
McKenzie et al, 2010	New Zealand	New Zealand Cancer Registry	New Zealand	2005-2007	All ages	Breast	New Zealand deprivation index (area-based)	4	4-year relative survival, Excess mortality ratios using generalized linear model (Poisson)	Survival was poorer among underprivileged women. Differential access to health care was a major contributor to theses socioeconomic inequities.	Age, ethnicity, tumor factors (extent, size and grade), hormone status (ER, PR, and HER2 status)
Morris et al, 2016	England & Wales	West Midlands Breast Screening Quality Assurance Reference Center (Cancer Registry) linked to Hospital Episode Statistics and the National Breast Screening Service records	West Midland	1981-2011	50-70	Breast	Index of Multiple Deprivation (area-based)	2	Flexible parametric models (5-year relative survival)	Disadvantaged women had higher excess risk of death from breast cancer irrespective of their screening status. The observed gap in survival was only partly explained by differences in stage at diagnosis and comorbidity. Other tumor characteristics and treatment did not contribute to the observed inequality in survival.	Age and year of diagnosis (stratified by screening status) Additional adjustment for stage at diagnosis, tumor size, histology, surgery, and comorbidity
O'Brien et al, 2015	United States	Florida Cancer Data System	Florida	1996-2007	≥18	Male Breast	Socio-economic status (neighborhood-level based on percentage of households in a census tract 2006)	4	Kaplan-Meier method, Cox proportional hazards regression (overall 5-year survival)	Higher SES groups had lower risk of death compared with the lowest SES group. Late stage at diagnosis due to poor access to diagnostic and health care services may partly explain worse overall survival among men from lower socio-economic areas.	Age, race/ethnicity, marital status, insurance status, tobacco use, geographic residence, clinical and hospital characteristics, tumor characteristics, treatments, and comorbidity

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Oh et al, 2020	United States	California Cancer Registry	California	1997-2014	All ages	Colorectum	Socio-economic status (neighborhood SES based on 2000 census)	5	Cox proportional hazards regression (cancer-specific 5-year survival)	The observed lower survival in colorectal cancer patients living in more disadvantage areas were not explained by differential stage at diagnosis, other tumor characteristics, treatment received, and neighborhood and hospital characteristics.	Age, year, sex and marital status (stratified by period of diagnosis) Additional adjustment for subsite, stage, tumor size, tumor grade, surgery, radiation, neighborhood and hospital characteristics
Phillips et al, 2019	England	Pan-Birmingham Gynaecological Cancer Center	Birmingham	2007-2017	All ages	Ovary (advanced disease)	Index of Multiple Deprivation (area-based)	5	Kaplan–Meier method (overall survival)	Socio-economic differences in overall survival observed among stage III and IV ovarian cancer patients were partly explained by not receiving surgical treatment.	Age
Quaglia et al, 2011	Italy	Liguria Region Cancer Registry	Genoa	1996-2000	All ages	Breast	Deprivation index (based on the information drawn from the census of 2001)	5	5-year relative survival (Hakulinen–Tenkanen method), Excess mortality ratios using generalized linear model (Poisson)	Deprived women had poorer survival compared with affluent women. Observed disparities could be partly explained by differences in tumor characteristics and the treatment received.	Age, tumor size, lymph nodes status, estrogen receptor status, type of surgery, radiotherapy, lymphadenectomy, hormonal therapy
Robertson et al, 2010	Scotland	Scottish Head and Neck Audit, Scotland Hospital (prospective cohort study)	Scotland	1999-2001	All ages	Head and Neck	Socio-economic status (area-based using the 2001 DEPCAT score)	3	Cox proportional hazards regression (overall and cancer-specific 5-year survival)	Socio-economic differences in survival from head and neck cancers explained by variations in stage at diagnosis, tumor differentiation, smoking, alcohol drinking and patient's performance status.	Age, stage, tumor site, differentiation, WHO performance status, smoking and alcohol drinking status
Rutherford et al, 2013	England	Eastern Cancer Registration and Information Center (ECRIC)	East of England	2006-2010	≥30	Breast	Index of Multiple Deprivation (area-based)	5	5-year relative survival, Excess mortality rate ratios (flexible parametric model)	Survival disparities among women with middle SES almost explained by stage at diagnosis, while disease stage had no effect on survival among the most deprived women.	Age, stage

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Seidelin et al, 2016	Denmark	Danish Gynaecological Cancer Database	Denmark	2005-2009	25-90	Endometrium	Education level (individual-level)	3	Logistic regression, Cox proportional hazards regression (overall survival)	Minimum education was associated with higher risk of death. Differences in stage at diagnosis partially explained educational inequalities in survival from endometrial cancer. Comorbidity did not alter the results.	Age, cohabitation status, body mass index (BMI), smoking status, comorbidity, stage
Shafique et al, 2013	Scotland	Scottish Cancer Registry	West of Scotland	1991-2007	All ages	Prostate	Scottish Index of Multiple Deprivation (SIMD) 2004 score (area-based)	5	5-year relative survival (Ederer II), Relative excess risk (full likelihood approach), Cox proportional hazards regression	Socio-economic inequalities exist in survival of prostate cancer and widened over time. Differential stage at diagnosis only partly explained deprivation gap in prostate cancer survival.	Age, Gleason grade, period of diagnosis
Sharif-Macro et al, 2015	United States	California Breast Cancer Survivorship Consortium	California	1993-2007	$\geq$25	Breast	Education (self-reported) Neighborhood socio-economic status (nSES)	4 5	Cox proportional hazards regression (overall and cancer-specific survival)	Cases with low education and low SES had lower overall and breast cancer-specific survival, which was partly explained by health-related lifestyle behaviors, co-morbidities and hospital factors. Treatment did not contribute to the observed gap in survival.	Age, year of diagnosis, cancer registry region, tumor factors (stratified by race/ ethnicity)(stratified by race/ethnicity) Additional adjustment for treatment (surgery, chemotherapy, radiation), parity, marital status, health-related lifestyle behaviors, comorbidity and hospital factors
Singer et al, 2017	Germany	Leipzig University Medical Center, St. Elisabeth Hospital Leipzig, St. Georg Hospital Leipzig	Leipzig	No information	$\geq$18	All malignancies combined	School education (individual-level) Vocational training (individual-level) Job grade (individual-level) Job type (individual-level) Income (household)	3 4 3 2 4	Poisson regression (overall 10-year survival)	There were no associations of school education and job grade with survival. Cases with blue-collar jobs, vocational training, and lower level of income have lower survival which was not explained by differences in health behaviors.	Age, sex, cohabitation, site, stage at diagnosis Additional adjustment for health behavior

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Sprague et al, 2011	United States	Two population-based, case-control studies	Wisconsin	1995-2003	20-69	Breast	Individual-level -Education -Income-to-poverty ratio community-level -% without a high school diploma -% in poverty	 3 3 3 3	Cox proportional hazards regression (overall and cancer-specific survival)	Survival rate was lower among patients with less education, less income, or living in areas with low community-level education. Screening participation, stage at diagnosis explained survival differences by individual-level income and explained some of the survival differences by individual- and community-level-education. Lifestyle factors had a minor effect on the observed differences in survival.	Age, year of diagnosis, histologic type, stage at diagnosis, mammography use, smoking history, family history of breast cancer, BMI (body mass index), postmenopausal hormone use and socio-economic variables (as required)
Stromberg et al, 2016	Sweden	National Cancer Register and the national Swedish Melanoma Quality Register	Southern and the Western Sweden	2004-2013	$\geq$15	Melanoma	Education level (individual-level)	3	5-year relative survival, 5-year excess mortality rates (maximum likelihood model)	Stage at diagnosis explained some of educational inequalities in survival from cutaneous malignant melanoma.	Age, sex, residential area, stage at diagnosis
Swords et al, 2020	United States	SEER (Survival, Epidemiology and End Results) registry	United States	2007-2015	18-80	Gastrointestinal malignancies (9 cancer types)	Census tract-level socio-economic status (SES)	2	Kaplan-Meier method (overall and cancer-specific 5-year survival) Causal mediation analysis	Differences in receiving surgery explained one third of socio-economic inequalities in survival for patients with esophageal adenocarcinoma, extrahepatic cholangiocarcinoma, and pancreatic adenocarcinoma.	Age, sex, race/ethnicity, personal cancer history, and year of diagnosis
Tervonen et al, 2017	Australia	New South Wales Cancer Registry	New South Wales	1980-2008	All ages	All malignancies	Index of Relative Socio-Economic Disadvantage (aggregated composite measure of socio-economic position based on cases usual residential address at the census closest to their year of diagnosis)	5	Competing risk regression models (Fine & Gray method) cancer-specific survival	Cases living in more disadvantaged areas had lower survival compared with those living in less disadvantaged regions. The observed gap in cancer survival was not explained by differential stage at diagnosis.	Age, sex, diagnostic period, remoteness, country of birth (stratified by period of diagnosis) Additional adjustment for cancer site and summary stage

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Torbrand et al, 2017	Sweden	Penile Cancer Data Base Sweden (PenCBaSe) linked to National Penile Cancer Register (NPECR) and several other population-based healthcare and sociodemographic registers	Sweden	2000-2012	All ages	Penis	Educational level (individual-level) Disposable income (individual-level)	3 2	Cox proportional hazards regression (overall and cancer-specific 1- and 3-year survival)	Lower levels of education and income were associated with lower survival although the confidence interval was wide. Inequalities in survival were not explained by differences in stage at diagnosis and co-morbid conditions.	Age Additional adjustment for TNM stage and comorbidity
Ueda et al, 2006	Japan	Osaka Cancer Registry	Osaka	1975-1997	All ages	Cervix and corpus	Socio-economic status (Municipality-based using unemployment and college/graduate schools graduates within 67 municipalities)	3 3	Kaplan-Meier method, Cox proportional hazards regression (overall 5-year survival)	Differences in survival for cervical and corpus cancer patients were observed among high, middle and low education/ unemployment municipalities. Stage, histology and treatment only partly explained observed socio-economic differences in survival from cervical cancer. Stage and histology partially explained socio-economic inequality in survival from corpus cancer; treatment did not make any difference.	Age, cancer stage, histology, treatment type
Vallance et al, 2018	England	National Bowel Cancer Audit (NBOCA) linked to Hospital Episode Statistics (HES) data	England	2011-2015	All ages	Colorectum (metastasized to liver)	Index of Multiple Deprivation (area-based)	5	Cox proportional hazards regression (overall 3-year survival)	Disadvantaged patients had lower survival which was partly explained by receiving liver resection.	Age, sex, emergency admission, co-morbidities, cancer site, stage, and hepatobiliary services on-site Stratified by liver resection

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Walsh et al, 2014	Ireland	Irish National Cancer Registry	Ireland	1999-2008	15-99	Breast	SAHRU index of social deprivation (area-based)	5	Modified Poisson regression, Cox proportional hazards regression (Age-standardized 5- and 10-year cause-specific survival)	Women from the most deprived areas were 33% more likely to die of breast cancer compared with women from the least disadvantaged areas. Patient and tumor characteristics partially explained deprivation-related inequality; treatment did not make any significant difference.	Stratified by age, TNM stage and tumor grade Adjusted for method of presentation, smoking status, region of residence, diagnosis year, tumor morphology, hormone receptor status, treatment within 12 months of diagnosis
Woods et al, 2016	England Australia	West Midlands and New South Wales cancer registries	West Midlands New South Wales	1997-2006	50-65	Breast	Socio-economic status based on the unemployment rate of the small area of residence	5	5-year net survival (Pohar-Perme method)	Survival was almost similar among affluent and deprived women in New South Wales irrespective of way of diagnosis; but in the West Midlands, there were significant large differences among affluent and deprived women in both screening groups, which were not explained by extent of disease at diagnosis.	Adjusted for region, calendar year, age, lead-time bias and over diagnosis
Yu et al, 2009	United States	13 population-based cancer registries participated in the SEER program	13 states in the US	1998-2002	≥ 15	Breast	socio-economic status (area-based)	4	Cox proportional hazards regression (cancer-specific 5-year survival)	Women from the most disadvantaged areas had higher risk of cancer-related death compared with women from affluent regions, which was mostly explained by stage at diagnosis and less by first course treatment.	Age, year of diagnosis, AJCC stage, number of positive lymph nodes, first course treatments, race, rural/urban residence

(continued)

Table 1. (continued)

Paper	Country of study	Data sources/Settings	Population included	Years of diagnosis	Age at diagnosis	Anatomic site of cancer(s)	Measures of socio-economic position (SEP)	No. of groups	Analyses	Description of results	Covariate adjusted for
Yu et al, 2008	Australia	New South Wales Central Cancer Registry	New South Wales	1992-2000	15-89	All malignancies (13 major types of cancers)	Index of Relative Socio-Economic Disadvantage (IRSD), aggregated composite measure of socio-economic position based on cases usual residential address at the census closest to their year of diagnosis	5	5-year relative survival (period method), relative excess risk model using Poisson regression	Patients from the most disadvantaged areas had poorer survival for cancers of the stomach, liver, lung, breast, colon, rectum, ovary, and all cancers combined. After controlling for stage at diagnosis, the significant survival differences between socio-economic groups disappeared for ovarian cancer; the effect of SES on survival from liver and breast cancer decreased after adjusting for stage. The survival differences for all cancers in the most disadvantaged areas decreased after controlling for remoteness of residence. Additional adjustment for stage did not change the results.	Age, sex, and year of follow-up, stage at diagnosis, remoteness of residence
Zaitsu et al, 2019	Japan	Kanagawa Cancer Registry	Kanagawa	1970-2011	All ages	Pancreas	Occupation (individual-level)	4	Kaplan-Meier method, Cox proportional hazards regression (overall 5-year survival)	Patients with lower levels of occupational class had lower survival, which was not explained by differences in surgery, chemotherapy, stage at diagnosi or smoking habits.	Age, sex, year of diagnosis Additional adjustment for surgery, chemotherapy, stage, tumor grade and smoking habits

Different approaches were used to attempt to explain the underlying reasons for socio-economic inequalities in cancer survival. Most studies applied the "difference method," which compares regression coefficients for exposure on outcome from models with and without adjusting for potential mediators.[6-8,10-15,17-28,30,31,33,35-37,39-44,46,47,50-53,55-57,59,60,62-67,69-79] Other studies examined the distribution of cases across socio-economic categories by the mediator(s) of interest or stratified the relative risk or survival rate estimates by potential mediators.[9,16,32,34,45,48,49,58,61] Four studies applied causal mediation analysis.[29,38,54,68]

Factors Explaining Socio-Economic Inequalities in Survival

Cancer-*specific survival.* Sixteen studies examined the underlying causes of educational and socio-economic inequalities in breast cancer survival: 8 from Europe,[9,13,18,30,32,36,44,49] 5 from the US,[59-61,65,67] 2 from New Zealand[76,77] and 1 from Australia.[74] Studies from Switzerland, Italy, Ireland, New Zealand and Australia applying the difference method reported consistent findings that stage at diagnosis, other tumor characteristics, method of detection or presentation (symptomatic, screening, incidental, unknown), and receiving suboptimal treatment and sector of care (private or public) only partly explained the observed socio-economic inequalities in breast cancer survival.[13,30,36,76,77,74] In contrast, studies from the Netherlands and Sweden found that the observed lower survival among disadvantaged women, or those with low level of education, was not explained by variation in stage of breast cancer at diagnosis, other tumor characteristics, number of nodes examined or the treatment received.[9,18]

A study from England using stage-specific analysis found that lower survival from breast cancer among women with mid-level SEP, relative to the most advantaged, was entirely explained by stage at diagnosis, while stage had no mediating effect on lower survival among the most disadvantaged patients.[32] Another study using data from England and Australia observed no differences in survival across socio-economic groups in New South Wales, Australia after stratifying on mode of detection (screen-detected or non-screen-detected)[49]; however, in the West Midlands, England, there were inequalities in survival between affluent and disadvantaged women with both screen-detected and non-screen-detected breast cancer, which were not explained by extent of disease at diagnosis.[49] In contrast, another study from England reported that inequalities in survival, irrespective of screening status (screen-detected or non-screen-detected), were only partly explained by differences in stage at diagnosis and co-morbidities; differences in other tumor characteristics and treatment did not contribute to lower survival in disadvantaged women.[44]

US studies measuring SEP at the individual and community level found that higher risk of death among the most disadvantaged women was mostly influenced by variation in annual screening mammography participation and disease stage, and less by lifestyle factors and first course treatment.[59,60] Other US studies reported that differences in stage at diagnosis, breast cancer subtype (triple negative, HER2 or luminal), co-morbid conditions and the treatment received did not explain lower survival for residents of disadvantaged areas,[61,65] while another study reported health-related lifestyle behaviors and co-morbidity, but not treatment, as contributing factors to the observed gap in breast cancer survival.[67]

Of the 7 studies that investigated cancer-specific survival after diagnosis with colon or rectal cancer, studies from Sweden, Australia and the US found that lower survival in disadvantaged or low educated patients was not explained by variations in stage at diagnosis, patient factors or other tumor characteristics, nor by differences in co-morbidities, hospital type/characteristics, and treatment e.g. elective or emergency surgery or preoperative radiotherapy for rectal cancer.[15,66,73,74] In contrast, studies from England, Switzerland and New Zealand concluded that rural-urban residence, extent of the disease and provision of treatment within the first month of diagnosis contributed to the observed lower survival in disadvantaged patients and those with low-level education.[28,40,76]

Three studies assessed the association of socio-economic disadvantage with survival from head and neck cancer. A study from Canada found that the anatomic extent of the tumor accounted for 3-23% of differences in survival from glottic cancer[71]; the authors also reported waiting time to receive treatment as an explanatory factor for lower survival among disadvantaged patients.[71] A US study of oral and pharyngeal cancer reported cigarette smoking as a contributing factor to socio-economic inequalities in survival; the authors reported that the indirect effect of smoking was larger for patients in the middle socio-economic group (21%) than for those in the lowest category (13%).[54] A Scottish study comparing HRs with and without adjusting for potential mediators proposed that socio-economic differences in survival from head and neck cancers (deprived compared with affluent cases, unadjusted HR 1.33; 95%CI 1.06-1.68) were explained by variations in stage at diagnosis, tumor differentiation, alcohol drinking, smoking status and patient performance status (fully adjusted HR 0.93; 95%CI 0.64-1.35).[31]

Three studies investigated socio-economic differences in survival from prostate cancer.[34,43,64] A study from Scotland stratifying the relative risk estimates by Gleason score found that differential stage of prostate cancer contributed to some of the observed deprivation-based gap in survival.[34] A US study concluded that differences in co-morbidities, health-related behaviors, hospital characteristics and environmental factors did not explain the observed lower survival for men with low level of education, although the gap in survival by socio-economic position (disadvantaged men compared with advantaged cases, base model HR 1.56; 95% CI 1.11-2.19) decreased after adjusting for these variables (fully adjusted HR 1.41; 95% CI 0.98-2.03).[64] A study from Denmark reported treatment and metabolic indicators such as body mass index and diabetes as contributing factors to lower survival among men with lowest education, whereas co-morbidities did not explain the observed gap in survival.[43]

Two studies from Sweden[19,35] and 1 from New Zealand[76] assessed cancer-specific survival from melanoma by education level or an area-based measure of SEP. A Swedish study, comparing models with and without adjusting for mediators of interest, found that stage at diagnosis largely explained worse survival among low educated relative to highly educated individuals (age and sex adjusted HR 1.58; 95%CI 1.40-1.77 decreased to HR 1.19; 95%CI 1.06-1.34 after adjusting for clinical stage).[19] Another study from Sweden reported consistent findings.[35] A New Zealand study showed that 50% of the observed deprivation gap in survival from melanoma was explained by extent of the disease.[76]

Of the remaining studies, a study of esophageal cancer from France concluded that lower survival among patients living in deprived areas was not explained by differences in stage, morphology, surgery, radiotherapy or chemotherapy.[27] A US study conducted tumor characteristics-specific analysis and suggested that lower survival from renal cancer among individuals from lower socio-economic background may be partly explained by advanced tumor at diagnosis, or tumor size or grade.[52] Another study of gastrointestinal cancers from the US, applying causal mediation analysis, showed that differences in surgery explained one third of socio-economic inequalities in survival for patients with esophageal adenocarcinoma, extrahepatic cholangiocarcinoma, and pancreatic adenocarcinoma.[68]

An Australian study concluded that stage at diagnosis was the underlying reason for lower survival from ovarian cancer in women living in the most disadvantaged areas.[74] Another study from New Zealand found that the extent of disease fully explained the observed lower survival from cervical cancer among more deprived women, while it only contributed to 5% of the deprivation gap in survival from uterine cancer.[76] A Swedish study of lung cancer showed that better survival from early-stage disease in women with high educational level, relative to low educated, persisted after adjusting for treatment (HR 0.33; 95%CI 0.14-0.77), while for stage III, the observed lower survival comparing high versus low educated men also remained (fully adjusted HR 1.41; 95%CI 1.04-1.90).[10] Another study from Sweden found that stage at diagnosis and co-morbidities did not contribute to socio-economic inequalities in survival from penile cancer.[47] Lastly, an Australian study of all malignancies found that stage at diagnosis did not explain the observed lower survival among cancer patients living in more disadvantaged areas.[75]

Overall *survival.* We identified 8 studies that assessed overall survival following breast cancer diagnosis. A Dutch study observed socio-economic differences in overall survival for women with screen-detected, non-screen-detected and interval breast cancers.[8] Lower survival among more disadvantaged women diagnosed via screening was partly explained by the higher prevalence of co-morbidities. For women with non-screen-detected and interval breast cancers, inequalities in survival appeared to be largely explained by differences in stage at diagnosis, while treatment explained very little.[8] A Canadian and a British study found that socio-economic inequalities in overall survival after breast cancer were partly mediated by differential stage and surgical treatment.[29,69] Similarly, studies from England, the US and Canada concluded that the higher risk of death for disadvantaged women was largely explained by their generally more advanced stage and co-morbid conditions.[17,51] Another study from the US reported insurance status, disease stage and treatment as major explanatory factors, although co-morbidities explained very little of the observed gap in survival.[53] A study conducted in Denmark showed that metabolic indicators, smoking status and alcohol intake accounted for part of the higher risk of death among women with lower educational attainment, while disease-related prognostic factors and co-morbidities played only a minor role.[26] The only study of male breast cancer, conducted in the US, suggested that later stage due to poor access to diagnostic and health care services may partly explain worse overall survival among men from lower socio-economic neighborhoods.[58]

Seven studies investigated the association of SEP and education with overall survival following diagnosis with colon or rectal cancer. Two studies from England reported that variations in co-morbid conditions, urgency of surgery and curative resection status explained part of lower overall survival among the most deprived patients with colorectal cancer.[12,48] A study of colon cancer, conducted in Canada, found no evidence that stage at diagnosis contributed to socio-economic differences in overall survival,[69] while a study from Norway found that educational inequality in overall survival from colon and rectal cancer is explained partly by stage at diagnosis and although less so, by smoking and alcohol drinking.[14] One study from Denmark noted that observed socio-economic differences in overall survival from colorectal cancer were partly mediated by co-morbidities and to a lesser extent by health-related behaviors, while stage at diagnosis, mode of admittance (admitted for surgery electively or acutely), type of surgery and specialization of surgeon did not contribute to these differences.[22] Two US studies found that lower overall survival among disadvantaged individuals with colon and rectal cancer was explained in part by disease stage, tumor grade and differential access to treatment.[55,57]

Six studies examined socio-economic and educational inequalities in overall survival from lung cancer. Of the 3 studies conducted in England, 1 found that the higher overall survival in the most affluent group, especially those with early-stage disease, was partly explained by variations in co-morbidities and treatment.[11] Two other studies also reported that differences in receipt of treatment explained part of the worse overall survival among patients residing in the most deprived areas.[20,25] A study from US found differential disease stage, tumor grade and receipt of the treatment explained some of the observed overall survival disadvantage among lung cancer patients from areas with higher concentration of deprivation and lower levels of education.[56] Similarly, a study from Denmark noted that educational inequalities in overall survival were partially explained by differences in stage of lung cancer at diagnosis, delivery of first-line treatment, co-morbidity and performance status.[16] In contrast, a German study found that lower survival observed for residents of more disadvantaged regions was not explained by differential stage at diagnosis or tumor grade.[41]

Of the 3 studies that investigated prostate cancer, 2 were conducted in Netherlands[6,7] and 1 in the US.[51] One study found that co-morbid conditions, physical activity level and smoking status did not contribute to lower overall survival in patients with lower levels of education.[6] Another study reported that socio-economic-based inequalities in overall survival were partly mediated by differences in treatment selection and by co-morbidities.[7] The US study found that disease stage explained at least part of lower survival among prostate cancer patients either living in poverty or having low educational level.[51]

With respect to head and neck and brain cancers, a study from Canada found that lower overall survival among disadvantaged patients was explained by differences in cigarette smoking, alcohol consumption, and stage at diagnosis.[70] In contrast, a second Canadian study of laryngeal cancer specifically, found that survival differences among socio-economic groups were not explained by stage at diagnosis.[71] Of the 2 studies that investigated socio-economic inequalities in overall survival from glioma, a study from US concluded that variations in receiving chemotherapy and radiotherapy did not contribute to the observed gap in survival.[62] In contrast, a second US study showed that lower survival in cases living in more disadvantaged areas was partly explained by differences in the receiving surgery and radiation therapy.[63]

We identified 8 studies that explored educational or socio-economic inequalities in relation to overall survival from cancers of the cervix, ovary, corpus or endometrium. A US study of cervical cancer showed that tumor characteristics and treatment explained some of the inequalities in overall survival.[50] A study from Japan reported similar findings.[78] A study from Denmark found that overall survival disadvantage in low educated women with cervical cancer was partially explained by stage at diagnosis and, to a lesser extent, by co-morbidities and smoking status.[24] Both studies, from Japan[78] and Denmark,[33] investigating uterine and endometrial cancer found that the lower survival among disadvantaged or less educated women was partly mediated by disease stage and histology, while co-morbid conditions and treatment had no mediating effect. Of the 4 studies that assessed ovarian cancer, studies from France and the US found that the observed gap in overall survival was partly explained by variations in stage at diagnosis and the treatment received.[42,45] A Danish study reported differential stage at diagnosis, tumor histological type, co-morbidities and health-related lifestyle behaviors as some of the explanatory factors.[23] In contrast, a study from Norway found that stage of ovarian cancer or smoking status prior to diagnosis did not contribute to overall survival gap between education groups.[14]

Of the remaining studies, studies from Denmark and Ireland found that late stage at diagnosis and emergency presentation contributed in part to educational inequalities in overall survival form non-Hodgkin's lymphoma.[21,38]A French study of acute myeloid leukemia showed that variations in initial treatment did not explain the observed gap in overall survival by socio-economic position.[37] Of the 2 studies that assessed pancreatic cancer, a study from Denmark concluded that differences in surgical resection and chemotherapy explained very little of the gap in overall survival across household incomes.[39] Another study conducted in Japan found no evidence that stage at diagnosis, smoking habits, surgery and chemotherapy contribute to lower survival observed among unemployed patients and those with lower levels of occupation.[79] A Canadian study reported variations in the provision of curative treatment and co-morbidity prevalence as major contributing factors to lower overall survival in disadvantaged patients with hepatocellular carcinoma.[72] Lastly, a study from Germany that assessed all cancer types found that cases with blue-collar jobs, vocational training and lower level of income have lower cancer survival which was not explained by differences in health-related lifestyle behaviors.[46]

Risk of Bias

Results from the assessment of the risk of bias of the eligible studies are summarized in Supplementary Table 2. All included studies had low risk of bias with respect to measurement and classification of the exposure and the outcome.

Age at cancer diagnosis, sex (for non-sex-specific cancers), ethnicity/race (for studies conducted in the US and New Zealand), and year of diagnosis (where applicable *i.e.* the period of diagnosis was $\geq$10 years) were considered to be important confounding domains that should be adjusted for in the analyses. Studies that applied a relative survival framework to estimate EMRRs should have used socio-economic- or deprivation-specific population life tables. With respect to confounding, several studies had moderate risk of bias; 7 studies did not use socio-economic-specific population life tables,[9,12,15,18,27,30,49] A US study did not adjust for ethnicity/race,[66] 5 did not control for sex,[28,31,62,69,71] and 6 studies did not adjust for year or period of diagnosis.[26,43,47,71,72,78] Based on existing literature,[2,3,80] we considered health-related lifestyle factors, screening participation, stage of cancer at diagnosis, other tumor characteristics, co-morbid conditions, emergency presentation and treatment modalities as potential mediators on the causal pathway that should not be adjusted for in the analyses (Figure 2). Consequently, all studies that used the difference method were classified as at high risk of bias. We also assumed that patient's rural-urban residence is a potential mediator as socio-economic position generally determines where a person lives, while acknowledging that it might be also a confounder (*i.e.* area of residence affects SEP as well).

Bias in the selection of participants into the study was low for all studies except 4 that identified cancer patients from a hospital,[31,37,46,70] which is problematic when estimating the mediating effects of treatment. All studies, except 3, had a low risk for the domain of bias due to selective reporting of results.[41,43,47] With respect to missing data, we assigned moderate risk of bias to twenty-three studies that had 10-20% of their

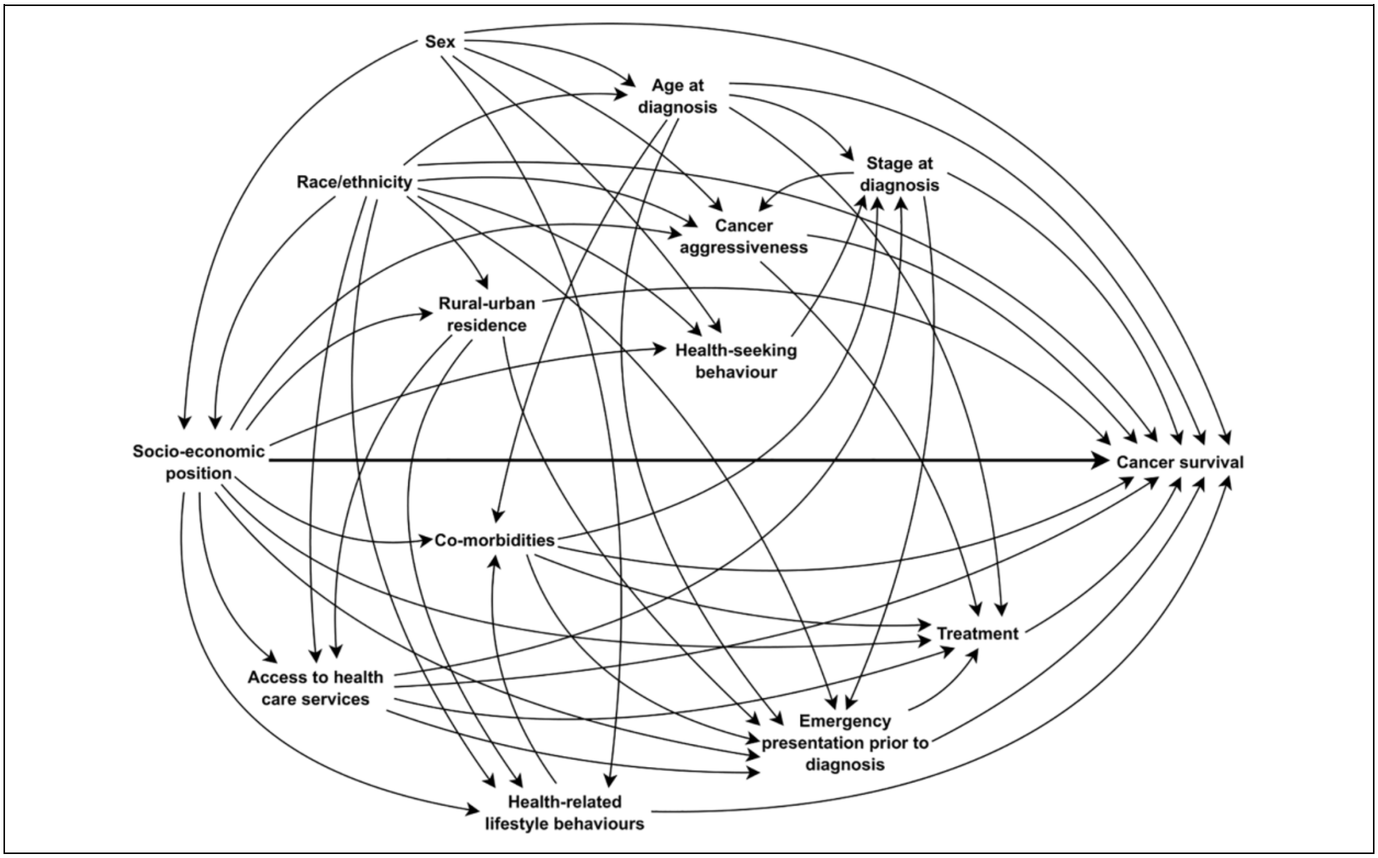

Figure 2. Directed acyclic graph (DAG) showing assumed causal associations between socio-economic position and cancer survival.

data missing,[7,13,20,25-27,30,34,37,38,40,42,44,45,53,54,57,58,61,64,67,69,78] and high risk to eleven studies with more than 20% missing data,[33,39,41,43,46,48,65,66,72,75,79] regardless of whether multiple imputation was applied.

Discussion

In this systematic review, studies relatively consistently reported differences in disease stage, other tumor characteristics such as size, grade or morphology, lifestyle behaviors including smoking and excessive alcohol intake, co-morbid conditions and the treatment received as contributing causes of socio-economic inequalities in cancer-specific survival, but the estimated mediating effects of these factors varied across countries and cancer sites. Of the studies investigating survival from breast cancer, the majority reported stage at diagnosis as a contributing factor to lower survival among disadvantaged women, while a few acknowledged the potential role of co-morbidities and treatment. Most research on survival following colon or rectal cancer showed that stage of disease did not explain inequalities in survival, whereas treatment and co-morbidities partly contributed to the observed differences. Research on survival from head and neck cancer found stage at diagnosis, smoking and alcohol intake as the primary reasons for these inequalities. Similarly, for melanoma and cancers of the ovary, cervix, kidney and prostate, disease stage and treatment were reported as contributing factors to the observed survival gap across socio-economic groups. We found no obvious differences in explanatory factors by year of publication or by country.

Findings of studies investigating underlying reasons for socio-economic inequalities in overall survival following a cancer diagnosis were generally in line with studies that assessed cancer-specific survival, although the estimated effects of potential mediators varied relative to studies considering death from a particular cancer as the outcome.

The most recent review published by IARC highlighted several factors, which may contribute to observed inequalities in cancer outcomes. There is compelling evidence from existing literature that individuals with lower levels of income and education have limited awareness about adverse effects of health-related behaviors; therefore, unhealthy diet, physical inactivity, smoking, heavy alcohol intake and co-morbid conditions are more prevalent among disadvantaged people.[80] Stage at diagnosis is cited as the primary reason for inequalities in cancer survival by socio-economic position, possibly due to higher rates of screening participation and better access to diagnostic services among advantaged people.[80] Differential access to treatment facilities and the quality of care received have also been reported as potential contributing factors to lower cancer survival.[80] We should consider the fact that the mediating effect of these factors may be country-specific, generally due to variation in healthcare systems.

A review of access to cancer treatment trials across socio-economic groups found that disadvantaged cancer patients were underrepresented due to several barriers such as presence of co-morbidities, travel distance to and from clinics and financial concerns.[81] Other research reported an increasing gap between advantaged and disadvantaged patients regarding access to novel targeted cancer treatments such as immunotherapy.[82] Research on the effect of psychological factors on socio-economic inequalities in cancer screening participation and attitudes toward cancer reported that people from lower socio-economic background have more negative beliefs about cancer screening, early detection and treatment such as worrying and not willing to know if they have cancer, as they believe cancer is a death sentence or cancer treatment is worse than cancer itself.[83,84]

The contribution of the above factors and social or psychological stresses to socio-economic inequalities in cancer patient survival is not clear due to methodological issues and data limitations. Also, it is unclear whether the interaction between the socio-demographic and clinical characteristics of cancer patients and the health care system partly explain these inequalities. In the absence of more in-depth knowledge, it is challenging to identify and prioritize actionable factors to address socio-economic inequalities in cancer survival and improve outcomes for disadvantaged patients.

Limitations

The findings of this review should be interpreted with caution, mainly due to between-study heterogeneity in measures of SEP (measured at individual or neighborhood level) and the methods used to identify the underlying causes of socio-economic inequalities in cancer survival. A limitation of using single individual-level indicators of SEP in investigating socio-economic inequalities in health outcomes is that each does not address the multi-dimensionality of SEP; for instance, a person can be classified as advantaged by one indicator (high level of education), but not another (low level of income).[85,86]Another issue is that in health inequalities research, it is common practice to adjust for socio-economic indicators other than the one of interest, which ignores the complexity of the pathways that connect SEP indicators to health.[86] Using composite measures of SEP defined by weighting and aggregating several socio-economic dimensions to measure material and social deprivation or social and economic standing, can potentially overcome the issues mentioned above, but these measures might not be suitable to answer particular policy questions.[87] Using area-based SEP measures may lead to misclassification and under-estimation of contribution of individual-level SEP to health outcomes, although the characteristics of an area, such as public resources and infrastructure, can also independently affect people's health, thereby over-estimating the association of individual-level SEP with the outcome of interest.[88]

The majority of the studies applied the difference method, by which regression models were compared with and without adjusting for potential mediators. This standard approach has some major limitations. The first problem arises when there are unmeasured mediator-outcome confounders. Adjusting for the mediator in the presence of mediator-outcome confounding is inappropriate as it creates a non-causal association between the exposure and the mediator-outcome confounder, which can induce substantial bias, known as collider bias.[89] Another limitation is the assumption of no interaction between the effects of the exposure and the mediator on the outcome, which may result in invalid inferences.[89,90] Moreover, this approach fails when multiple mediators are of interest and the mediators affect or interact with each other (for example, interactions between stage and treatment or co-morbidity and treatment); in this case, adding mediators one-by-one to the model could give biased estimates.[89,90]

About half of the included studies assessed overall survival, which is problematic when exploring the reasons for socio-economic inequalities in cancer survival as there is solid evidence that socio-economic position is associated with death due to causes other than cancer.[91] In addition, for screen-detectable cancers such as breast, colorectal and prostate cancer, the effect of overdiagnosis, lead-time and length-time bias should not be neglected as screen-detected cancers show higher survival, even in the presence of co-morbidities and ineffective treatment.

Conclusion

Socio-economic inequalities in cancer survival appear to be partly explained by differences in disease stage, health-related behaviors, chronic conditions and treatment modalities. Discrepancies in findings across studies could be due to variation in the covariates included in the analyses. It is essential that future studies apply novel methods of mediation analysis to population-based linked health data to generate more reliable evidence about the medical and psychological mechanisms underlying these inequalities, which may lead to better resource allocation and change in cancer control policies to improve cancer survival for all patients.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: N.A. was the recipient of an Australian Government Research Training Program Scholarship.

ORCID iD

Nina Afshar, PhD https://orcid.org/0000-0001-5587-9540
Roger L. Milne, PhD https://orcid.org/0000-0001-5764-7268

Supplemental Material

Supplemental material for this article is available online.

References

1. Quaglia A, Lillini R, Mamo C, Ivaldi E, Vercelli M. Socio-economic inequalities: a review of methodological issues and the relationships with cancer survival. *Crit Rev Oncol Hematol*. 2013; 85(3):266-277.
2. Kogevinas M, Porta M. Socioeconomic differences in cancer survival: a review of the evidence. *IARC Sci Publ*. 1997;138(138): 177-206.
3. Woods L, Rachet B, Coleman M. Origins of socio-economic inequalities in cancer survival: a review. *Ann Oncol*. 2005; 17(1):5-19.
4. Auvinen A, Karjalainen S. Possible explanations for social class differences in cancer patient survival. *IARC Sci Publ*. 1997;(138): 377-397.
5. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *System Rev*. 2015;4(1):1.
6. Aarts MJ, Kamphuis CBM, Louwman MJ, Coebergh JWW, Mackenbach JP, van Lenthe FJ. Educational inequalities in cancer survival: a role for comorbidities and health behaviours? *J Epidemiol Community Health*. 2013;67(4):365-373 369p.
7. Aarts MJ, Koldewijn EL, Poortmans PM, Coebergh JWW, Louwman M. The impact of socioeconomic status on prostate cancer treatment and survival in the Southern Netherlands. *Urology*. 2013;81(3):593-600.
8. Aarts MJ, Voogd AC, Duijm LEM, Coebergh JWW, Louwman WJ. Socioeconomic inequalities in attending the mass screening for breast cancer in the south of the Netherlands-associations with stage at diagnosis and survival. *Breast Cancer Res Treat*. 2011; 128(2):517-525.
9. Bastiaannet E, De Craen AJM, Kuppen PJK, et al. Socioeconomic differences in survival among breast cancer patients in the Netherlands not explained by tumor size. *Breast Cancer Res Treat*. 2011; 127(3):721-727.
10. Berglund A, Holmberg L, Tishelman C, Wagenius G, Eaker S, Lambe M. Social inequalities in non-small cell lung cancer management and survival: a population-based study in central Sweden. *Thorax*. 2010;65(4):327-333.
11. Berglund A, Lambe M, Luchtenborg M, et al. Social differences in lung cancer management and survival in South East England: a cohort study. *BMJ Open*. 2012;2 (3): e001048.
12. Bharathan B, Welfare M, Borowski DW, et al. Impact of deprivation on short- and long-term outcomes after colorectal cancer surgery. *Br J Surg*. 2011;98(6):854-865.
13. Bouchardy C, Verkooijen HM, Fioretta G. Social class is an important and independent prognostic factor of breast cancer mortality. *Int J Cancer*. 2006;119(5):1145-1151.
14. Braaten T, Weiderpass E, Lund E. Socioeconomic differences in cancer survival: the Norwegian women and cancer study. *BMC Public Health*. 2009;9(178):178.
15. Cavalli-Björkman N, Lambe M, Eaker S, Sandin F, Glimelius B. Differences according to educational level in the management and survival of colorectal cancer in Sweden. *Eur J Cancer*. 2011; 47(9):1398-1406 1399p.
16. 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(5): 797-804 798p.
17. Downing A, Prakash K, Gilthorpe MS, Mikeljevic JS, Forman D. Socioeconomic background in relation to stage at diagnosis, treatment and survival in women with breast cancer. *Br J Cancer*. 2007;96(5):836-840.
18. Eaker S, Halmin M, Bellocco R, et al. Social differences in breast cancer survival in relation to patient management within a National Health Care System (Sweden). *Int J Cancer*. 2009; 124(1):180-187.
19. Eriksson H, Lyth J, Mansson-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. *European J Cancer*. 2013; 49(12):2705-2716.
20. Forrest LF, Adams J, Rubin G, White M. The role of receipt and timeliness of treatment in socioeconomic inequalities in lung cancer survival: population-based, data-linkage study. *Thorax*. 2015; 70(2):138-145.
21. Frederiksen BL, Dalton SO, Osler M, Steding-Jessen M, De Nully Brown P. Socioeconomic position, treatment, and survival of non-Hodgkin lymphoma in Denmark—a nationwide study. *Br J Cancer*. 2012;106(5):988-995.
22. Frederiksen BL, Osler M, Harling H, Ladelund S, Jørgensen T. Do patient characteristics, disease, or treatment explain social inequality in survival from colorectal cancer? *Soc Sci Med*. 2009;69(7):1107-1115 1109p.
23. Ibfelt EH, Dalton SO, Hogdall 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(3):353-359.
24. Ibfelt EH, Kjaer SK, Hogdall 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(9):2489-2495.
25. Jack RH, Gulliford MC, Ferguson J, Moller H. Explaining inequalities in access to treatment in lung cancer. *J Eval Clin Pract*. 2006;12(5):573-582.
26. Larsen SB, Kroman N, Ibfelt EH, Christensen J, Tjønneland A, Dalton SO. Influence of metabolic indicators, smoking, alcohol and socioeconomic position on mortality after breast cancer. *Acta Oncol*. 2015;54(5):780-788 789p.
27. Launay L, Dejardin O, Pornet C, et al. Influence of socioeconomic environment on survival in patients diagnosed with esophageal cancer: a population-based study. *Dis Esophagus*. 2012;25(8): 723-730.
28. Lejeune C, Sassi F, Ellis L, et al. Socio-economic disparities in access to treatment and their impact on colorectal cancer survival. *Int J Epidemiol*. 2010;39(3):710-717.

29. Li R, Daniel R, Rachet B. How much do tumor stage and treatment explain socioeconomic inequalities in breast cancer survival? Applying causal mediation analysis to population-based data. *Eur J Epidemiol*. 2016;31(6):603-611.
30. Quaglia A, Lillini R, Casella C, et al. The combined effect of age and socio-economic status on breast cancer survival. *Crit Rev Oncol-Hematol*. 2011;77(3):210-220.
31. Robertson G, Greenlaw N, Bray CA, Morrison DS. Explaining the effects of socio-economic deprivation on survival in a national prospective cohort study of 1909 patients with head and neck cancers. *Cancer Epidemiol*. 2010;34(6):682-688.
32. Rutherford MJ, Hinchliffe SR, Abel GA, Lyratzopoulos G, Lambert PC, Greenberg DC. 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(9):2192-2200.
33. Seidelin UH, Ibfelt E, Andersen I, et al. Does stage of cancer, comorbidity or lifestyle factors explain educational differences in survival after endometrial cancer? A cohort study among Danish women diagnosed 2005-2009. *Acta Oncol*. 2016;55(6): 680-685.
34. Shafique K, Morrison DS. Socio-economic inequalities in survival of patients with prostate cancer: role of age and Gleason grade at diagnosis. *PLoS One*. 2013;8(2):e56184.
35. Stromberg U, Peterson S, Holmberg E, et al. Cutaneous malignant melanoma show geographic and socioeconomic disparities in stage at diagnosis and excess mortality. *Acta Oncol*. 2016;55(8): 993-1000.
36. Walsh PM, Byrne J, Kelly M, McDevitt J, Comber H. Socioeconomic disparity in survival after breast cancer in Ireland: observational study. *PLoS One*. 2014;9(11):e111729.
37. Berger E, Delpierre C, Despas F, et al. Are social inequalities in acute myeloid leukemia survival explained by differences in treatment utilization? Results from a French longitudinal observational study among older patients. *BMC Cancer*. 2019;19(1):1-12.
38. Comber H, De Camargo Cancela M, Haase T, Johnson H, Sharp L, Pratschke J. Affluence and private health insurance influence treatment and survival in non-Hodgkin's lymphoma. *PLoS One*. 2016;11(12):e0168684.
39. Engberg H, Steding-Jessen M, Oster I, Jensen JW, Fristrup CW, Moller H. Regional and socio-economic variation in survival after a pancreatic cancer diagnosis in Denmark. *Dan Med J*. 2020; 67(2):A08190438.
40. Feller A, Schmidlin K, Bordoni A, et al. Socioeconomic and demographic inequalities in stage at diagnosis and survival among colorectal cancer patients: evidence from a Swiss population-based study. *Cancer Med*. 2018;7(4):1498-1510.
41. Finke I, Behrens G, Schwettmann L, et al. Socioeconomic differences and lung cancer survival in Germany: investigation based on population-based clinical cancer registration. *Lung Cancer*. 2020;142:1-8.
42. Gardy J, Dejardin O, Thobie A, Eid Y, Guizard A-V, Launoy G. Impact of socioeconomic status on survival in patients with ovarian cancer. *Int J Gynecol Cancer*.2019;29(4):792-801.
43. Larsen SB, Brasso K, Christensen J, et al. Socioeconomic position and mortality among patients with prostate cancer: influence of mediating factors. *Acta Oncol*.2017;56(4):563-568.
44. Morris M, Woods LM, Rachet B. What might explain deprivation-specific differences in the excess hazard of breast cancer death amongst screen-detected women? Analysis of patients diagnosed in the West Midlands region of England from 1989 to 2011. *Oncotarget*. 2016;7(31):49939-49947.
45. Phillips A, Kehoe S, Singh K, et al. Socioeconomic differences impact overall survival in advanced ovarian cancer (AOC) prior to achievement of standard therapy. *Arch Gynecol Obstetr*. 2019; 300(5):1261-1270.
46. Singer S, Bartels M, Briest S, et al. Socio-economic disparities in long-term cancer survival-10 year follow-up with individual patient data. *Support Care Cancer*.2017;25(5):1391-1399.
47. Torbrand C, Wigertz A, Drevin L, et al. Socioeconomic factors and penile cancer risk and mortality; a population-based study. *BJU Int*. 2017;119(2):254-260.
48. Vallance AE, van der Meulen J, Kuryba A, et al. Socioeconomic differences in selection for liver resection in metastatic colorectal cancer and the impact on survival. *Eur J Surg Oncol*. 2018; 44(10):1588-1594.
49. Woods LM, Rachet B, O'Connell D, Lawrence G, Coleman MP. Impact of deprivation on breast cancer survival among women eligible for mammographic screening in the West Midlands (UK) and New South Wales (Australia): women diagnosed 1997-2006. *Int J Cancer*. 2016;138(10):2396-2403.
50. Brookfield KF, Cheung MC, Lucci J, Fleming LE, Koniaris LG. Disparities in survival among women with invasive cervical cancer: a problem of access to care. *Cancer*. 2009;115(1):166-178.
51. Byers TE, Wolf HJ, Bauer KR, et al. The impact of socioeconomic status on survival after cancer in the United States: findings from the national program of cancer registries patterns of care study. *Cancer*. 2008;113(3):582-591.
52. Danzig MR, Weinberg AC, Ghandour RA, Kotamarti S, McKiernan JM, Badani KK. The association between socioeconomic status, renal cancer presentation, and survival in the United States: a survival, epidemiology, and end results analysis. *Urology*. 2014; 84(3):583-589.
53. Feinglass J, Rydzewski N, Yang A. The socioeconomic gradient in all-cause mortality for women with breast cancer: findings from the 1998 to 2006 National Cancer Data Base with follow-up through 2011. *Ann Epidemiol*. 2015;25(8):549-555.
54. Guo Y, Logan HL, Marks JG, Shenkman EA. The relationships among individual and regional smoking, socioeconomic status, and oral and pharyngeal cancer survival: a mediation analysis. *Cancer Med*. 2015;4(10):1612-1619.
55. Hines R, Markossian T, Johnson A, Dong F, Bayakly R. Geographic residency status and census tract socioeconomic status as determinants of colorectal cancer outcomes. *Am J Publ Health*. 2014;104(3): e63-71.
56. Johnson AM, Hines RB, Johnson JA, Bayakly AR. Treatment and survival disparities in lung cancer: the effect of social environment and place of residence. *Lung Cancer*. 2014; 83(3):401-407.

57. Kim J, Artinyan A, Mailey B, et al. An interaction of race and ethnicity with socioeconomic status in rectal cancer outcomes. *Ann Surg*. 2011;253(4):647-654.
58. O'Brien B, Koru-Sengul T, Miao F, et al. Disparities in overall survival for male breast cancer patients in the state of Florida (1996-2007). *Clin Breast Cancer*. 2015;15(4): e177-187.
59. Sprague BL, Trentham-Dietz A, Gangnon RE, et al. Socioeconomic status and survival after an invasive breast cancer diagnosis. *Cancer*. 2011;117(7):1542-1551.
60. Yu XQ. Socioeconomic disparities in breast cancer survival: relation to stage at diagnosis, treatment and race. *BMC Cancer*. 2009; 9(1):1-7.
61. Abdel-Rahman O. Impact of NCI socioeconomic index on the outcomes of nonmetastatic breast cancer patients: analysis of SEER census tract-level socioeconomic database. *Clin Breast Cancer*. 2019;19(6): e717-e722.
62. Cote DJ, Ostrom QT, Gittleman H, et al. Glioma incidence and survival variations by county-level socioeconomic measures. *Cancer*. 2019;125(19):3390-3400.
63. Deb S, Pendharkar AV, Schoen MK, Altekruse S, Ratliff J, Desai A. The effect of socioeconomic status on gross total resection, radiation therapy and overall survival in patients with gliomas. *J Neuro-Oncol*. 2017;132(3):447-453.
64. DeRouen MC, Schupp CW, Koo J, et al. Impact of individual and neighborhood factors on disparities in prostate cancer survival. *Cancer Epidemiol*. 2018;53:1-11.
65. Keegan TH, Kurian AW, Gali K, et al. Racial/ethnic and socioeconomic differences in short-term breast cancer survival among women in an integrated health system. *Am J Publ Health*. 2015; 105(5):938-946.
66. Oh DL, Santiago-Rodriguez EJ, Canchola AJ, Ellis L, Tao L, Gomez SL. Changes in colorectal cancer 5-year survival disparities in California, 1997-2014. *Cancer Epidemiol Biomark Prevent*. 2020;29(6):1154-1161.
67. Shariff-Marco S, Yang J, John EM, et al. Intersection of race/ethnicity and socioeconomic status in mortality after breast cancer. *J Commun Health*. 2015; 40(6):1287-1299.
68. Swords DS, Mulvihill SJ, Brooke BS, Firpo MA, Scaife CL. Size and importance of socioeconomic status-based disparities in use of surgery in nonadvanced stage gastrointestinal cancers. *Ann Surg Oncol*.2020;27(2):333-341.
69. Booth CM, Li G, Zhang-Salomons J, Mackillop WJ. The impact of socioeconomic status on stage of cancer at diagnosis and survival: a population-based study in Ontario, Canada. *Cancer*. 2010; 116(17):4160-4167.
70. Chu KP, Habbous S, Kuang Q, et al. Socioeconomic status, human papillomavirus, and overall survival in head and neck squamous cell carcinomas in Toronto, Canada. *Cancer Epidemiol*. 2016;40:102-112.
71. Groome PA, Schulze KM, Keller S, et al. Explaining socioeconomic status effects in laryngeal cancer. *Clin Oncol*. 2006;18(4): 283-292.
72. 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(7): e40917.
73. Beckmann KR, Bennett A, Young GP, et al. Sociodemographic disparities in survival from colorectal cancer in South Australia: a population-wide data linkage study. *BMC Health Serv Res*. 2015; 16(1):1-4.
74. Yu XQ, O'Connell DL, Gibberd RW, Armstrong BK. Assessing the impact of socio-economic status on cancer survival in New South Wales, Australia 1996-2001. *Cancer Causes Control*. 2008; 19(10):1383-1390.
75. Tervonen HE, Aranda S, Roder D, et al. Cancer survival disparities worsening by socio-economic disadvantage over the last 3 decades in new South Wales, Australia. *BMC Publ Health*.2017; 17(1):1-11.
76. Jeffreys M, Sarfati D, Stevanovic V, et al. Socioeconomic inequalities in cancer survival in New Zealand: the role of extent of disease at diagnosis. *Cancer Epidemiol Biomark Prevent*. 2009;18(3):915-921.
77. McKenzie F, Ellison-Loschmann L, Jeffreys M. Investigating reasons for socioeconomic inequalities in breast cancer survival in New Zealand. *Cancer Epidemiol*. 2010;34(6): 702-708.
78. Ueda K, Kawachi I, Tsukuma H. Cervical and corpus cancer survival disparities by socioeconomic status in a metropolitan area of Japan. *Cancer Sci*. 2006;97(4):283-291.
79. Zaitsu M, Kim Y, Lee H-E, Takeuchi T, Kobayashi Y, Kawachi I. Occupational class differences in pancreatic cancer survival: a population-based cancer registry-based study in Japan. *Cancer Med*.2019;8(6):3261-3268.
80. Vaccarella S, Lortet-Tieulent J, Saracci R, Conway DI, Straif K, Wild CP, editors. Reducing social inequalities in cancer: evidence and priorities for research. Lyon (FR): International Agency for Research on Cancer; 2019. PMID: 33443989.
81. Sharrocks K, Spicer J, Camidge D, Papa S. The impact of socioeconomic status on access to cancer clinical trials. *Br J Cancer*. 2014;111(9):1684-1687.
82. Mano M. The burden of scientific progress: growing inequalities in the delivery of cancer care. *Acta Oncol*. 2006;45(1): 84-86.
83. Quaife SL, Winstanley K, Robb KA, et al. Socioeconomic inequalities in attitudes towards cancer: an international cancer benchmarking partnership study. *Eur J Cancer Prevent*. 2015; 24(3):253.
84. Von Wagner C, Good A, Whitaker K, Wardle J. Psychosocial determinants of socioeconomic inequalities in cancer screening participation: a conceptual framework. *Epidemiol Rev*. 2011; 33(1):135-147.
85. Braveman PA, Cubbin C, Egerter S, et al. Socioeconomic status in health research: one size does not fit all. *JAMA*. 2005;294(22): 2879-2888.
86. Green MJ, Popham F. Interpreting mutual adjustment for multiple indicators of socioeconomic position without committing mutual adjustment fallacies. *BMC Publ Health*. 2019;19(1): 1-7.
87. Shavers VL, Shavers VL. Measurement of socioeconomic status in health disparities research. *J National Med Assoc*. 2007;99(9): 1013-1023.

88. Demissie K, Hanley JA, Menzies D, Joseph L, Ernst P. Agreement in measuring socio-economic status: area-based versus individual measures. *Chronic Dis Can*. 2000;21(1): 1-7.
89. VanderWeele T, Vansteelandt S. Mediation analysis with multiple mediators. *Epidemiol Methods*. 2014;2(1):95-115.
90. Richiardi L, Bellocco R, Zugna D. Mediation analysis in epidemiology: methods, interpretation and bias. *Int J Epidemiol*. 2013; 42(5):1511-1519.
91. Mackenbach JP, Stirbu I, Roskam A-JR, et al. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med*. 2008;358(23):2468-2481.