Investigating socioeconomic disparities in cancer survival using geographic area-based measures

Julia Frances Claire Stanbury

Thesis submitted in fulfilment of
the requirements for the Degree of

Master of Philosophy

Medicine
School of Public Health

The University of Sydney

2016

TABLE OF CONTENTS

STATEMENT OF AUTHENTICITY

This thesis is submitted to the University of Sydney in fulfilment of the requirements for the Degree of Master of Philosophy.

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

Signature……  …… Date……**30/12/2015**……

ACKNOWLEDGEMENTS

There are many people I wish to acknowledge whose invaluable support contributed to my completion of this thesis.

Firstly, I wish to thank my primary supervisor, Dr Xue Qin Yu for oversighting my work throughout all stages of research and writing. His encouragement, patience, advice and guidance have been invaluable. Additionally I wish to acknowledge my associate supervisor, Associate Professor Peter Baade for his constructive criticism, encouragement, and editorial input of my work.
I am most grateful to both of my supervisors for their generosity in sharing their knowledge and experience throughout my candidature.

I would also like to thank Mr Yan (Ray) Yu, the co-author of the manuscripts for this thesis. His statistical knowledge and assistance with data analysis has been invaluable.

My sincere thanks to the reviewers and editors of the journals who have reviewed and considered the two papers in this thesis.

I wish to thank the Cancer Research Division (CRD) team at the Cancer Council NSW, where I completed my thesis, for their facilitation and support throughout my studies. I also acknowledge the role of the NSW central cancer registry and the Australian Bureau of Statistics for providing the patient data. In particular I thank Ms Julia Fitzgerald for investigating the availability of relevant population SEIFA data required for my thesis.

In addition, I acknowledge the board members of the Gowrie Trust Fund and thank them for awarding me the 2014 Gowrie Scholarship to support my research. I also thank Dr Clare Vajdic for her support in my application to the Gowrie Trust.

Finally, I thank my family for their tireless support throughout my candidature, their enduring support and encouragement, from near and afar. Special mention to Dr. Denis Smith for his late night editorial advice. Many thanks as well to my wonderful friends, without whom I would no doubt have finished much earlier.

STRUCTURE OF THESIS

This thesis is structured into five chapters. The first chapter is an introduction to the thesis work which outlines the research questions being investigated, the purpose of the research and the specific research aims.

The second chapter presents a literature review on recent studies of socioeconomic disparities in cancer survival, including an examination of temporal trends in these disparities, to provide context for the following publications.

The body of this thesis consists of chapters three and four, which comprise two original research papers. Chapter three is our submitted manuscript “Cancer survival in New South Wales, Australia: Socioeconomic disparities remain despite overall improvements” (*BMC Cancer*, 2015). This chapter analyses trends in socioeconomic survival disparities over time for ten major cancers in New South Wales (NSW), highlighting priority groups and the potential impact of minimising these disparities.

The fourth chapter is our submitted manuscript “Impact of geographic area level on measuring socioeconomic disparities in cancer survival in New South Wales, Australia” (*Cancer Epidemiology*, 2015). This paper presents our comparison of two different area-units, Local Government Areas (LGA) and census Collection Districts (CD), for measuring socioeconomic disparities in cancer survival detected in NSW and investigates the extent of misclassification by socioeconomic status (SES) that may occur between these two area units, to determine which unit is the better alternative for measuring socioeconomic survival disparities.

The final chapter is a comprehensive discussion of the research conducted and conclusions drawn from this work. I consider many proposed reasons for cancer survival disparities by socioeconomic status and discuss how the use of different geographic area units can impact on the survival disparities detected. I summarise the findings of my research and discuss the wider implications of this thesis, including identifying specific cancers types that require additional attention to improve survival, and the potential for both cancer registry data and other population based data sources to utilise various small geographic units to improve future accuracy.

In addition, there are sections with acknowledgements, an abstract, the author’s contribution, and appendices containing statements from the co-authors of the included manuscripts and supplementary material related to these manuscripts.

ABSTRACT

Many studies in developed countries around the world have reported variations in cancer survival associated with socioeconomic status. Understanding the causes of survival disparities is of continued interest to inform interventions targeting these socioeconomic disparities, as well as monitoring survival trends over time to evaluate the effectiveness of such interventions.

Cancer survival is a useful measure in the evaluation of cancer control efforts, giving a quantifiable measure of the effectiveness of diagnostic and treatment services, and the management of cancer care services. Ecologic analyses are widely used as the preferred approach for evaluating the effectiveness of a population intervention. Increased socioeconomic variability within geographic area-units makes it difficult to isolate the discrete effect of socioeconomic status on cancer survival, particularly when using few, or large, geographic units. Despite recent research interest in socioeconomic disparities in cancer outcomes, NSW cancer-registry data has not been used to track temporal trends in survival disparities for many years. Furthermore, no study investigating how the geographic area-level at which SES is measured impacts the survival disparities detected, The body of this thesis includes two original research articles addressing these two concerns. The first is under consideration for publication by BMC Cancer (minor revisions submitted 24 December, 2015. And the second is under consideration with Cancer Epidemiology (revision submitted 23 December, 2015.

The first article analyses trends in socioeconomic survival disparities over time for ten major cancers in New South Wales, demonstrating that recent health and social policies in NSW have accompanied an increase in cancer survival overall, but they have not been associated with a reduction in socioeconomic inequalities. Socioeconomic disparities persisted in NSW over the study period while a large number of deaths attributable to a diagnosis of cancer could have been postponed if these disparities were eliminated. The second article compares of two different area-units for measuring socioeconomic disparities in cancer survival in NSW, showing that while patient SES classification differed between area-units, the impact on cancer survival disparities of SES misclassification when using the larger area-unit was relatively small and inconsistent.

Overall, this thesis emphasizes the importance of assessing progress toward eliminating cancer survival inequalities. The findings of this thesis have important implications for predicting and planning for the future needs of cancer care services in NSW, thus informing health and social policies aiming to reduce the socioeconomic inequalities in cancer survival in NSW. This thesis also contributes to the field of epidemiology by improving our understanding of the impact of using area-based measures of differing geographical precision when investigating socioeconomic inequalities in health outcomes.

AUTHOR'S CONTRIBUTION

Miss Julia F Stanbury conducted the research presented in this thesis under the supervision of two supervisors; Dr Xue Qin Yu (primary supervisor) and Associate Professor Peter Baade (auxiliary supervisor). Miss Stanbury was the major contributor to all aspects of the work, including conceiving the project with inputs from Dr Yu, planning the research, conducting the literature review, performing data analysis with assistance from Mr Yan Yu, interpretation of results, discussion of the main results, implications of the research findings and future directions of this research, writing of publication manuscripts for peer-reviewed journals and writing of the thesis.

CHAPTER 1: INTRODUCTION

ABOUT THIS CHAPTER

This chapter presents the background for this thesis. Firstly, I explain the purpose of conducting this research and define the aims of the thesis. The subsequent section provides a brief overview of the use of area-based or 'ecological' studies, and their usefulness in investigating socioeconomic variations in cancer survival at the population level, to provide context for the following chapters.

AIMS

The purpose of conducting research for this thesis is to investigate the associations between socioeconomic status (SES) and cancer survival in the state of New South Wales (NSW), Australia. The primary aim of this thesis is to provide up-to-date information on the socioeconomic differentials in cancer survival in NSW. This research will also estimate the number of lives potentially extendable beyond 5 years if no socioeconomic differentials in cancer survival existed in NSW. The secondary aim of this thesis is to compare two geographic area-based units for classifying patients according to SES and estimate the degree of patient misclassification between these units and the impact of such misclassification on measuring socioeconomic disparities in cancer survival.

BACKGROUND

Many studies in developed countries around the world have reported variations in cancer survival associated with socioeconomic status, in which patients from more socioeconomically disadvantaged backgrounds show poorer survival rates for many major cancers (1-4). Research into understanding the causes of such survival disparities is of continued interest, to inform the development of interventions to reduce and ultimately eliminate these socioeconomic disparities. There is also increasing research focus on monitoring survival trends over time to evaluate the effectiveness of these interventions to reduce these disparities.

Ecologic analyses are widely used as the preferred approach for evaluating the effectiveness of a population intervention (5). Cancer survival is a useful measure in the evaluation of cancer control efforts, giving a quantifiable measure of the effectiveness of diagnostic and treatment services, and the management of cancer care services. Using population-based cancer registry data allows us to measure survival rates at the population level, as well as consider important information such as patient age, sex, stage of disease and residential location at diagnosis in our analyses. By

monitoring temporal and socioeconomic trends in patient survival, we can assess priorities and equity in cancer care services, inform health resource management and evaluate the potential for future improvements in cancer control strategies.

As is common for population-based registry data, relative survival will be used in this study to calculate survival estimates, as described previously (6). Relative survival compares the survival rate of cancer patients to that of people in comparable group, usually the general population. That is, it removes the effect of the 'background' mortality rate, or mortality from other causes (7). Thus relative survival provides a measure of excess mortality due to a diagnosis of cancer. As it can be difficult to determine the degree to which a patient's death is due specifically to their cancer diagnosis, this approach provides a more objective and possibly more accurate means of removing the effect of mortality from other causes (8). Using relative survival also removes the need to obtain specific cause of death information for cancer patients, which is often incomplete or inaccurate in population-based cancer registries (9, 10).

Ecological studies use a group as the unit of analysis, typically defined by a geographic area. They allow large datasets to be analysed efficiently, in a more cost effective and less time consuming manner than studies using individual level data. Area-based measures of the SES of individual patients are widely used in health research since individual level information is not available in population-based studies. However, analysis issues can arise here due to varying sizes of areas, and thus of populations within groups. Additionally, data on many important individual variables such as treatment regime, patient lifestyle factors and socioeconomic information are not available, since population-based cancer registries do not collect this information. Increased socioeconomic variability within geographic area-units makes it difficult to isolate the discrete effect of socioeconomic status on cancer survival, particularly when using few, or large, geographic units. As a result, misclassification of patients can occur when using aggregated data, such that ecological studies of cancer survival are subject to limitations, particularly when interpreting results. This inferential problem can be minimised by creating groups as socioeconomically homogenous as possible, by using small area units for classification and then aggregating for analysis, thereby ensuring a more valid and precise estimate of effect.

Previous research in Australia has shown that more disadvantaged patients experience poorer survival rates than the least disadvantaged patients (6, 11, 12). Such studies commonly use aggregate estimates of socioeconomic status obtained from national census data of the Local Government Area (LGA) of a patient's address. LGAs in Australia vary greatly in both area and population size, ranging from small urban areas with very large populations to extremely large rural areas with small populations. Using LGAs for SES classification therefore may potentially result in misclassification of many cancer patients according to SES, as observed in similar studies where

larger area-units have been used (13-16). Consequently, the true socioeconomic disparities in cancer survival in NSW may vary from those previously reported.

Cancer data from the population-based NSW Central Cancer Registry became available that would allow us to use the smaller geographic area unit of census collection district (CD) for SES classification. CDs were the smallest geographic area unit used by the Australian Bureau of Statistics (ABS) until 2011 and are known to represent a more socioeconomically homogenous population than LGAs (17). Comparing analyses of LGA and CD level data could identify the extent to which cancer cases may be misclassified according to SES when investigating socioeconomic disparities in cancer survival.

Despite recent research interest in socioeconomic disparities in cancer outcomes, there has been limited work monitoring cancer survival disparities in NSW. NSW cancer-registry data has not been used to track temporal trends in cancer survival disparities for many years. Furthermore, no study investigating how the geographic area-level at which SES is measured impacts the survival disparities detected, comparing the units of LGA and CD, has been published in Australia. In this thesis, I report on temporal trends in cancer survival in NSW, using the most recent available cancer registry data to provide the most informative results. I then investigate the impact on the observed socioeconomic variation in cancer survival rates from using two different geographic area-level units for classifying patients according to socioeconomic status.

Chapter 2 is a literature review of recent studies investigating temporal trends in socioeconomic disparities in cancer survival, both locally and internationally, and examines the various effects of area-level socioeconomic classification on measuring cancer survival disparities. Chapter 3 presents comprehensive analysis of temporal trends in socioeconomic cancer survival disparities in NSW and explores many proposed reasons for these disparities. In Chapter 4 I demonstrate the effect of using different area-level units to classify patient socioeconomic status, and show how misclassification of patient SES can impact the survival and risk estimates in such analyses. In Chapter 5, I examine all the findings from this thesis as a whole and discuss what new knowledge this research contributes to the field of cancer epidemiology.

REFERENCES

1. Woods LM, Rachet B, Coleman MP. Origins of socio-economic inequalities in cancer survival: a review. Annals of Oncology. 2006;17(1):5-19.
2. Dalton SO, Schuz J, Engholm G, Johansen C, Kjaer SK, Steding-Jessen M, et al. Social inequality in incidence of and survival from cancer in a population-based study in Denmark, 1994-2003: Summary of findings. European Journal of Cancer. 2008;44(14):2074-85.
3. 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):4160-7.
4. Ito Y, Nakaya T, Nakayama T, Miyashiro I, Ioka A, Tsukuma H, et al. Socioeconomic inequalities in cancer survival: a population-based study of adult patients diagnosed in Osaka, Japan, during the period 1993-2004. Acta Oncologica. 2014;53(10):1423-33.
5. Morgenstern H. Uses of ecologic analysis in epidemiologic research. American Journal of Public Health. 1982;72(12):1336-44.
6. 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):1383-90.
7. Ederer F, Axtell LM, Cutler SJ. The relative survival rate: a statistical methodology. Natl Cancer Inst Monogr. 1961;6:101–21.
8. Berkson J, Gage RP. Calculation of survival rates for cancer. Proceedings of the Staff Meetings of the Mayo Clinic. 1950;25(11):270-86.
9. Coleman MP, Alyin P, (Eds). Death Certification and Mortality Statistics: an International Perspective. In: Office of National Statistics. Studies on Medical and Population Statistics. London: TSO; 2000.
10. Luo Q, Yu XQ, Cooke-Yarborough C, Smith DP, O'Connell DL. Characteristics of cases with unknown stage prostate cancer in a population-based cancer registry. Cancer Epidemiology. 2013;37(6):813-9.
11. AIHW. Cancer survival and prevalence in Australia: period estimates from 1982 to 2010. Asia-Pacific Journal of Clinical Oncology. 2013;9(1):29-39.
12. Baade PD, Dasgupta P, Aitken JF, Turrell G. Geographic remoteness, area-level socioeconomic disadvantage and inequalities in colorectal cancer survival in Queensland: a multilevel analysis. BMC Cancer. 2013;13:493.
13. Wan N, Zhan FB, Cai Z. Socioeconomic disparities in prostate cancer mortality and the impact of geographic scale. Southern Medical Journal. 2011;104(8):553-9.
14. Tian N, Goovaerts P, Zhan FB, Wilson JG. Identification of racial disparities in breast cancer mortality: does scale matter? International Journal of Health Geographics [Electronic Resource]. 2010;9:35.
15. Woods LM, Rachet B, Coleman MP. Choice of geographic unit influences socioeconomic inequalities in breast cancer survival. British Journal of Cancer. 2005;92(7):1279-82.
16. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: the Public Health Disparities Geocoding Project. American Journal of Epidemiology. 2002;156(5):471-82.
17. Trewin D. Technical Paper: Census of Population and Housing - Socio-Economic Indexes for Areas (SEIFA), Australia, 2001. Canberra: Australian Bureau of Statistics, 2003.

CHAPTER 2: LITERATURE REVIEW

ABOUT THIS CHAPTER

In this chapter I provide a detailed review of the previous studies of socioeconomic inequalities in cancer survival, including the few recent studies that monitor temporal trends in these inequalities. I chose to limit this review to studies published from 2006 onwards, after the last major review of socioeconomic inequalities in cancer survival was published (1), up to the end of 2014. I also limited the included studies to those which used population-based cancer registry data and included 3 or more years of patient follow-up for calculating survival. I further limited the selected studies to those which examine one or more of the cancers to be considered in this thesis, these being stomach, colorectal, liver, lung, melanoma of the skin, female breast, cervical, uterine, ovarian and prostate cancers. Studies that fulfill these requirements are of most relevance to the context of this thesis.

SOCIOECONOMIC INEQUALITIES IN CANCER SURVIVAL

Several population-based studies have been conducted investigating socioeconomic inequalities in survival for stomach (2-9), colorectal (2-7, 9-15), liver (3, 4, 9, 16), lung (2-7, 9, 11), melanoma of the skin (2, 4-7, 9), female breast (2-7, 9, 11, 14, 17-20), cervical (2-7, 9, 11, 21, 22), uterine (2-7, 9, 22), ovarian (2-7, 9) and prostate (2-7, 9, 23) cancers since 2006. Several of these studies examined multiple, typically common cancer types to provide an overview of survival inequalities, while others conducted detailed analyses of inequalities in survival for a single cancer site. A summary of the studies included in this review, detailing the location, outcome measure(s), socioeconomic measure(s) and main results, is provided in Table 1.

Among the studies examining individual cancer types, most investigated survival inequalities in more common cancers, particularly colorectal (10, 12-15) and breast (14, 17-20), which both contribute greatly to prevalence and cancer-related mortality in populations. Additionally, socioeconomic survival disparities would be likely to exist for these cancers due to the availability of early diagnostic techniques and effective treatments for early stage disease. Socioeconomic disparities in survival from colorectal cancer have been reported in studies from the UK (12, 14, 15), the US (13) and Australia (10). In a study of 181,359 patients diagnosed with colorectal cancer between 1996 and 2004 in England, Moller et al reported 4-7% lower survival from colon cancer in the most deprived group compared to the most affluent, and a 6-15% survival difference for rectal cancer. Most of this survival variation was observed within 2 years of diagnosis, after which small survival disparities persisted, but had little association with patient SES (15). Jeffreys and colleagues also investigated survival disparities for rectal cancer using data from 132,542 patients

in England and Wales, reporting 5-year relative survival in the most deprived SES group at 45.5% compared to 53.8% in the most affluent SES group for patients diagnosed between 1996 and 1999, however the effect of deprivation on survival was most pronounced in the first year after diagnosis (12). Similar disparities were found by Lyratzopoulos et al, whose study extended the analysis by Jeffreys up to 2007. They reported a deprivation gap in survival of -11% between the highest and lowest SES groups by 2007, using data from 187,104 men with rectal cancer in England (14). The inequalities found in all three of these studies however are likely to be due in part to the impact of differential stage at diagnosis, which could not be accounted for as UK cancer registries do not routinely collect stage data. In California, Le and colleagues reported lower survival for both colon and rectal cancer in lower socioeconomic groups, in a study of 90,273 colon and 37,532 rectal cancer patients diagnosed in the ten years 1994-2003. The authors noted however that part of their observed survival inequalities were likely attributable to differences in treatment by SES, specifically treatment refusal, which was strongly associated with low SES in multivariate analysis (13). In Australia, Baade and colleagues recently reported significant associations between socioeconomic disadvantage and poorer cancer-specific and all-cause survival in colorectal cancer patients after adjusting for multiple factors including disease stage and clinical data (10).

Several studies have also examined inequalities in breast cancer survival by socioeconomic status in the US (18, 20), UK (14), New Zealand (19) and Australia (17). Using data from the US National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) program from 1987-2004, Harper et al reported that women over 50 of lower SES experienced higher cause-specific probability of death (100 – survival rate) from breast cancer compared to women of high SES. This was likely influenced by the higher rates of late stage disease found in lower SES women, who were the least likely to attend mammography screening (18). Tannenbaum and colleagues found similar results using data from Florida, where an incremental improvement in survival was found for each higher SES group compared to the lowest in 3- and 5-year survival analyses ($p<0.001$) after adjustment for race, comorbidity, stage, tumour grade, node status, treatments and demographic variables (20). In addition to rectal cancer, Lyratzopoulos and colleagues studied data from 921,611 women with breast cancer in England and reported a deprivation gap in survival of -6% between the highest and lowest SES groups by 2007. However, this study could not account for stage in the analysis, so the introduction of breast cancer screening in the UK during the study period is likely to have contributed to the disparities observed (14). McKenzie et al studied inequalities in survival for 2,968 women with breast cancer in New Zealand and found that lower survival rates in more deprived women, as well as significantly higher excess mortality in the four most deprived groups compared to the four least deprived (19). Similarly in Australia, Dasgupta and colleagues examined data from Queensland and found a 5-year relative survival rate in the most disadvantaged group of 89.9% compared to 93.4% in the least disadvantaged ($p<0.001$). The

authors also reported significantly increased risk of breast cancer-specific death in the most deprived socioeconomic group (p=0.032), after adjusting for stage of disease and patient characteristics (17).

Other studies that examined survival inequalities in individual cancers focused on stomach (8), liver (16), cervical (21, 22), uterine (22) and prostate (23) cancers. In a study of stomach cancer patients in the north-east of the Netherlands, Seimerink et al examined survival inequalities in the period 1989-2009 for 9,239 patients, reporting that the RER of death of high SES patients was significantly reduced compared to low SES patients, a difference that could not be explained by stage or treatment factors (8). Yu et al also found significantly lower relative survival in low SES patients with stomach cancer in Australia (9). Ueda and colleagues investigated disparities in survival for 3,113 patients with uterine cancer in Osaka, Japan, finding significantly lower 5-year relative survival for women in lower SES groups compared to the highest SES group, when using both education level and unemployment level SES measures (both p<0.0001). The same study also reported significant survival inequalities between socioeconomic groups of low and high unemployment, for 14,055 patients with cervical cancer (22). Similarly, Eggleston et al found significantly shorter survival time for low SES women diagnosed with both early (p<0.001) and late (p<0.001) stage cervical cancers in Texas between 1995 and 2001 (21). For prostate cancer, Yu et al reported that men living in more disadvantaged areas of NSW having significantly higher mortality risk than those living in the least disadvantaged areas (p<0.001) (23). In contrast to others cancers however, no disparities in survival from liver cancer were in Canada by Jembere and colleagues, who analysed 5,481 patients diagnosed during 1990-2001 in Ontario. The authors found no significant difference in median survival time between income-based socioeconomic quintiles. A slightly decreased mortality risk was initially detected in the 3 highest income quintiles, which then became insignificant after adjusting for curative intent treatment, suggesting that higher rates of curative intent treatment in higher income groups explained their survival advantage (16).

Among the studies that examined survival inequalities for multiple cancer types, survival rates were generally found to be lower in more deprived or lower socioeconomic groups for the majority of cancers. Typically these studies investigated more frequently occurring cancers such as colon and rectal, lung, breast and prostate cancers, as well as those of good prognosis such as melanoma, cervical and uterine cancers. These studies used data from a diverse range of international contexts, including Canada (11), the United Kingdom (6, 7), Japan (3), several European countries (2, 4, 5) and Australia (9), reflecting the widespread nature of socioeconomic survival inequalities.

Using data from all 3.22 million Danish residents, Dalton et al investigated disparities in survival by level of education and disposable income, for cancers diagnosed during 1994-2003. The authors reported marked differences in relative survival for many cancers, including colon, breast, cervical

and prostate cancers, patients with basic education and lower income having poorer survival. For cancers of poorer prognosis such as lung and ovarian cancers, small survival disparities were only observed in the short term (<1 year) after diagnosis (2). Jansen et al reported similar results in their analysis of pooled data on 983, 601 cancer patients from 200 federal state districts in Germany. This study found significantly lower 5-year relative survival for 21 of 25 cancer sites in the most deprived districts ($p<0.0001$) during 2003-2006, after adjusting for cancer stage (4). Similarly, Pokhrel and colleagues found less educated patients in Finland had lower survival for nearly all cancers sites considered between 1971 and 2005, though these differences were due in part to less favourable stage distribution in lower educated patients (5). Shack and colleagues in Scotland reported that 5-year overall survival was lower in more deprived patients for 25 of 30 cancer-sex combinations diagnosed during 1996-2000 (7). In Canada, Booth et al found significantly lower overall survival in the poorest communities in Ontario (11), while Ito et al in Japan reported significant deprivation gaps in survival for 16 of 20 cancer-sex combinations. In striking contrast to evidence of wider disparities in the short-term following diagnosis from other locations, these survival inequalities in Japan tended to widen with time since diagnosis. The authors suggested this could possibly due to under-staging of cancers and/or non-optimal management of patients (3). Finally, Yu and colleagues investigated relative survival inequalities for 13 common cancers in New South Wales, Australia, reporting 10-20% lower survival in more educationally disadvantaged groups (9).

Survival disparities for several cancers were only examined in these studies of multiple sites, including lung cancer, melanoma of the skin and ovarian cancer. These cancers are studied less as they generally have poorer prognosis (lung and ovarian cancer) or are not seen as a cancer of priority internationally (melanoma). Despite the overall poor survival, lower socioeconomic groups were shown to experience significantly lower survival from lung cancer in Australia (9), Germany (4) and Japan (3). Evidence for survival inequalities for melanoma however was inconsistent between studies, with Dalton et al in Denmark and Jansen et al in Germany both reporting significantly lower survival in lower SES groups (2, 4), and Shack and colleagues finding significant disparities in women diagnosed in Scotland (7). Conversely, no survival differences between SES groups were reported by Yu et al in Australia (9). Ovarian cancer survival also showed inconsistent disparities between studies, with no difference or small, insignificant inequalities found in Denmark (2), Scotland (7), Germany (4) and Australia (9), but significant disparities in survival found between SES groups in Japan (3) and Finland (5).

Table 1. Summary of included studies

First author (Year) Setting	Cancer Type(s)	Outcome measure	SES measure	Main results
Baade PD (2013) Australia (10)	Colorectal	5-Year cancer-specific and all cause survival	SES Index (relative disadvantage)	Significantly lower all-cause and cancer-specific survival for lower SES patients
Booth C (2010) Canada (11)	Breast, colon, rectal, lung and cervical	5-Year all cause and 3-year cancer-specific survival	Income	Significantly lower breast-, colon- and laryngeal- specific survival, and significantly lower all cause survival from all cancers, in lower SES patients
Dalton S (2008) Denmark (2)	21 Cancers	5-Year relative survival	Individual-level education, and income	Lower relative survival consistently observed for lower SES patients (shorter education, lower income, pensioners and rented housing)
Dasgupta P (2011) Australia (17)	Breast	5-Year cancer specific survival	SES Index (relative disadvantage)	Lower cause-specific 5-year survival observed for lower SES groups
Eggleston KS (2006) United States (21)	Cervical	Cancer-specific survival	SES Index (composite of education, income, employment and poverty)	Lower cancer-specific survival time observed for women of lower SES
Harper S (2009) United States (18)	Breast	5-Year cancer-specific probability of death	Area-level poverty rate	Significantly higher cancer-specific probability of death in more disadvantaged groups. Survival disparities declined over study period
Ito Y (2014) Japan (3)	13 Cancers	Deprivation gap in 5-year net survival	SES Index (deprivation)	Lower SES groups generally experienced lower net survival. Deprivation gaps in survival persisted over the study period
Jansen L (2013) Germany (4)	25 Cancers	5-Year, conditional 1- and 5-year relative survival	SES Index (deprivation)	Significantly lower relative survival in the most deprived group compared to all other groups combined for most cancers
Jeffreys M (2006) United Kingdom (12)	Rectal and anal	5-Year relative survival	Carstair's Index or SES Index (deprivation)	Lower relative survival for lower SES patients with both cancers. Survival disparities increased over the study period for both cancers
Jembere N (2012) Canada (16)	Liver	5-Year all-cause survival	Income	Significantly lower survival for lowest SES group in age/sex adjusted model.
Le H (2008) United States (13)	Colorectal	1-, 5- and 10-Year overall and cancer-specific survival	SES Index (composite of income, education, occupation and poverty)	Significantly lower survival observed for lower SES patients in all analyses

First author (Year) Setting	Cancer Type(s)	Outcome measure	SES measure	Main results
Lyratzopoulos G (2011) United Kingdom (14)	Breast and rectal	1- and 5-Year relative survival	Carstair's Index or SES Index (income/deprivation)	Lower survival observed in lower SES patients with both cancers. Deprivation gap in breast cancer survival narrowed over the study period, while deprivation gap in rectal cancer survival widened
McKenzie F (2010) New Zealand (19)	Breast	4-Year relative survival	SES Index (deprivation)	Lower SES patients experienced lower relative survival
Moller M (2012) United Kingdom (15)	Colon and rectal	Cumulative 5-year relative survival	SES Index (income/deprivation)	Lower SES patients experienced lower relative survival
Pokhrel A (2010) Finland (5)	27 Cancers	Cancer-specific 5-year survival	Education (and health-conscious occupation sub-group)	Lower cancer-specific survival in lower SES patients. Health-conscious sub-group had even higher cancer-specific survival.
Rachet B (2010) United Kingdom (6)	35 Cancers	Cumulative 1- and 3-year relative survival	SES Index (income/deprivation)	Significantly lower survival for lower SES group for most cancers. Survival inequalities persisted over study period
Shack L (2007) Scotland (7)	20 Cancers	5-Year relative survival	SES Index (Deprivation)	Lower relative survival in lower SES patients for most cancers. Survival inequalities increased over study period
Siemerink E (2011) The Netherlands (8)	Stomach	Relative survival	SES rank scores (based on income and education)	Lower relative survival in patients with low SES.
Tannenbaum SL (2013) United States (20)	Breast	Median, 1-, 3- and 5-year overall survival	Area-level poverty rate	Significantly lower survival for lower SES patients in all analyses
Ueda K (2006) Japan (22)	Uterine and cervical	Cumulative 5-year relative survival	SES rank scores (based on unemployment and education)	Low SES patients had lower uterine and cervical cancer survival. Survival inequalities larger for uterine cancer
Yu XQ (2008) Australia (9)	13 Cancers	5-Year relative survival	SES Index (education)	Lower SES groups experienced lower relative survival
Yu XQ (2014) Australia (23)	Prostate	10-Year relative survival	SES Index (relative disadvantage)	Significantly lower survival for men of lower SES. Survival inequalities persisted over the study period

TEMPORAL TRENDS IN SOCIOECONOMIC INEQUALITIES IN CANCER SURVIVAL

Among the studies included in this review, 7 studies examined temporal trends in the survival inequalities detected (3, 5-7, 12, 14, 18). In general, improved survival was seen for the majority of cancers over time, but changes reported in socioeconomic inequalities in survival were inconsistent between studies.

Examining long-term trends in survival inequalities, Lyratzpoulos et al thought to identify whether the advent of major treatments was followed by narrowing widening of the inequalities (14). For women with breast cancer in England and Wales, relative survival increased steadily over time with improvements seen in each deprivation group. The deprivation gap in survival between more affluent and deprived groups decreased gradually over the study period 1973-2004. Lyratzpoulos and colleagues suggested that most of the reduction in breast cancer mortality observed was attributable to wider availability and use of chemotherapy and endocrine therapy, which coincided with the study period. Additionally for men with rectal cancer, Lyratzpoulos et al observed improved survival over study period and improved in each deprivation group, but not at the same pace. As such, the deprivation gap in rectal cancer survival widened over the study period. These widening inequalities were thought to be caused by combination of differential SE trends in earlier diagnosis and clinical management developments, such as surgical specialization and treatment advances (14). Concordant with Lyratzpoulos' study, Rachet et al reporting improved survival for most cancers in England during the introduction period of the National Health Service (NHS) cancer plan (2000), but wide survival inequalities remained for many cancers by the end of their study in 2006 (6). Similarly, improved survival over time for rectal cancer in England and Wales was reported by Jeffreys and colleagues, but survival inequalities were found to have widened between 1986 and 2001 by approximately 5% between affluent and deprived groups (12). In Scotland, survival improved overall but the deprivation gap in survival widened between 1986 and 2000 for 15 of the 20 cancers studied, including uterine and prostate cancers. No change in survival disparities was observed for breast, ovarian or cervical cancers, but the deprivation gap decreased for men with stomach cancer (7).

Statistical modelling by Pokhrel et al showed that the higher cancer-specific and relative survival rates generally observed among highly educated patients in Finland had persisted over time during 1971-2005 (5). In Japan, Ito and colleagues reported increased survival for most cancers over the study period 1993-2004, excluding cervical, uterine, ovarian and colorectal cancers in women, and stomach cancer in both sexes, which all saw no survival improvement. Interestingly, again contrary to general trends seen in other locations, no change in the deprivation gap in 5-year survival was observed over the study period for the majority of cancers, only small reductions in one-year

survival for stomach cancer in women and lung cancer in men (3). Finally, since 1987, absolute socioeconomic disparities in cause-specific probability of death from breast cancer in the US declined overall by 20%, with improvements seen in all socioeconomic groups. More disadvantaged groups however improved at a slower rate, evidenced by increasing relative disparity between socioeconomic groups. The authors proposed that a lack of adequate health insurance and not having a usual source of health care were likely important barriers to appropriate care in these groups (18).

Table 2. Summary of included studies by cancer type

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Stomach	Dalton (2008) (2)	In men: No survival disparity between basic and higher education groups, 5-year survival disparity between low income group 12% and high group 13%. In women: No survival disparity between basic and higher education groups, 5-year survival disparity between low income group 15% and higher group 18%.
	Ito (2014) (3)	Deprivation gap between highest and lowest SES groups -10.6% (95% CI -12.3– -8.9, p<0.001), Non-significant change in deprivation gap over time +3.8% (95% CI -0.4– 7.9) In women: deprivation gap between highest and lowest SES groups -2.7% (95% CI -5.1– -0.3, p<0.05), Non-significant change in deprivation gap over time +3.4% (95% CI -2.4– 9.1)
	Jansen (2013) (4)	5-Year relative survival in lowest SES group 29.6% compared to highest group 33.4%. RER of death of lowest SES group compared to 4 higher groups combined 1.09 (95% CI 1.04-1.13, p<0.0001)
	Pokhrel (2010) (5)	In men: 5-year cause-specific survival in lowest SES group 24.0% compared to highest 28.8%. In women: 5-year cause-specific survival in lowest SES group 29.9% compared to highest 29.2%. Health-occupational group had higher survival and lower RR of death than the highest SES groups
	Rachet (2010) (6)	Most recent 3-year relative survival in men in highest SES group 19.2%, deprivation gap between highest and lowest SES groups -0.4%; 3-year relative survival in women in highest SES group 18.0%, deprivation gap -1.4%.
	Seimerink (2011) (8)	RER of death in highest SES group 0.89 (95% CI 0.81-0.98) compared to lowest SES group.
	Shack (2007) (7)	In men: deprivation gap between highest and lowest SES groups -1.5% (95% CI -2.8– 5.8), change in deprivation gap over time -0.8% (95% CI 0.1–1.4, p<0.05) In women: deprivation gap between highest and lowest SES groups -2.7% (95% CI -7.8– 2.5), change in deprivation gap over time -2.6% (95% CI -3.5– -1.8, p<0.05)
	Yu (2008) (9)	5-Year relative survival in men in lowest SES group 23.3% compared to highest group 32.6%, in women in lowest SES group 28.6% compared to highest group 35.1%. RER of death (both sexes) of lowest SES group compared to highest group 1.34 (p=0.0005)
Colon and rectal	Baade (2013) (10)	Odds ratio of mortality in lowest compared to highest SES quintile OR 1.25 (95% CI = 1.10-1.36, p<0.001) for all-cause and OR 1.23 (95% CI =1.09-1.30, p<0.001) for cancer-specific survival

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Colon and rectal (continued)	Booth (2010) (11)	3-Year colon cancer-specific survival in lowest SES quintile 68.4% compared to highest 71.0% (p=0.002), rectal cancer-specific survival 67.9% compared to 71.8% (p=0.096) 5-Year overall survival for colon cancer in lowest SES quintile 52.0% compared to highest 59.8% (p<0.001), overall survival for rectal cancer 51.5% compared to 60.0% (p<0.001)
	Dalton (2008) (2)	Colon in men: 5-year survival disparity between basic education group 42% and higher group 46%, Significant 5-year survival disparity between low income group 40% and high group 46%. In women: 5 survival disparity between basic education group 46% and higher group 49%, significant 5-year survival disparity between low income group 45% and higher group 55%. Rectal in men: 5-year survival disparity between basic education group 44% and higher group 50%, significant 5-year survival disparity between low income group 41% and higher group 51%. In women: 5-year survival disparity between basic education group 51% and higher group 71%, 5-year survival disparity between low income group 49% and higher group 58%
	Ito (2014) (3)	In men: deprivation gap between highest and lowest SES groups -10.9% (95% CI -13.0– -8.9, p<0.001), non-significant change in deprivation gap over time +1.9% (95% CI -3.3– 7.2) In women: deprivation gap between highest and lowest SES groups -5.4% (95% CI -7.8– -3.0, p<0.001), non-significant change in deprivation gap over time +1.7% (95% CI -4.2– 7.5)
	Jansen (2013) (4)	5-Year relative survival in lowest SES group 59.6 compared to highest group 64.5. RER of death of lowest SES group compared to 4 higher groups combined 1.17 (95% CI 1.12-1.19, p<0.0001)
	Jeffreys (2006) (12)	Most recent 5-year relative survival in lowest SES group 45.5% compared to highest 53.8%, RER of death in men 1.13 (95% CI 1.08-1.20) and in women 1.13 (95% CI 1.06-1.21). Survival increased from 36.2% in the lowest SES group and from 39.8% in the highest group over the study period.
	Le (2008) (13)	5-Year colon cancer-specific survival in lowest SES group 66% compared to highest 73% (p<0.0001), and rectal cancer-specific survival in lowest group 64% compared to highest 76% (p<0.0001).
	Lyratzopoulos (2011) (14)	5-year relative survival increased in the lowest SES group from 27% to 47%, and in the highest SES group from 32% to 58% over the study period. Deprivation gap relative survival increased from -5% to -11% over the study period.
	Moller (2012) (15)	Deprivation gap by age group for 5-year relative survival between lowest and highest SES groups was 4-7% for colon cancer, deprivation gap by age group for rectal cancer was 6-15%

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Colon and rectal (continued)	Pokhrel (2010) (5)	In men: 5-year cause-specific survival for colon in lowest SES group 54.5% compared to highest 54.8%, 5-year cause-specific survival for rectal in lowest SES group 52.7% compared to highest 59.8% In women: 5-year cause-specific survival for colon in lowest SES group 55.8% compared to highest 60.1%, 5-year cause specific survival for rectal in lowest SES group 56.8% compared to highest 62.4%. Health-occupational group had higher survival and lower RR of death than highest SES groups
	Rachet (2010) (6)	Most recent colon 3-year relative survival in men in highest SES group 59.8%, deprivation gap between highest and lowest SES groups -8.5% (p<0.001); 3-year relative survival in women in highest SES group 58.8%, deprivation gap -8.8% (p<0.001) Most recent rectal 3-year relative survival in men in highest SES group 64.9%, deprivation gap between highest and lowest SES groups -13.0% (p<0.001); 3-year relative survival in women in highest SES group 63.6%, deprivation gap -9.0% (p<0.001)
	Shack (2007) (7)	Colon in men: deprivation gap between highest and lowest SES groups -5.7% (95% CI -10.1– 0.2, p<0.05), change in deprivation gap over time -4.4% (95% CI -5.2– -3.5, p<0.05) In women: deprivation gap between highest and lowest SES groups -6.1% (95% CI -10.2– -1.9, p<0.05), change in deprivation gap over time -2.4% (95% CI -3.2– -1.6, p<0.05) Rectal in men: deprivation gap between highest and lowest SES groups -5.3% (95% CI -10.7– 0.2), change in deprivation gap over time -0.7% (95% CI -1.8– 0.4) In women: deprivation gap between highest and lowest SES groups -8.0% (95% CI -14.5– -1.5, p<0.05), change in deprivation gap over time -2.9% (95% CI -4.1– -1.7, p<0.05)
	Yu (2008) (9)	Colon 5-Year relative survival in men in lowest SES group 62.0% compared to highest group 63.7%, in women in lowest SES group 59.8% compared to highest group 64.5%. RER of death (both sexes) of lowest SES group compared to highest group 1.14 (p=0.03) Rectal 5-Year relative survival in men in lowest SES group 60.0% compared to highest group 62.5%, in women in lowest SES group 63.7% compared to highest group 65.6%. RER of death (both sexes) of lowest SES group compared to highest group 1.11 (p=0.01)
Liver	Ito (2014) (3)	In men: deprivation gap between highest and lowest SES groups -4.5% (95% CI -6.2– -2.8, p<0.001), non-significant change in deprivation gap over time -1.4% (95% CI -5.6– 2.7) In women: non-significant deprivation gap between highest and lowest SES groups -1.1% (95% CI -3.7– -1.5), non-significant change in deprivation gap over time +3.7% (95% CI -2.7– 10.2)
	Jansen (2013) (4)	5-Year relative survival disparity between lowest SES group 9.7% and highest 12.5%. RER of death of lowest SES group compared to 4 higher groups combined 1.16 (95% CI 1.09-1.23, p<0.0001)

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Liver (continued)	Jembere (2012) (16)	5-Year survival (unadjusted) in lowest SES group 11.9% compared to highest group 15.3%. RER of death (age/sex adjusted) for highest SES group compared to lowest group 0.905 (95% CI 0.821-0.998, p<0.05)
	Yu (2008) (9)	5-Year relative survival in men in lowest SES group 11.5% compared to highest group 20.9%, in women in lowest SES group 11.1% compared to highest group 17.7%. RER of death (both sexes) of lowest SES group compared to highest group 1.34(p=0.01)
Lung	Booth (2010) (11)	No significant disparity observed in 3-Year cancer-specific survival 5-Year overall survival in lowest SES quintile 15.4% compared to highest 18.6% (p=0.002)
	Dalton (2008) (2)	In men: significant survival disparity between basic education group 7% and higher group 10%, significant survival disparity between low income group 7% and high group 8% In women: 5-year survival disparity between low education group 9% and high group 10%, 5-year survival disparity between low income group 9% and high group 10%
	Ito (2014) (3)	In men: deprivation gap between highest and lowest SES groups -4.9% (95% CI -6.3– -3.6, p<0.001), change in deprivation gap over time -3.5% (95% CI -6.8– -0.2, p<0.05) In women: deprivation gap between highest and lowest SES groups -4.9% (95% CI -6.3– -3.6, p<0.001), Non-significant change in deprivation gap over time -3.0% (95% CI -8.6– 2.7)
	Jansen (2013) (4)	5-Year relative survival disparity between lowest SES group 14.4% and highest 18.0%. RER of death of lowest SES group compared to 4 higher groups combined 1.07 (95% CI 1.04-1.09, p<0.0001)
	Pokhrel (2010) (5)	In men: 5-year cause-specific survival in lowest SES group 9.2% compared to highest 10.6%. In women: 5-year cause-specific survival in lowest SES group 12.3% compared to highest 18.8%. Health-occupational group had higher survival and lower RR of death than the highest SES groups
	Rachet (2010) (6)	Most recent 3-year relative survival in men in highest SES group 10.0%, deprivation gap between highest and lowest SES groups -1.1% (p<0.05); 3-year relative survival in women in highest SES group 11.7%, deprivation gap -1.0%.
	Shack (2007) (7)	In men: deprivation gap between highest and lowest SES groups -1.6% (95% CI -3.1– -0.1, p<0.05), change in deprivation gap over time -0.6% (95% CI -0.9–0.3, p<0.05) In women: deprivation gap between highest and lowest SES groups -1.5% (95% CI -3.3– 0.4), change in deprivation gap over time -1.2% (95% CI -1.5– -0.9, p<0.05)
	Yu (2008) (9)	5-Year relative survival in men in lowest SES group 12.2% compared to highest group 14.0%, in women in lowest SES group 16.9% compared to highest group 17.1%. RER of death (both sexes) of lowest SES group compared to highest group 1.18 (p=0.0001)

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Melanoma	Dalton (2008) (2)	In men: significant survival disparity between basic education group 75% and higher group 81%, significant survival disparity between low income group 73% and high group 82% In women: significant survival disparity between basic education group 86% and higher group 92%, significant survival disparity between low income group 87% and high group 92%
	Jansen (2013) (4)	5-Year relative survival in lowest SES group 85.0% compared to highest 89.7%. RER of death of lowest SES group compared to 4 higher groups combined 1.44 (95% CI 1.24-1.66, p<0.0001)
	Pokhrel (2010) (5)	In men: 5-year cause-specific survival in lowest SES group 77.4% compared to highest 82.7%. In women: 5-year cause-specific survival in lowest SES group 84.5% compared to highest 91.9%. Health-occupational group had higher survival and lower RR of death than the highest SES groups
	Rachet (2010) (6)	Most recent 3-year relative survival in men in highest SES group 87.7%, deprivation gap between highest and lowest SES groups -6.9% (p<0.001); 3-year relative survival in women in highest SES group 94.2%, deprivation gap -1.6%.
	Shack (2007) (7)	In men: deprivation gap between highest and lowest SES groups -5.9% (95% CI -12.3– 0.5), change in deprivation gap over time 1.3% (95% CI -0.1–2.8) In women: deprivation gap between highest and lowest SES groups -4.0% (95% CI -7.6– -0.5, p<0.05), change in deprivation gap over time -1.9% (95% CI -2.8– -1.1, p<0.05)
	Yu (2008) (9)	5-Year relative survival in men in lowest SES group 90.0% compared to highest group 89.5%, in women in lowest SES group 94.3% compared to highest group 94.2%. RER of death (both sexes) of lowest SES group compared to highest group 1.06 (p=0.50)
Breast	Booth (2010) (11)	3-Year cancer-specific survival in lowest SES quintile 88.2% compared to highest 92.1% (p<0.001), 5-Year overall survival in lowest SES quintile 76.5% compared to highest 83.6% (p<0.001)
	Dalton (2008) (2)	Significant 5-year survival disparity between basic education group 77% and higher group 84%, Significant 5-year survival disparity between low income group 75% and high group 83%
	Dasgupta (2012) (17)	5-Year relative survival disparity between lowest SES group 89.9% and highest 93.4% (p<0.001). Cancer specific mortality Odds Ratio (OR) of lowest SES group compared to highest group 1.37 (95% CI 1.11-1.69, p=0.032)
	Harper (2009) (18)	Disparity in 5-year cancer-specific probability of death between lowest SES group 15.4% and highest group 10.9% in 2004. Reduction in probability over time since 1987 (20.6% compared to 15.3%) approximately equal across SES groups.
	Ito (2014) (3)	Deprivation gap between highest and lowest SES groups -2.8% (95% CI -4.3– -1.2, p<0.001), Non-significant change in deprivation gap over time +1.3% (95% CI -2.5– 5.1)

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Breast (continued)	Jansen (2013) (4)	5-Year relative survival disparity between lowest SES group 81.4% and highest 84.5%. RER of death of lowest SES group compared to 4 higher groups combined 1.18 (95% CI 1.08-1.21, *p*<0.0001)
	Lyratzopoulos (2011) (14)	5-year relative survival increased in the lowest SES group from 50% to 81%, and in the highest SES group from 60% to 87% over the study period. Deprivation gap relative survival decreased from -10% to -6% over the study period.
	McKenzie (2010) (19)	4-Year relative survival in lowest SES group 84.19% compared to highest 92.51% (*p* <0.05)
	Pokhrel (2010) (5)	5-year cause-specific survival in lowest SES group 84.9% compared to highest 89.4%. Health-occupational group had higher survival and lower RR of death than the highest SES group.
	Rachet (2010) (6)	Most recent 3-year relative survival in highest SES group 91.0%, deprivation gap between highest and lowest SES groups -4.7% (*p*<0.001)
	Shack (2007) (7)	Deprivation gap between highest and lowest SES groups -4.1% (95% CI -6.0– -2.2, *p*<0.05), change in deprivation gap over time -0.2% (95% CI -0.6– 0.2)
	Tannenbaum (2013) (20)	5-Year relative survival in lowest SES group 65.0% compared to highest 79.2%. Hazard ratio of death in highest SES group compared to lowest 0.80 (95% CI 0.77-0.84, *p*<0.001)
	Yu (2008) (9)	5-Year relative survival in lowest SES group 84.3% compared to highest 88.8%. RER of death of lowest SES group compared to highest 1.31 (*p*=0.0001)
Cervical	Booth (2010) (11)	Non-significant disparity observed in 3-Year cancer-specific survival 5-Year overall survival in lowest SES quintile 63.0% compared to highest 78.7%
	Dalton (2008) (2)	Significant 5-year survival disparity between basic education group 68% and high group 78%, 5-Year survival disparity between low income group 68% and high group 73%
	Eggleston (2006) (21)	Significant cancer-specific survival disparity between lowest and highest SES quartile HR=1.9 (95% CI 1.6-2.3, *P*<0.001)
	Ito (2014) (3)	Deprivation gap between highest and lowest SES groups -6.6% (95% CI -10.8– -2.5, *p*<0.01), Non-significant change in deprivation gap over time +6.2% (95% CI -3.8– 16.2)
	Jansen (2013) (4)	5-Year relative survival disparity between lowest SES group 63.3% and highest 66.3%. Non-significant RER of death in lowest SES group compared to 4 higher groups combined 1.09 (95% CI 0.97-1.19)
	Pokhrel (2010) (5)	5-year cause-specific survival in lowest SES group 63.3% compared to highest 78.5%. Health-occupational group had higher survival and lower RR of death than the highest SES group.
	Rachet (2010) (6)	Most recent 3-year relative survival in highest SES group 77.6%, deprivation gap between highest and lowest SES groups -9.0% (*p*<0.001)

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Cervical (continued)	Shack (2007) (7)	Deprivation gap between highest and lowest SES groups -4.4% (95% CI -10.8– 1.6, $p<0.05$), change in deprivation gap over time 0.2% (95% CI -1.0– -1.3)
	Ueda (2006) (22)	5-Year survival in lowest SES (unemployment) group 50.9%, highest group 68.9% ($p<0.0001$), RER of death of lowest SES group compared to highest group 1.39 (95% CI 1.28-1.50, $p<0.05$). 5-Year survival in lowest SES (education) group 56.1%, highest group 65.1% ($p<0.0001$), RER of death of lowest SES group compared to highest group 1.21 (95% CI 1.12-1.31, $p<0.05$).
	Yu (2008) (9)	5-Year relative survival in lowest SES group 68.3% compared to highest group 74.3%. RER of death of lowest SES group compared to highest group 1.33 ($p=0.40$)
Uterine	Dalton (2008) (2)	5-Year survival disparity between basic education group 79% and higher group 81%, Significant 5-year survival disparity between low income group 77% and high group 83%
	Ito (2014) (3)	Deprivation gap between highest and lowest SES groups -7.8% (95% CI -12.8– -2.8, $p<0.01$), Non-significant change in deprivation gap over time +9.9% (95% CI -2.3– 22.2)
	Jansen (2013) (4)	No evidence of 5-year relative survival disparity between lowest SES group 80.2% and highest 80.4%. Non-significant RER of death in lowest SES group compared to 4 higher groups combined 1.04 (95% CI 0.89-1.11)
	Pokhrel (2010) (5)	5-year cause-specific survival in lowest SES group 82.2% compared to highest 87.8%. Health-occupational group had higher survival and lower RR of death than the highest SES group.
	Rachet (2010) (6)	Most recent 3-year relative survival in highest SES group 82.6%, deprivation gap between highest and lowest SES groups -6.2% ($p<0.001$)
	Shack (2007) (7)	Deprivation gap between highest and lowest SES groups -5.2% (95% CI -10.7– -0.3), change in deprivation gap over time -4.7% (95% CI -5.8– -3.5, $p<0.05$)
	Ueda (2006) (22)	5-Year cumulative survival in lowest SES (unemployment) group 51.7% compared to highest group 72.4% ($p<0.0001$), RER of death of lowest SES group compared to highest group 1.54 (95% CI 1.31-1.82, $p<0.05$). 5-Year cumulative survival in lowest SES (education) group 59.2% compared to highest group 69.2% ($p<0.0001$), RER of death of lowest SES group compared to highest group 1.17 (95% CI 0.99-1.39).
	Yu (2008) (9)	5-Year relative survival in lowest SES group 83.5% compared to highest group 84.4%. RER of death of lowest SES group compared to highest group 1.97 ($p=0.56$)
Ovarian	Dalton (2008) (2)	No survival disparity between basic and higher education groups 5-year survival disparity between low income group 36% and high group 39%

Cancer	First author (Year)	Socioeconomic inequality in survival observed
Ovarian (continued)	Ito (2014) (3)	Deprivation gap between highest and lowest SES groups -12.0% (95% CI -16.9– -7.2, p<0.001), Non-significant change in deprivation gap over time -3.2% (95% CI -15.2– 8.8)
	Jansen (2013) (4)	5-Year relative survival disparity between lowest SES group 40.8% and highest 38.7%. Non-significant RER of death in lowest SES group compared to 4 higher groups combined 1.02 (95% CI 0.94-1.08)
	Pokhrel (2010) (5)	5-year cause-specific survival in lowest SES group 44.5% compared to highest 53.2%. Health-occupational group had higher survival and lower RR of death than the highest SES group.
	Rachet (2010) (6)	Most recent 3-year relative survival in highest SES group 47.9%, deprivation gap between highest and lowest SES groups -1.0%
	Shack (2007) (7)	Deprivation gap between highest and lowest SES groups -0.4% (95% CI -5.6– 4.8), change in deprivation gap over time 0.8% (95% CI -0.2– 1.7)
	Yu (2008) (9)	5-Year relative survival in lowest SES group 35.6% compared to highest group 44.4%. RER of death of lowest SES group compared to highest group 1.25 (p=0.11)
Prostate	Dalton (2008) (2)	Significant 5-year survival disparity between basic education group 75% and higher group 81%, Significant 5-year survival disparity between low income group 47% and high group 56%
	Ito (2014) (3)	Deprivation gap between highest and lowest SES groups -15.3% (95% CI -19.3– -11.3, p<0.001), Non-significant change in deprivation gap over time +1.5% (95% CI -9.1– 12.1)
	Jansen (2013) (4)	5-Year relative survival in lowest SES group 85.2 compared to highest group 88.8. RER of death of lowest SES group compared to 4 higher groups combined 1.55 (95% CI 1.46-1.84, p<0.0001)
	Pokhrel (2010) (5)	5-year cause-specific survival in lowest SES group 80.3% compared to highest 87.4%. Health-occupational group had higher survival and lower RR of death than the highest SES group.
	Rachet (2010) (6)	Most recent 3-year relative survival in highest SES group 89.8%, deprivation gap between highest and lowest SES groups -4.5% (p<0.001)
	Shack (2007) (7)	Deprivation gap between highest and lowest SES groups -6.9% (95% CI -10.3– -3.4, p<0.05), change in deprivation gap over time -2.9% (95% CI -3.7– -2.2, p<0.05)
	Yu (2008) (9)	5-Year relative survival in lowest SES group 85.3% compared to highest group 86.4%. RER of death of lowest SES group compared to highest group 1.09 (p=0.68)
	Yu (2014) (23)	RER of death in lowest SES group compared to highest 1.40 (p<0.001).

FACTORS CONTRIBUTING TO SOCIOECONOMIC INEQUALITIES IN CANCER SURVIVAL

The causes of inequalities in cancer survival by SES are not thoroughly understood. Variations in diagnosis, treatment, health care system features and patient characteristics, may contribute.

Stage of disease at diagnosis is a significant predictive factor for cancer survival. Significant differences in the distribution of stage by SES have been reported in Australia, with low SES patients more often presenting at a later stage (24). Population-based cancer screening programs have been successful in improving survival rates, primarily through increased diagnosis of small and early stage cancers (24-27). However, lower rates of screening participation generally occur in more disadvantaged socioeconomic groups, (18, 25, 28, 29). Variation in cancer treatment by SES may also contribute to disparities in survival, as patients of lower SES more often receive sub-optimal or non-guideline therapy (8, 30-33). Reduced compliance with recommended treatment regimes in low SES patients may also contribute to lower survival rates (34, 35). Organisation of the health care system has also been shown to impact on cancer survival inequalities, where patients with access to universal health care experience smaller survival inequalities compared to those whose care is provided on a fee-for-service basis (36-38).

Patient lifestyle factors impact on cancer survival mainly by affecting overall health (39, 40). Recent reports have found that patients from lower socioeconomic areas had significantly higher occurrences of poor lifestyle behaviours including smoking, risky alcohol consumption and insufficient physical activity (41, 42). Some lifestyle factors such as smoking have been shown to directly impact on the benefits of cancer treatment (43, 44). Lifestyle factors also impact on the occurrence of other chronic diseases, known as comorbidities. Variation in comorbidities between socioeconomic groups may partly explain socioeconomic inequalities in cancer survival, as lower socioeconomic groups typically experience higher chronic disease prevalence (41, 45-47). Comorbidities can impact on cancer survival through patient suitability for and benefit from various treatment options (40, 48, 49). However, a recent population-based study in the US found that socioeconomic disparities in breast cancer survival continued after controlling for several comorbid conditions (20), suggesting that variations in comorbidity cannot fully explain survival disparities.

In summary, the extensive and widespread evidence presented in this review supports the correlation between SES and cancer survival. While survival from most cancers has increased over time throughout Europe, North America, Japan and Australia, the socioeconomic variations in survival described have generally persisted over time, in some cases since the 1970's. The causes of this relationship between SES and cancer survival remain unclear, and further research is necessary to fully understand the associations.

REFERENCES

1. Woods LM, Rachet B, Coleman MP. Origins of socio-economic inequalities in cancer survival: a review. Annals of Oncology. 2006;17(1):5-19.
2. Dalton SO, Schuz J, Engholm G, Johansen C, Kjaer SK, Steding-Jessen M, et al. Social inequality in incidence of and survival from cancer in a population-based study in Denmark, 1994-2003: Summary of findings. European Journal of Cancer. 2008;44(14):2074-85.
3. Ito Y, Nakaya T, Nakayama T, Miyashiro I, Ioka A, Tsukuma H, et al. Socioeconomic inequalities in cancer survival: a population-based study of adult patients diagnosed in Osaka, Japan, during the period 1993-2004. Acta Oncologica. 2014;53(10):1423-33.
4. Jansen L, Eberle A, Emrich K, Gondos A, Holleczek B, Kajuter H, et al. Socioeconomic deprivation and cancer survival in Germany: an ecological analysis in 200 districts in Germany. International Journal of Cancer. 2014;134(12):2951-60.
5. Pokhrel A, Martikainen P, Pukkala E, Rautalahti M, Seppa K, Hakulinen T. Education, survival and avoidable deaths in cancer patients in Finland. British Journal of Cancer. 2010;103(7):1109-14.
6. Rachet B, Ellis L, Maringe C, Chu T, Nur U, Quaresma M, et al. Socioeconomic inequalities in cancer survival in England after the NHS cancer plan. British Journal of Cancer. 2010;103(4):446-53.
7. Shack LG, Rachet B, Brewster DH, Coleman MP. Socioeconomic inequalities in cancer survival in Scotland 1986-2000. British Journal of Cancer. 2007;97(7):999-1004.
8. Siemerink EJM, Hospers GAP, Mulder NH, Siesling S, van der Aa MA. Disparities in survival of stomach cancer among different socioeconomic groups in North-East Netherlands. Cancer Epidemiology. 2011;35(5):413-6.
9. 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):1383-90.
10. Baade PD, Dasgupta P, Aitken JF, Turrell G. Geographic remoteness, area-level socioeconomic disadvantage and inequalities in colorectal cancer survival in Queensland: a multilevel analysis. BMC Cancer. 2013;13:493.
11. 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):4160-7.
12. Jeffreys M, Rachet B, McDowell S, Habib AG, Lepage C, Coleman MP. Survival from rectal and anal cancers in England and Wales, 1986-2001. European Journal of Cancer. 2006;42(10):1434-40.
13. Le H, Ziogas A, Lipkin SM, Zell JA. Effects of socioeconomic status and treatment disparities in colorectal cancer survival. Cancer Epidemiology Biomarkers & Prevention. 2008;17(8):1950-62.
14. Lyratzopoulos G, Barbiere JM, Rachet B, Baum M, Thompson MR, Coleman MP. Changes over time in socioeconomic inequalities in breast and rectal cancer survival in England and Wales during a 32-year period (1973-2004): the potential role of health care. Annals of Oncology. 2011;22(7):1661-6.
15. Moller H, Sandin F, Robinson D, Bray F, Klint S, Linklater KM, et al. Colorectal cancer survival in socioeconomic groups in England: variation is mainly in the short term after diagnosis. European Journal of Cancer. 2012;48(1):46-53.
16. Jembere N, Campitelli MA, Sherman M, Feld JJ, Lou WD, Peacock S, 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).
17. Dasgupta P, Baade PD, Aitken JF, Turrell G. Multilevel determinants of breast cancer survival: association with geographic remoteness and area-level socioeconomic disadvantage. Breast Cancer Research & Treatment. 2011;132(2):701-10.
18. Harper S, Lynch J, Meersman SC, Breen N, Davis WW, Reichman MC. Trends in Area-Socioeconomic and Race-Ethnic Disparities in Breast Cancer Incidence, Stage at Diagnosis,

Screening, Mortality, and Survival among Women Ages 50 Years and Over (1987-2005). Cancer Epidemiology Biomarkers & Prevention. 2009;18(1):121-31.
19. McKenzie F, Ellison-Loschmann L, Jeffreys M. Investigating reasons for socioeconomic inequalities in breast cancer survival in New Zealand. Cancer Epidemiology. 2010;34(6):702-8.
20. Tannenbaum SL, Koru-Sengul T, Miao F, Byrne MM. Disparities in survival after female breast cancer diagnosis: a population-based study. Cancer Causes & Control. 2013;24(9):1705-15.
21. Eggleston KS, Coker AL, Williams M, Tortolero-Luna G, Martin JB, Tortolero SR. Cervical cancer survival by socioeconomic status, race/ethnicity, and place of residence in Texas, 1995-2001. Journal of Women's Health. 2006;15(8):941-51.
22. Ueda K, Kawachi I, Tsukuma H. Cervical and corpus cancer survival disparities by socioeconomic status in a metropolitan area of Japan. Cancer Science. 2006;97(4):283-91.
23. Yu XQ, Luo Q, Smith DP, O'Connell DL, Baade PD. Geographic variation in prostate cancer survival in New South Wales. Medical Journal of Australia. 2014;200(10):586-90.
24. Luke C, Nguyen AM, Priest K, Roder D. Female breast cancers are getting smaller, but socio-demographic differences remain. Australian & New Zealand Journal of Public Health. 2004;28(4):312-6.
25. Ananda SS, McLaughlin SJ, Chen F, Hayes IP, Hunter AA, Skinner IJ, et al. Initial impact of Australia's National Bowel Cancer Screening Program. Medical Journal of Australia. 2009;191(7):378-81.
26. Puliti D, Miccinesi G, Manneschi G, Buzzoni C, Crocetti E, Paci E, et al. Does an organised screening programme reduce the inequalities in breast cancer survival? Annals of Oncology. 2012;23(2):319-23.
27. Luke C, Priest K, Roder D. Changes in incidence of in situ and invasive breast cancer by histology type following mammography screening. Asian Pacific Journal of Cancer Prevention: Apjcp. 2006;7(1):69-74.
28. AIWH. Cervical screening in Australia 2011-2012. Cancer series no. 82. Cat. no. CAN 79. Canberra: AIHW, 2014.
29. AIHW. BreastScreen Australia monitoring report 2010–2011.Cancer series no.77. Cat. no. CAN 74. Canberra: AIHW, 2013.
30. Chawla N, Butler EN, Lund J, Warren JL, Harlan LC, Yabroff KR. Patterns of Colorectal Cancer Care in Europe, Australia, and New Zealand. JNCI Monographs. 2013;2013(46):36-61.
31. Byers TE, Wolf HJ, Bauer KR, Bolick-Aldrich S, Chen VW, Finch JL, 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):582-91.
32. Yu XQ. Socioeconomic disparities in breast cancer survival: relation to stage at diagnosis, treatment and race. BMC Cancer. 2009;9:364.
33. Quaglia A, Lillini R, Casella C, Giachero G, Izzotti A, Vercelli M, et al. The combined effect of age and socio-economic status on breast cancer survival. Critical Reviews in Oncology Hematology. 2011;77(3):210-20.
34. Land SR, Cronin WM, Wickerham DL, Costantino JP, Christian NJ, Klein WMP, et al. Cigarette Smoking, Obesity, Physical Activity, and Alcohol Use As Predictors of Chemoprevention Adherence in the National Surgical Adjuvant Breast and Bowel Project P-1 Breast Cancer Prevention Trial. Cancer Prevention Research. 2011;4(9):1393-400.
35. Bouchardy C, Verkooijen HM, Fioretta G. Social class is an important and independent prognostic factor of breast cancer mortality. International Journal of Cancer. 2006;119(5):1145-51.
36. Gorey KM. Breast cancer survival in Canada and the USA: meta-analytic evidence of a Canadian advantage in low-income areas. International Journal of Epidemiology. 2009;38(6):1543-51.
37. Gorey KM, Luginaah IN, Bartfay E, Fung KY, Holowaty EJ, Wright FC, et al. Effects of Socioeconomic Status on Colon Cancer Treatment Accessibility and Survival in Toronto, Ontario, and San Francisco, California, 1996-2006. American Journal of Public Health. 2011;101(1):112-9.

38. Gorey KM, Luginaah IN, Holowaty EJ, Fung KY, Hamm C. Breast cancer survival in ontario and california, 1998-2006: socioeconomic inequity remains much greater in the United States. Annals of Epidemiology. 2009;19(2):121-4.
39. Braaten T, Weiderpass E, Lund E. Socioeconomic differences in cancer survival: the Norwegian Women and Cancer Study. BMC Public Health. 2009;9:178.
40. Haydon AM, Macinnis RJ, English DR, Giles GG. Effect of physical activity and body size on survival after diagnosis with colorectal cancer. Gut. 2006;55(1):62-7.
41. AIHW. Australia's health 2014. Australia's health series no. 14. Cat. no. AUS 178. Canberra: AIHW, 2014.
42. Rosengren A, Wilhelmsen L. Cancer incidence, mortality from cancer and survival in men of different occupational classes. European Journal of Epidemiology. 2004;19(6):533-40.
43. Browman GP, Wong G, Hodson I, Sathya J, Russell R, McAlpine L, et al. Influence of cigarette smoking on the efficacy of radiation therapy in head and neck cancer. New England Journal of Medicine. 1993;328(3):159-63.
44. Steinberger E, Kollmeier M, McBride S, Novak C, Pei X, Zelefsky MJ. Cigarette smoking during external beam radiation therapy for prostate cancer is associated with an increased risk of prostate cancer-specific mortality and treatment-related toxicity. BJU International. 2014:In Press.
45. Louwman WJ, Aarts MJ, Houterman S, van Lenthe FJ, Coebergh JWW, Janssen-Heijnen MLG. A 50% higher prevalence of life-shortening chronic conditions among cancer patients with low socioeconomic status. Br J Cancer. 2010;103(11):1742-8.
46. 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? Journal of Epidemiology and Community Health. 2013;67(4):365-73.
47. Charlton J, Rudisill C, Bhattarai N, Gulliford M. Impact of deprivation on occurrence, outcomes and health care costs of people with multiple morbidity. Journal of Health Services & Research Policy. 2013;18(4):215-23.
48. Smith BD, Gross CP, Smith GL, Galusha DH, Bekelman JE, Haffty BG. Effectiveness of radiation therapy for older women with early breast cancer. Journal of the National Cancer Institute. 2006;98(10):681-90.
49. Gross CP, McAvay GJ, Guo Z, Tinetti ME. The impact of chronic illnesses on the use and effectiveness of adjuvant chemotherapy for colon cancer. Cancer. 2007;109(12):2410-9.

CHAPTER 3: SOCIOECONOMIC INEQUALITIES IN CANCER SURVIVAL IN NSW 1996-2008

ABOUT THIS CHAPTER

This chapter is our submitted manuscript "Cancer survival in New South Wales, Australia: Socioeconomic disparities remain despite overall improvements" (*BMC Cancer*, 2015). The authors of this manuscript are Julia F Stanbury, Peter D Baade, Yan Yu and Xue Qin Yu. This chapter analyses trends in socioeconomic survival disparities over time for ten major cancers in New South Wales, highlighting priority groups and the potential impact of minimising these disparities.

ABSTRACT

BACKGROUND Disparities in cancer survival by socioeconomic status have been reported previously in Australia. We investigated whether those disparities have changed over time.
METHODS We used population-based cancer registry data for 377,493 patients diagnosed with one of 10 major cancers in New South Wales (NSW), Australia. Patients were assigned to an area-based measure of socioeconomic status. Five-year relative survival was estimated for each socioeconomic quintile in each 'at risk' period (1996-2000 and 2004-2008) for the 10 individual cancers. Poisson-regression modelling was used to adjust for several prognostic factors. The relative excess risk of death by socioeconomic quintile derived from this modelling was compared over time.
RESULTS Although survival increased over time for most individual cancers, Poisson-regression models indicated that socioeconomic disparities continued to exist in the recent period. Significant socioeconomic disparities were observed for stomach, colorectal, liver, lung, breast, and prostate cancer in 1996-2000 and remained so for 2004-2008, while significant disparities emerged for cervical and uterus cancer in 2004-2008 (although the interaction between period and socioeconomic status was not significant). About 13.4% of deaths attributable to a diagnosis of cancer could have been postponed if this socioeconomic disparity was eliminated.
CONCLUSION While recent health and social policies in NSW have accompanied an increase in cancer survival overall, they have not been associated with a reduction in socioeconomic inequalities.

INTRODUCTION

Internationally, cancer patients from more socioeconomically disadvantaged backgrounds have been shown to have poorer outcomes for many major cancers (1-4). Similar socioeconomic disparities in survival have also been reported in Australia (5, 6). In the few studies that have monitored such disparities over time in a population, most report either no change in the extent of disparities detected or widening disparities, for several major cancers (7-9). Generally these studies report on only one or few cancer types and involve limited adjustment for potential prognostic factors.

In 2008, Yu et al reported that persons from more socioeconomically disadvantaged areas of NSW, Australia experienced poorer survival for many types of cancer than those from the least disadvantaged areas (6). These disparities are well recognised by health professionals and providers; however there is little knowledge about whether these socioeconomic disparities in cancer survival have reduced over time.

The purpose of this study is to determine whether the socioeconomic variations in cancer survival for 10 major cancers in NSW, Australia have changed over time, after account for the impact of demographics and tumour characteristics.

MATERIALS AND METHODS

Data were obtained from the population-based NSW Central Cancer Registry for all patients aged 15-89 years at the time of their diagnosis of a primary cancer between January 1991 and December 2008. Notification of cancer diagnosis to the registry is a statutory requirement in NSW. We included ten cancers with high incidence and large contribution to mortality (see Table 1), defined by International Classification of Diseases for Oncology 3rd Edition codes (10).

Cases were followed up for survival status up to the 31 December 2008 through record linkage of the cancer cases in the Cancer Registry with death records from the NSW Register of Births, Deaths and Marriages and the National Death Index. Cases notified to the registry by death certificate only or first identified at post-mortem were excluded.

To maintain comparability with the previously mentioned study by Yu and colleagues (6), we used an area-based socioeconomic measure, the “Index of Education and Occupation” score. This is a composite index of relative advantage, based on data from the national Australian census (11). An area with a high index score indicates a relatively high level of educational attainment and skilled employment of the resident population. For each analysis period, socioeconomic quintiles were

created by ranking all the Local Government Areas (LGA) in NSW by their index score from the 2001 census, and dividing them into five groups of approximately equal population. The included cases were then classified into these SES quintiles based on the LGA of their residential address at diagnosis. In 2001 there were 175 LGAs in NSW, ranging from small urban areas with large populations to extremely large rural areas with small populations, each with an average population of 35,954 residents (IQR: 4,713 – 43,809) [ABS Online data 2001]. Cases were excluded from analysis if they had insufficient information to assign an LGA or if index scores were not available.

Disease stage at diagnosis was based on pathology reports and statutory notifications by hospitals, then coded using a modified summary classification: localised (stage I), regional (a combination of stages II and III), distant (stage IV) and unknown (including missing) stage.

Statistical Analysis

Relative survival, the ratio of the observed proportion surviving in a group of cancer patients to the expected proportion that would have survived in an age- and sex-comparable group of people from the general population (12), was used in this analysis because we used all-cause mortality from a population-based cancer registry. Survival time for each case was calculated from the month of diagnosis to the month of death or censoring (31 December 2008) using life-table methods (13). Relative survival was calculated using the Pohar-Perme method to estimate net survival (14). We constructed SES-specific life tables for each year 1996-2000 and 2004-2008 by collapsing all-cause mortality data and corresponding population data by LGA into the SES quintiles used for classifying cancer cases. The period method (15) was used as in the previous study (6). For each of these two ‘at risk’ periods (1996-2000 and 2004-2008), we calculated 5-year relative survival by SES quintile for 10 individual cancers. We chose the two ‘at risk’ periods for analysis to allow a reasonable “lead in time” from the start of the diagnostic cohort (1991) and to enable sufficient time for changes in survival disparity to occur.

We investigated the effect of SES on survival for each cancer using multivariate modelling to adjust for potentially confounding variables. Firstly, we calculated the relative excess risk (RER) of death due to cancer using a Poisson-regression model (16). In this model, the main-effect variables were SES quintile, age group at diagnosis (<50 years, 50-59 years, 60-69 years, 70-79 years, 80-89 years), sex, year of follow-up (1-5 years) and cancer stage at diagnosis. We included the natural logarithm of the population size as the offset (log person-year at risk) and a special link function to take account of background mortality. The RER derived from this model is the ratio of the excess risk of death in a given SES quintile to the reference SES group (the least disadvantaged quintile) after controlling for the other factors included in the model. Ninety-five percent confidence intervals (CIs) for the RERs were calculated using the estimated coefficients and standard errors from the

Poisson model. Secondly, we added an interaction term between SES quintile and time period to the model, to allow the effect of SES to change between periods and then used a likelihood ratio test between the nested models to determine if this interaction was significant.

Finally, an estimate of the number of lives potentially extendable to 5 years from cancer diagnosis was calculated for the four more disadvantaged SES quintiles for each period 1996-2000 and 2004-2008. This was done in three steps. First, for each of the four more disadvantaged quintiles, we calculated the difference between the number of stage-adjusted deaths within each specific cancer cohort and that of the age-sex equivalent group in the general population of the same quintile (i.e. cancer mortality minus background mortality) (17). This is the observed number of excess deaths. Second, we calculated the number of deaths that would have occurred if the stage-adjusted RER of cancer death for these four quintiles equalled that of the least disadvantaged quintile at five years from diagnosis (6). This is the optimum number of excess deaths. Finally, the number of potentially extendable lives is the difference between the observed number of excess deaths and the optimum number of excess deaths (observed minus optimum excess deaths). This measure, similar to that used in the EUROCARE-4 study (18), among others (19, 20), has been used in different health settings and is exchangeable with “avoidable deaths” and the “number potentially saved” within a set time period since diagnosis. A Pearson chi-square test was then used to determine if the two proportions of “extendable” lives were significantly different over time.

All significance tests with p-value <0.05 were taken to indicate statistical significance. Statistical analyses were completed using STATA software, v13.1 (StataCorp LP: College Station, TX).

RESULTS

A total of 380,306 cases diagnosed between 1991 and 2008 that were prevalent cases between periods of 1996-2000 and 2004-2008 were identified. About 0.7% (2 663 cases) were excluded from analysis due to being notified to the registry by death certificate only or first identified at post-mortem, while a further 150 cases were excluded due to missing SES data. In total, 139,234 cases at-risk in 1996-2000 and 238,259 cases at-risk in 2004-2008 were included in the final cohort (Appendix B: supplementary table 1). The numbers of cases included in the analysis increased over time and were relatively evenly distributed across the socioeconomic quintiles in both periods. Liver, breast, ovarian and prostate cancers saw higher case numbers in the less disadvantaged SES groups, whereas the opposite trend occurred for lung cancer.

Table 1: Five-year relative survival (%) by socioeconomic disadvantage for 10 cancers in NSW, Australia, 1996-2000 and 2004-2008

Cancer	Five-year relative survival (%)									
	1996-2000					2004-2008				
	Least	Second	Third	Fourth	Most	Least	Second	Third	Fourth	Most
Stomach (C16)	33.4	24.6	27.6	24.9	25.2	35.2	31.6	28.1	31.0	26.1
Colorectum (C18-21)	63.5	60.8	60.9	59.6	60.2	68.7	66.0	66.1	64.6	64.7
Liver (C22)	22.7	16.3	10.6	13.4	11.5	22.6	18.4	14.7	19.8	17.1
Lung (C33-34)	16.2	16.4	14.5	15.0	14.5	18.1	17.2	16.3	17.0	14.2
Melanoma (C43)	91.0	91.1	92.2	88.8	90.2	92.1	90.9	90.3	89.2	90.4
Breast (C50)	87.8	85.7	83.9	83.9	83.2	92.6	88.5	87.9	88.4	89.2
Cervix (C53)	71.7	72.9	74.3	69.0	73.2	76.2	72.0	75.5	73.4	60.9
Uterus (C54-55)	81.4	80.5	79.0	80.0	79.2	84.8	77.2	74.5	79.1	83.1
Ovary (C56-57)	44.4	41.6	38.5	38.9	38.2	44.5	44.5	44.7	39.4	41.0
Prostate (C61)	85.9	84.0	84.5	83.4	81.8	94.4	93.6	91.0	94.5	90.6

Relative survival increased over time for the majority of cancers, as shown in Table 1. However, the socioeconomic disparities observed in the first period (1996-2000) remain broadly similar in the late period (2004-2008).

Figure 1 shows the results of the multivariable modelling: RERs by SES quintile (with the reference group being the least disadvantaged quintile). Values of these RER estimates and p-value of significance tests are presented in Table 2. During 1996-2000, the RER of death was significantly higher for more disadvantaged patients with stomach, colorectal, liver, lung, breast and prostate cancers. No significant variation in RER was found for melanoma, ovarian, cervix or uterine cancers. By the period of 2004-2008, significant RER's continued to exist for, stomach, colorectal, liver, lung, breast, prostate cancers, while RER variations in cervical and uterine cancers became highly significant ($p=0.008$ and 0.001 respectively). Melanoma and ovarian cancer again showed no significant variation in RER of death by SES in 2004-2008.

Figure 1: Relative excess risk of death by socioeconomic status for 10 cancers in NSW, Australia, 2004-2008, by LGA and CD

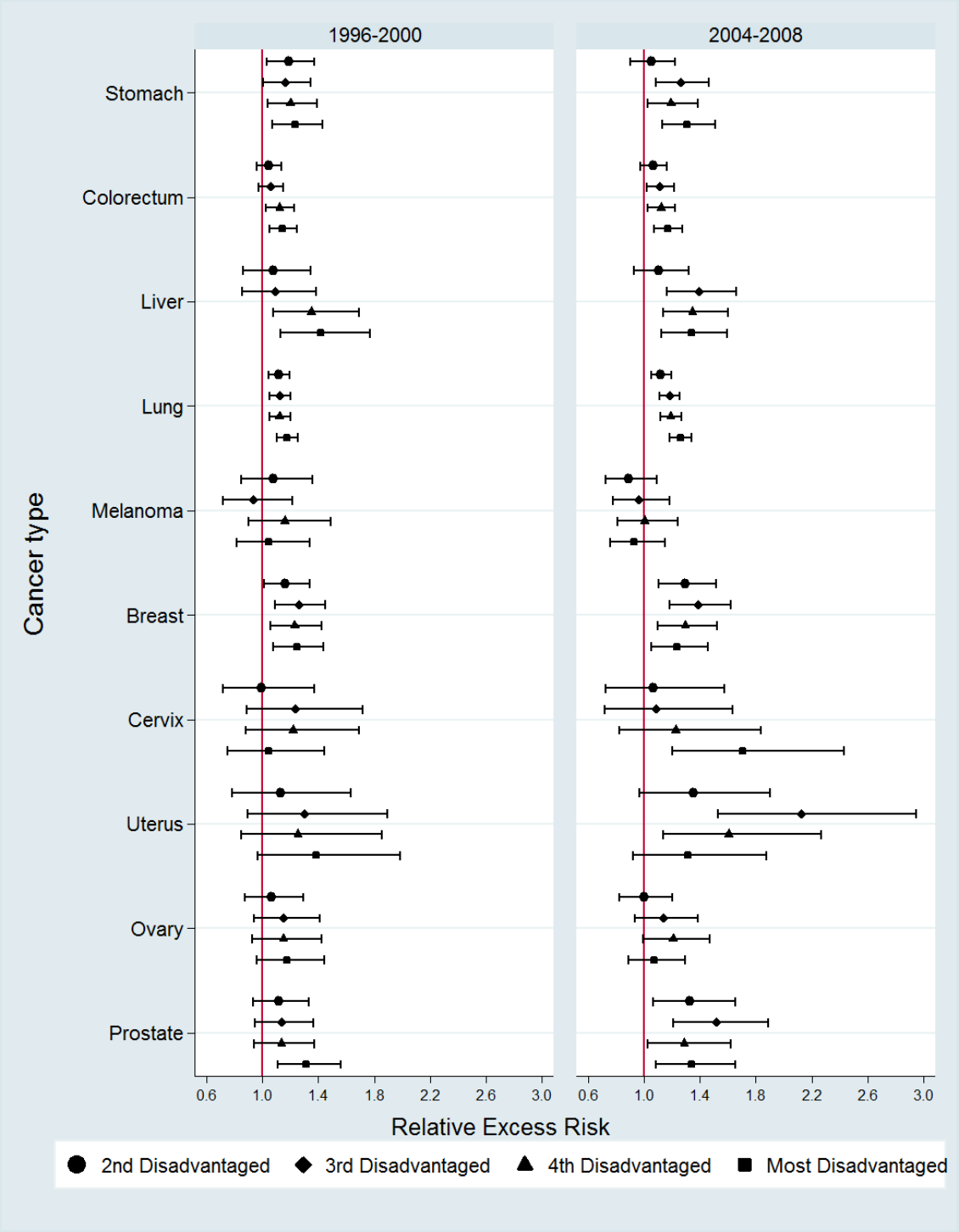


Table 2: Relative excess risk of death by socioeconomic disadvantage for 10 cancers in NSW, Australia, 1996-2000 and 2004-2008

Cancer type	Relative excess risk of death* and (95% confidence interval)												
	1996-2000						2004-2008						*p*-value[¥]
	Least	2nd	3rd	4th	Most	*p*-value[§]	Least	2nd	3rd	4th	Most	*p*-value[§]	
Stomach	1.00	1.19 (1.03, 1.37)	1.16 (1.00, 1.34)	1.20 (1.04, 1.39)	1.24 (1.07, 1.43)	*0.04*	1.00	1.05 (0.91, 1.22)	1.26 (1.08, 1.46)	1.19 (1.02, 1.39)	1.31 (1.13, 1.51)	*0.001*	*0.40*
Colorectum	1.00	1.05 (0.96, 1.14)	1.06 (0.97, 1.15)	1.12 (1.03, 1.23)	1.15 (1.05, 1.25)	*0.01*	1.00	1.06 (0.98, 1.16)	1.11 (1.02, 1.22)	1.12 (1.03, 1.23)	1.17 (1.07, 1.27)	*0.005*	*0.93*
Liver	1.00	1.08 (0.86, 1.34)	1.09 (0.86, 1.39)	1.35 (1.08, 1.69)	1.42 (1.13, 1.77)	*0.008*	1.00	1.11 (0.93, 1.32)	1.39 (1.16, 1.66)	1.35 (1.13, 1.60)	1.34 (1.13, 1.60)	*0.0003*	*0.44*
Lung	1.00	1.12 (1.05, 1.19)	1.12 (1.05, 1.20)	1.12 (1.05, 1.20)	1.17 (1.10, 1.25)	*<0.0001*	1.00	1.12 (1.05, 1.19)	1.18 (1.11, 1.26)	1.19 (1.12, 1.27)	1.26 (1.19, 1.34)	*<0.0001*	*0.55*
Melanoma	1.00	1.08 (0.85, 1.36)	0.93 (0.72, 1.21)	1.16 (0.90, 1.49)	1.05 (0.82, 1.34)	*0.53*	1.00	0.89 (0.72, 1.09)	0.96 (0.78, 1.18)	1.00 (0.81, 1.24)	0.93 (0.76, 1.15)	*0.77*	*0.74*
Breast	1.00	1.16 (1.01, 1.34)	1.26 (1.09, 1.45)	1.23 (1.06, 1.43)	1.25 (1.08, 1.44)	*0.009*	1.00	1.30 (1.11, 1.51)	1.38 (1.18, 1.62)	1.29 (1.10, 1.52)	1.24 (1.05, 1.46)	*0.001*	*0.74*
Cervix	1.00	0.99 (0.72, 1.37)	1.24 (0.89, 1.72)	1.22 (0.88, 1.69)	1.04 (0.75, 1.44)	*0.52*	1.00	1.07 (0.72, 1.58)	1.09 (0.72, 1.63)	1.23 (0.82, 1.83)	1.71 (1.20, 2.43)	*0.008*	*0.11*
Uterus	1.00	1.13 (0.78, 1.63)	1.30 (0.90, 1.90)	1.25 (0.85, 1.86)	1.39 (0.97, 1.99)	*0.43*	1.00	1.35 (0.97, 1.90)	2.12 (1.53, 2.95)	1.61 (1.14, 2.27)	1.32 (0.92, 1.88)	*0.0001*	*0.21*
Ovary	1.00	1.07 (0.88, 1.29)	1.15 (0.94, 1.41)	1.15 (0.93, 1.42)	1.18 (0.96, 1.44)	*0.48*	1.00	1.00 (0.83, 1.20)	1.14 (0.93, 1.38)	1.21 (0.99, 1.47)	1.07 (0.89, 1.30)	*0.25*	*0.87*
Prostate	1.00	1.12 (0.94, 1.33)	1.14 (0.95, 1.36)	1.14 (0.94, 1.37)	1.32 (1.11, 1.56)	*0.03*	1.00	1.33 (1.07, 1.66)	1.51 (1.21, 1.89)	1.29 (1.02, 1.62)	1.34 (1.08, 1.66)	*0.008*	*0.35*

* Adjusted for age group, sex, year of follow-up and stage at diagnosis in a Poisson model
§ Wald test for the effect of SES quintiles in the Poisson model
¥ Wald test for interaction between time period and SES quintile

The total of excess deaths due to cancer in 1996-2000 was 25,420 for all 10 cancers, of which 2,690 lives (10.6% of excess deaths) were potentially extendable if the SES survival disparity did not exist (Table 3). The corresponding number for 2004-2008 increased to 26,583, of which 4,253 lives (16.0% of excess deaths) were potentially extendable. The increase in the proportion of extendable lives over time was significant (*p<0.001*) for the majority of cancers. Lung, colorectal and breast cancers respectively accounted for the greatest numbers of extendable lives in both periods.

Table 3: Number of lives that might be extended beyond 5 years from diagnosis for 10 cancers in NSW, Australia 1996-2000 and 2004-2008

	Number of lives potentially extended						
	1996-2000			2004-2008			
Cancer	Number of excess deaths	Lives potentially extended[§]	Proportion of excess deaths (%)	Number of excess deaths	Lives potentially extended[§]	Proportion of excess deaths (%)	*p-value*[†]
Stomach	1,967	316	16.1	1,895	324	17.1	*0.389*
Colorectum	6,069	443	7.3	6,189	606	9.8	*<0.001*
Liver	739	137	18.6	1,312	312	23.8	*0.006*
Lung	9,729	1,090	11.2	11,002	1,779	16.2	*<0.001*
Melanoma	941	0*	0	1,213	0*	0	
Breast	2,188	393	17.9	1,855	472	25.5	*<0.001*
Cervix	388	0*	0	318	92	28.9	*<0.001*
Uterus	356	0*	0	474	256	54.0	*<0.001*
Ovary	970	0*	0	1,051	0*	0	
Prostate	2,073	311	15.0	1,275	411	32.3	*<0.001*
All of the above	25,420	2,690	10.6	26,583	4,253	16.0	*<0.001*

* RER coefficients are not significant in the relative survival model for specified cancer
§ Estimated by equating the RER of death due to cancer in the four more disadvantaged quintiles to that of the least disadvantaged quintile and calculating the difference in the number of cancer deaths
† Pearson chi-square test of the difference between proportions of excess deaths over time (two periods)

DISCUSSION AND CONCLUSIONS

We found that while survival for 10 cancers has either remained stable or increased over time, patients living in more disadvantaged areas of NSW have continued to experience lower survival rates than the least disadvantaged patients for cancers of the stomach, colorectum, liver, lung, female breast and prostate, and new disparities have emerged for cervical and uterine cancer.

There are several strengths in the design and methods of this study. Our population-based data reflect the survival experience of people diagnosed with major types of cancer in NSW Australia. We used a well-established ecological study design and statistical methods, as used previously and recommended for measuring socioeconomic inequalities in health (6, 11). In addition, we provide two measures of socioeconomic disparity, one relative (RER) and one absolute (number of lives potentially extendable). The availability and adjustment for stage of disease at diagnosis data

further strengthens our analysis, as stage is widely known to be an important predictor for cancer survival (21, 22).

A limitation of our study comes from the use of aggregated area-level data to classify patients according to SES. Individual level socioeconomic data for cancer patients was not available for this study. However, recent studies using individual-level socioeconomic data detected comparable trends in cancer survival disparities (20, 23), suggesting a similar impact of individual and area-based measures of SES on cancer survival. Area-level methods for measuring health disparities have been validated previously and were shown to appropriately detect trends in survival inequalities (24). In addition, the index used in this study has been extensively reviewed and validated using nine different methods (11) and has been widely used as a socioeconomic measure in numerous studies of different health outcomes in Australia (6, 25, 26).

Previous research has shown that the definition of the socioeconomic index generally has little impact on the survival disparities detected (27). Under Australia's universal healthcare system, access to health care is (theoretically) independent of a patient's financial resources. As such, compared to the index used here, other income-based or economic-disadvantage indicators of SES may be less relevant to identifying disparities in this context.

Our results of increased survival from cancer overall and continuing socioeconomic disparities in survival are consistent with both current Australian and international evidence. Persistent survival disparities by SES have been found for stomach (28), colorectal (29), liver (30), lung (1), breast (1, 21, 31), cervical (1, 29), uterine (29) and prostate (29, 31) cancers. The reasons for the socioeconomic survival disparities are not thoroughly understood, and evidence on contributing factors is both limited and often inconclusive. Some factors thought to contribute to survival disparities by SES relate to differences in diagnosis and treatment factors, patient characteristics and health care system features (2).

Previous studies of ovarian cancer survival have also found no association with SES (6, 32). The non-specific nature of symptoms and lack of a definitive screening-diagnostic test could explain this finding, as the majority of diagnoses in all socioeconomic groups in NSW in both periods occurred at an unknown or already advanced stage (Supplementary Table 2), by which point effective treatment options are limited (33). Despite Australia having the highest incidence of melanoma worldwide (5) we found no significant variation in survival by SES in NSW, which is consistent with previous findings (34). This finding is likely associated with the time–delayed effects of long running and effective skin cancer awareness campaigns in Australia, which have developed a strong culture of protective behaviours (35, 36). Patient ethnicity has been associated with both melanoma incidence and survival internationally (37, 38) though this data is not recorded by the

registry and so any potential confounding of survival rates by ethnicity could not be controlled for in our analysis. Australian evidence of this association is both limited and inconclusive (39). Data on anatomic location of melanomas was not included in this study, but previous Australian studies reported that melanomas most commonly occurred on the trunk and limbs, areas which have relatively higher survival rates (40), and that anatomic location of melanomas did not vary significantly by SES (34, 41).

We found significant differences in the distribution of stage at diagnosis between SES groups, with low SES patients more often presenting at more advanced or unknown stage for several cancers (online supplementary table S2) as reported previously (42). This is consistent with evidence of lower screening participation among more disadvantaged groups in Australia (43) and internationally (44). However this stage differential by SES is unlikely to explain the survival differential observed in this study, because adjusting for spread of cancer did not greatly alter our estimates. While some misclassification of recorded stage information by the Registry has been reported (45, 46), our findings suggest that increasing early diagnosis of cancers is less important than improving non-diagnostic factors, such as patient lifestyle and treatment factors, in reducing survival disparities in NSW. Notable exceptions to this were cervical and prostate cancers, which both had significant survival differentials over time prior to stage adjustment that became insignificant after adjustment. Consequently, socioeconomic variation in rates of early diagnosis may be a possible contributor to disparities in cervical and prostate cancer survival.

Patient lifestyle factors may impact on cancer survival by affecting overall health. Australian and international reports have shown that lower socioeconomic groups had significantly higher occurrences of poor lifestyle behaviours (47, 48). Some lifestyle factors such as smoking (48) and comorbidities (49) have been shown to directly impact on the benefits of cancer treatment. However, a recent population-based study in the US found that socioeconomic disparities in breast cancer survival continued after controlling for several comorbid conditions (50), suggesting that variations in comorbidity cannot fully explain survival disparities. While we did not specifically adjust for patient comorbid conditions in our study, we did use SES-specific life tables for relative survival calculations to reduce the effect on mortality from different levels of competing causes of death across the population.

Variation in cancer management by SES may also contribute to disparities in survival, as patients of lower SES are more likely to receive sub-optimal or non-guideline therapy (21, 28). Reduced compliance with recommended treatment regimes in low SES patients may also contribute to lower survival rates (51). Australia's universal healthcare system should provide consistent access to cancer treatments to all socioeconomic groups. However, it has been suggested that poorer survival in patients from lower socioeconomic areas in Australia is affected more by health system

features, such as unequal access to specialist treatment centres across NSW (52). We did not have access to information on treatment or patient management in this study, so we were unable to investigate these suggestions further.

The number of lives that might be extended beyond 5 years from diagnosis has been used previously to highlight the importance of socioeconomic survival disparities and demonstrate the potential public health benefits of improving cancer services (6, 17, 20, 53). Estimating the number of these “avoidable deaths” (or lives “potentially saved”) can assist health authorities in allocating cancer services and resources to areas of greatest need, and increase attention on the need to further explore causes of socioeconomic variation in survival (17). The increased number of reported avoidable deaths over time reflects both the higher incidence and improved cancer survival in NSW. The observed increases in the percentage of total excess deaths that are avoidable emphasises the trend of persistent cancer survival disparities between socioeconomic groups in NSW. These results indicate that the greatest benefit would be derived from reducing survival disparities for lung cancer patients, and that focused health and social policies should be implemented to address these disparities, as suggested previously (6). Additional benefit would also be achieved by reducing disparities in colorectal cancer survival.

In conclusion, we have reported that survival disparities by area-level SES have persisted over time for several cancers in NSW after adjusting for stage at diagnosis. While the causes of these socioeconomic disparities in survival are not thoroughly understood, variations in treatment, patient characteristics and health system factors may contribute. Despite increased awareness of SES disparities in cancer survival, and overall increases in cancer survival, this study suggests that recent health and social policies in NSW have not been effective in reducing socioeconomic inequalities in survival.

REFERENCES

1. 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):4160-7.
2. Woods LM, Rachet B, Coleman MP. Origins of socio-economic inequalities in cancer survival: a review. Ann Oncol. 2006;17(1):5-19.
3. Dalton SO, Schuz J, Engholm G, Johansen C, Kjaer SK, Steding-Jessen M, et al. Social inequality in incidence of and survival from cancer in a population-based study in Denmark, 1994-2003: Summary of findings. Eur J Cancer. 2008;44(14):2074-85.
4. Ito Y, Nakaya T, Nakayama T, Miyashiro I, Ioka A, Tsukuma H, et al. Socioeconomic inequalities in cancer survival: a population-based study of adult patients diagnosed in Osaka, Japan, during the period 1993-2004. Acta Oncol. 2014;53(10):1423-33.
5. AIHW. Cancer survival and prevalence in Australia: period estimates from 1982 to 2010. Asia Pac J Clin Oncol. 2013;9(1):29-39.
6. 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):1383-90.
7. Jeffreys M, Rachet B, McDowell S, Habib AG, Lepage C, Coleman MP. Survival from rectal and anal cancers in England and Wales, 1986-2001. Eur J Cancer. 2006;42(10):1434-40.
8. Lyratzopoulos G, Barbiere JM, Rachet B, Baum M, Thompson MR, Coleman MP. Changes over time in socioeconomic inequalities in breast and rectal cancer survival in England and Wales during a 32-year period (1973-2004): the potential role of health care. Ann Oncol. 2011;22(7):1661-6.
9. Shack LG, Rachet B, Brewster DH, Coleman MP. Socioeconomic inequalities in cancer survival in Scotland 1986-2000. Br J Cancer. 2007;97(7):999-1004.
10. Fritz A, Percy C, Jack A, Shanmugaratnam K, Sobin L, Parkin DM, et al. International Classification of Diseases for Oncology 3rd Edition (ICD-O-3). Geneva: World Health Organization; 2000.
11. Trewin D. Socio-Economic Indexes for Areas (SEIFA) - Technical Paper 2001. Canberra: Australian Bureau of Statistics, 2003.
12. Berkson J, Gage RP. Calculation of survival rates for cancer. Proc Staff Meet Mayo Clin. 1950;25(11):270-86.
13. Chiang C. Introduction to stochastic processes in biostatistics. New York: Wiley; 1968.
14. Pohar-Perme M, Stare J, Estève J. On estimation in relative survival. Biometrics. 2012;68(1):113-20.
15. Brenner H, Gefeller O. An alternative approach to monitoring cancer patient survival. Cancer. 1996;78(9):2004-10.
16. Dickman PW, Sloggett A, Hills M, Hakulinen T. Regression models for relative survival. Stat Med. 2004;23(1):51-64.
17. Yu XQ, O'Connell DL, Gibberd RW, Smith DP, Dickman PW, Armstrong BK. Estimating regional variation in cancer survival: a tool for improving cancer care. Cancer Causes Control. 2004;15(6):611-8.
18. Berrino F, De Angelis R, Sant M, Rosso S, Bielska-Lasota M, Coebergh JW, et al. Survival for eight major cancers and all cancers combined for European adults diagnosed in 1995-99: results of the EUROCARE-4 study. Lancet Oncol. 2007;8(9):773-83.
19. Ellis L, Coleman MP, Rachet B. How many deaths would be avoidable if socioeconomic inequalities in cancer survival in England were eliminated? A national population-based study, 1996-2006. Eur J Cancer. 2012;48(2):270-8.
20. Pokhrel A, Martikainen P, Pukkala E, Rautalahti M, Seppa K, Hakulinen T. Education, survival and avoidable deaths in cancer patients in Finland. Br J Cancer. 2010;103(7):1109-14.
21. Yu XQ. Socioeconomic disparities in breast cancer survival: relation to stage at diagnosis, treatment and race. BMC Cancer. 2009;9:364.
22. Yu XQ, O'Connell DL, Gibberd RW, Coates AS, Armstrong BK. Trends in survival and excess risk of death after diagnosis of cancer in 1980-1996 in New South Wales, Australia. Int J Cancer. 2006;119(4):894-900.

23. Chang CM, Su YC, Lai NS, Huang KY, Chien SH, Chang YH, et al. The combined effect of individual and neighborhood socioeconomic status on cancer survival rates. PLoS ONE. 2012;7(8):e44325.
24. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Choosing area based socioeconomic measures to monitor social inequalities in low birth weight and childhood lead poisoning: The Public Health Disparities Geocoding Project (US). J Epidemiol Community Health. 2003;57(3):186-99.
25. Brennan SL, Henry MJ, Wluka AE, Nicholson GC, Kotowicz MA, Williams JW, et al. BMD in population-based adult women is associated with socioeconomic status. J Bone Miner Res. 2009;24(5):809-15.
26. Page A, Morrell S, Taylor R. Suicide differentials in Australian males and females by various measures of socio-economic status, 1994-98. Aust N Z J Public Health. 2002;26(4):318-24.
27. Woods LM, Rachet B, Coleman MP. Choice of geographic unit influences socioeconomic inequalities in breast cancer survival. Br J Cancer. 2005;92(7):1279-82.
28. Siemerink EJ, Hospers GA, Mulder NH, Siesling S, van der Aa MA. Disparities in survival of stomach cancer among different socioeconomic groups in North-East Netherlands. Cancer Epidemiol. 2011;35(5):413-6.
29. Aarts MJ, Lemmens VE, Louwman MW, Kunst AE, Coebergh JW. Socioeconomic status and changing inequalities in colorectal cancer? A review of the associations with risk, treatment and outcome. Eur J Cancer. 2010;46(15):2681-95.
30. Jembere N, Campitelli MA, Sherman M, Feld JJ, Lou WD, Peacock S, 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).
31. Aarts MJ, Kamphuis CB, Louwman MJ, Coebergh JW, Mackenbach JP, van Lenthe FJ. Educational inequalities in cancer survival: a role for comorbidities and health behaviours? J Epidemiol Community Health. 2013;67(4):365-73.
32. Schrijvers CT, Mackenbach JP, Lutz JM, Quinn MJ, Coleman MP. Deprivation, stage at diagnosis and cancer survival. Int J Cancer. 1995;63(3):324-9.
33. AIHW, NBOCC. Ovarian cancer in Australia: an overview. Cancer series no. 52. Cat. no. CAN 48. Canberra: AIHW, 2010.
34. Downing A, Yu XQ, Newton-Bishop J, Forman D. Trends in prognostic factors and survival from cutaneous melanoma in Yorkshire, UK and New South Wales, Australia between 1993 and 2003. Int J Cancer. 2008;123(4):861-6.
35. Gillespie HS, Watson T, Emery JD, Lee AJ, Murchie P. A questionnaire to measure melanoma risk, knowledge and protective behaviour: assessing content validity in a convenience sample of Scots and Australians. BMC Med Res Methodol. 2011;11:123.
36. Hill D, White V, Marks R, Borland R. Changes in sun-related attitudes and behaviours, and reduced sunburn prevalence in a population at high risk of melanoma. Eur J Cancer Prev. 1993;2(6):447-56.
37. Agbai ON, Buster K, Sanchez M, Hernandez C, Kundu RV, Chiu M, et al. Skin cancer and photoprotection in people of color: a review and recommendations for physicians and the public. J Am Acad Dermatol. 2014;70(4):748-62.
38. Raimondi S, Sera F, Gandini S, Iodice S, Caini S, Maisonneuve P, et al. MC1R variants, melanoma and red hair color phenotype: a meta-analysis. Int J Cancer. 2008;122(12):2753-60.
39. Holman CD, Armstrong BK. Pigmentary traits, ethnic origin, benign nevi, and family history as risk factors for cutaneous malignant melanoma. J Natl Cancer Inst. 1984;72(2):257-66.
40. Green AC, Baade P, Coory M, Aitken JF, Smithers M. Population-based 20-year survival among people diagnosed with thin melanomas in Queensland, Australia. Journal of clinical oncology : official journal of the American Society of Clinical Oncology. 2012;30(13):1462-7.
41. Buettner PG, MacLennan R. Geographical variation of incidence of cutaneous melanoma in Queensland. The Australian journal of rural health. 2008;16(5):269-77.
42. Luke C, Nguyen AM, Priest K, Roder D. Female breast cancers are getting smaller, but socio-demographic differences remain. Aust N Z J Public Health. 2004;28(4):312-6.
43. Ananda SS, McLaughlin SJ, Chen F, Hayes IP, Hunter AA, Skinner IJ, et al. Initial impact of Australia's National Bowel Cancer Screening Program. Med J Aust. 2009;191(7):378-81.

44. Banks E, Beral V, Cameron R, Hogg A, Langley N, Barnes I, et al. Comparison of various characteristics of women who do and do not attend for breast cancer screening. Breast Cancer Res. 2002;4(1):R1.
45. Luo Q, Yu XQ, Cooke-Yarborough C, Smith DP, O'Connell DL. Characteristics of cases with unknown stage prostate cancer in a population-based cancer registry. Cancer Epidemiol. 2013;37(6):813-9.
46. Yu XQ, O'Connell DL, Gibberd RW, Abrahamowicz M, Armstrong BK. Misclassification of colorectal cancer stage and area variation in survival. Int J Cancer. 2008;122(2):398-402.
47. AIHW. Australia's health 2014. Australia's health series no. 14. Cat. no. AUS 178. Canberra: AIHW, 2014.
48. Browman GP, Wong G, Hodson I, Sathya J, Russell R, McAlpine L, et al. Influence of cigarette smoking on the efficacy of radiation therapy in head and neck cancer. N Engl J Med. 1993;328(3):159-63.
49. Smith BD, Gross CP, Smith GL, Galusha DH, Bekelman JE, Haffty BG. Effectiveness of radiation therapy for older women with early breast cancer. J Natl Cancer Inst. 2006;98(10):681-90.
50. Tannenbaum SL, Koru-Sengul T, Miao F, Byrne MM. Disparities in survival after female breast cancer diagnosis: a population-based study. Cancer Causes Control. 2013;24(9):1705-15.
51. Land SR, Cronin WM, Wickerham DL, Costantino JP, Christian NJ, Klein WM, et al. Cigarette smoking, obesity, physical activity, and alcohol use as predictors of chemoprevention adherence in the National Surgical Adjuvant Breast and Bowel Project P-1 Breast Cancer Prevention Trial. Cancer Prev Res (Phila). 2011;4(9):1393-400.
52. Roder D, Zorbas HM, Kollias J, Pyke CM, Walters D, Campbell ID, et al. Analysing risk factors for poorer breast cancer outcomes in residents of lower socioeconomic areas of Australia. Aust Health Rev. 2014;38(2):134-41.
53. Yu XQ, Luo Q, Smith DP, O'Connell DL, Baade PD. Geographic variation in prostate cancer survival in New South Wales. Med J Aust. 2014;200(10):586-90.

CHAPTER 4: MEASURING SOCIOECONOMIC DISPARITIES IN CANCERS SURVIVAL USING DIFFERENT GEORAPHIC AREA UNITS (*Cancer Epidemiology* 2015)

ABOUT THIS CHAPTER

This chapter is our submitted manuscript "Impact of geographic area level on measuring socioeconomic disparities in cancer survival in New South Wales, Australia" (Cancer Epidemiology, 2015). The authors of this manuscript are Julia F Stanbury, Peter D Baade, Yan Yu and Xue Qin Yu. This paper presents our comparison of two different area-units, LGA and CD, for measuring socioeconomic disparities in cancer survival detected in NSW and investigates the extent of misclassification by SES that may occur between these two area units, to determine which unit is the better alternative for measuring socioeconomic survival disparities.

ABSTRACT

BACKGROUND: Area-based socioeconomic measures are widely used in health research. In theory, the larger the area used the more individual misclassification is introduced, thus biasing the association between such area level measures and health outcomes. In this study, we examined the socioeconomic disparities in cancer survival using two geographic area-based measures to see if the size of the area matters.

METHODS: We used population-based cancer registry data for 239,513 patients prevalent with one of 10 major cancers in New South Wales (NSW), Australia during 2004-2008. Patients were assigned index measures of socioeconomic status (SES) based on two area-level units, census Collection District (CD) and Local Government Area (LGA) of their address at diagnosis. Five-year relative survival was estimated for each socioeconomic quintile at each area-level for each cancer. Poisson-regression modelling was used to adjust for socioeconomic quintile, sex, age-group at diagnosis and disease stage at diagnosis. The relative excess risk of death (RER) by socioeconomic quintile derived from this modelling was compared between area-units.

RESULTS: We found extensive disagreement in SES classification between CD and LGA levels across all socioeconomic quintiles, particularly for more disadvantaged groups. In general, more disadvantaged patients had significantly lower survival than the least disadvantaged group for both CD and LGA classifications. The socioeconomic survival disparities detected by CD classification were larger than those detected by LGA. Adjusted RER estimates by SES were similar for most cancers when measured at both area levels.

CONCLUSIONS: With data confidentiality concerns increasing with the level of geographical precision, the observed relatively small and inconsistent impact of misclassification of LGAs on cancer survival disparities suggest they remain a valuable spatial unit for use in Australian health and social research. Greater availability of small-area level health and census data will allow for further methodological advances in epidemiological studies of SES and health-related outcomes.

INTRODUCTION

Many published studies which report socioeconomic disparities in cancer survival use area-based measures of socioeconomic status (SES) (1, 2). Individual-level demographic data is preferable and most accurate, but often very difficult to obtain in population-based studies. Instead, these "ecological" studies use census-derived area-based measures of SES to classify patients based on characteristics of the aggregate population of the area in which they live. Misclassification of individuals may result depending on the extent of variation within the population of a specific area (3). Small spatial areas are known to represent more socioeconomically homogeneous populations compared to larger areas, primarily due to their smaller resident population and so their socioeconomic index values are more likely to accurately represent the characteristics of that population (4, 5).

We previously reported socioeconomic disparities in cancer survival in New South Wales (NSW), Australia using Local Government Areas (LGA) to classify cases by SES (*Submitted paper BMC Cancer 2015*). LGAs are a valuable and widely used spatial unit in Australian health and social research, since data are readily available at this level. Compared to other spatial units in Australia, LGAs are considered to be 'relatively' small. However the use of LGAs in ecological studies has been criticised due to the inherent population heterogeneity within each LGA introducing potential misclassification of individuals (6). It is unknown to what extent this misclassification may occur and what impact it may have on research results. Similar misclassification effects have been observed in previous studies where area-based geographic units have been used (3, 5). Consequently, the true disparities in cancer survival in NSW may vary from those previously reported.

Cancer incidence data from the NSW Central Cancer Registry has recently become available at the smaller area unit of census Collection District (CD), the smallest area unit for which a measure of SES is available (7). Comparing analyses of LGA and CD geocoded data will be able to more accurately detect and identify the extent to which cancer cases may be misclassified according to SES when investigating cancer survival disparities.

To date, few studies have used population-based data to compare cancer survival disparities between area level measures (4, 5, 8). This study aims to compare the area units of CD and LGA to quantify the extent to which cancer patients could be misclassified by SES between these two area-levels and the impact of such misclassification on estimating socioeconomic disparity in cancer survival, with specific reference to cancer survival data in NSW in 2004-2008.

MATERIALS AND METHODS

Data were obtained from the population-based NSW Central Cancer Registry for all patients aged 15-89 at diagnosis of a first primary cancer between January 1999 and December 2008 that were prevalent cases between 2004 and 2008. Notification of a cancer diagnosis to the Registry is mandatory in NSW since 1972. We chose ten cancers for analysis as defined by International Classification of Diseases for Oncology 3rd Edition (9) codes (see Table 2). These cancers were chosen based on their high incidence and large contribution to population mortality. Cases were linked to records from the NSW State Registry of Births, Deaths and Marriages and the National Death Index and followed up to 31 December 2008 for survival status. Cases were excluded if notified to the registry by death certificate only or first identified at post-mortem.

LGAs in NSW range from small urban areas with large populations to extremely large rural areas with small populations. In 2001 there were 175 LGAs in NSW, each with an average population of 35,954 (IQR: 4,713-43,809) [Australian Bureau of Statistics (ABS) online data 2001]. Comparatively, CDs were the smallest area units used by the ABS at the time of the study period (2004-2008) (10), and represent a more socioeconomically homogenous population than LGAs (7). In 2001, NSW contained 11,510 CDs, each containing about 200 'dwellings' or an average population of 547 residents (IQR: 369-696) [ABS data 2001].

Patient SES was measured using the 2001 ABS Index of Education and Occupation score of the residential address at diagnosis collected by the Registry. A high index score indicates an area with a relatively high level of educational attainment and skilled employment in the population (10). This index allows us to maintain comparability with previous studies of SES and cancer survival in NSW (11). Two versions of this SES measure were used – the first, using aggregated socioeconomic quintiles created by ranking all the CDs in NSW by their index score and then dividing them into 5 groups of approximately equal population; the second, using quintiles created by LGAs aggregated in the same manner. Cases were excluded from analysis if they had insufficient information to assign a CD or LGA or if index scores were not available.

Stage of disease at diagnosis was based on pathology reports and statutory notifications by hospitals, coded using a modified summary classification: localised (stage I), regional (a combination of stages II and III), distant (stage IV) and unknown stage.

Statistical Analysis

Relative survival was used in this study, which is the ratio of the observed proportion of people surviving 5 years in a group of cancer patients, to the expected proportion of people who would

have survived in a comparable group (same age and sex distribution); in this case the general population. Observed survival time for each case was calculated from the month of diagnosis to the month of death or censoring (31 December 2008) using life-table methods. Relative survival was calculated using the Pohar-Perme method to estimate net survival(12). We constructed LGA level SES-specific life tables for each year 2004-2008 using LGA level all-cause mortality data and the corresponding population data divided into the SES quintiles used for classifying cancer cases. *These LGA level life tables were used in both the LGA and CD level analyses,* as data of all-cause mortality and general population at CD level were not available.

We used the same analysis strategy for both CD and LGA classification and then compared the two sets of results. Five-year relative survival by SES quintile for each cancer was calculated using the period method, to provide a more recent estimate of patient survival (13). We then investigated the effect of SES on survival time for each cancer using multivariate models to adjust for potentially confounding variables. We used a Poisson-regression model to calculate the relative excess risk (RER) of death due to cancer, after controlling for the other factors included in the model (14). The RER is the ratio of excess risk of death in a particular SES quintile compared to that of the reference (least disadvantaged) SES group, after controlling for the other factors. In this model, the main-effect variables were SES quintile, age group at diagnosis (<50 years, 50-59 years, 60-69 years, 70-79 years, 80-89 years), sex, stage of disease at diagnosis and year of follow-up (1-5 years), with the natural logarithm of the population size as the offset (log person-year at risk) and a special link function to take account of background mortality. The estimated coefficients and standard errors from the Poisson model were used to calculate ninety-five per-cent confidence intervals (CIs) for the RERs.

All significance tests with *p*-value <*0.05* were taken to indicate statistical significance. All statistical analysis was completed using STATA v13.1 software (StataCorp LP: College Station, TX).

RESULTS

A total of 239 513 cases diagnosed with one of the ten cancers between 1999 and 2008 that were prevalent in 2004-2008 were identified from the Registry. 944 Cases (0.4%) were excluded from analysis due to registry notification by death certificate only or first identified post-mortem. A further 1,879 cases were excluded due to missing socioeconomic data. The final cohort used for analyses contained 236 690 cases.

Table 1 shows the cross-tabulation of SES quintile by the two area levels. Assuming the smaller CD-specific area classification is more accurate (3-5), extensive misclassification in LGA-based SES can be seen across all quintiles, particularly for the 3rd and 4th CD-specific quintiles. Overall

agreement between the two SES level classifications was 47.3%. The highest agreement occurred in the least disadvantaged quintile (quintile 1), where 75.8% of cases were assigned to the same SES quintile using CDs and LGAs. Agreement by SES was lowest in SES quintile 3, with only 31.1% of patients correctly classified by both area-levels.

Table 1: Cross-tabulation of SES quintiles classified by LGA and CD, in NSW, Australia, 2004-2008

Variance in SES assignment between LGA and CD classifications							
Number		**SES by CD**					
Percentage (%)		Least	Second	Third	Fourth	Most	Total
SES by LGA	Least	37,458	10,104	1,190	304	348	49,404
		75.8	20.5	2.4	0.6	0.7	100(20.9)
	Second	9,635	23,203	10,540	4,935	2,731	51,044
		18.9	45.5	20.6	9.7	5.4	100(21.6)
	Third	1,813	9,847	14,495	11,189	9,259	46,603
		3.9	21.1	31.1	24.0	19.9	100(19.7)
	Fourth	278	4,281	10,350	14,084	12,682	41,675
		0.7	10.3	24.8	33.8	30.4	100(17.6)
	Most	24	1,913	7,735	14,058	24,234	47,964
		0.05	4.0	16.1	29.3	50.5	100(20.3)
	Total	49,208	49,348	44,310	44,570	49,254	236,690
		20.8	20.8	18.7	18.8	20.8	100(100)

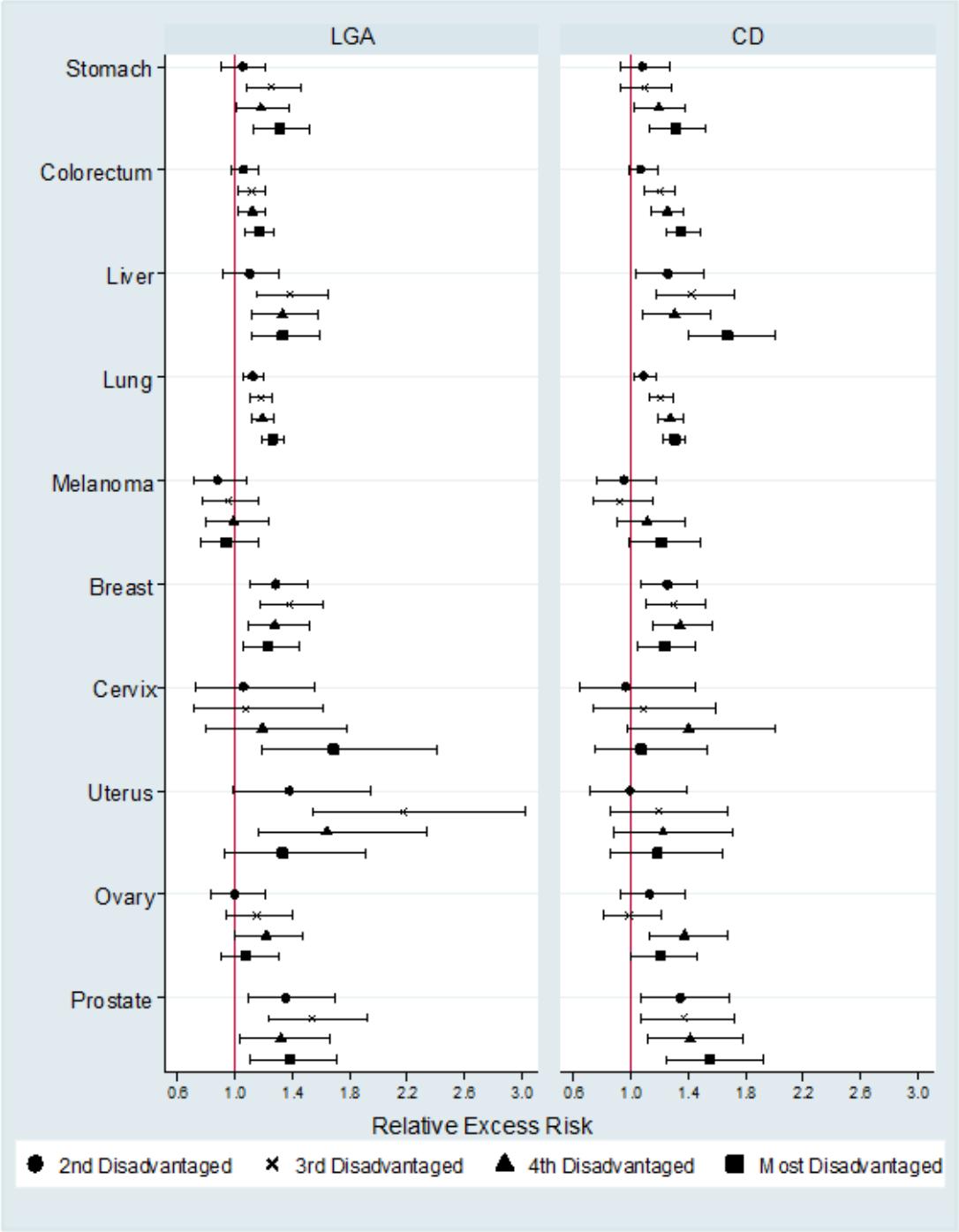
Relative survival rates by SES, classified by CD and LGA, for the 10 cancers are shown in Table 2. More disadvantaged patients with stomach, colorectal, liver, lung, breast and prostate cancers had significantly lower survival than the least disadvantaged group, for both CD and LGA classifications. In general, the survival disparities by CD classification (as measured by the range of quintile-specific values) were greater than those detected by LGA classification, the bias introduced here being towards the null hypothesis. Stomach, cervical and uterine cancers were notable exceptions, for which larger survival disparities were measured at the LGA level.

Table 2: Relative survival by socioeconomic status for 10 cancers in NSW, Australia, 2004-2008, by LGA and CD

Cancer	Five-year relative survival (%)									
	LGA					CD				
	Least	Second	Third	Fourth	Most	Least	Second	Third	Fourth	Most
Stomach (C16)	35.0	31.5	28.1	31.0	25.8	35.4	30.1	29.6	29.8	27.4
Colorectum (C18-21)	68.7	66.0	66.0	64.6	64.7	70.5	68.5	65.1	65.2	61.7
Liver (C22)	22.3	18.4	14.7	19.9	17.0	26.1	17.5	16.1	19.6	14.8
Lung (C33-34)	18.1	17.3	16.3	17.0	14.3	19.3	18.4	16.4	15.9	14.4
Melanoma (C43)	92.2	91.0	90.3	89.1	90.4	93.2	91.1	91.2	89.1	88.3
Breast (C50)	92.5	88.6	87.9	88.4	89.2	92.5	89.2	88.5	88.0	88.5
Cervix (C53)	75.8	72.0	75.5	73.7	60.7	73.2	75.8	72.1	64.1	70.9
Uterus (C54-55)	85.1	77.2	74.5	78.9	83.3	82.5	81.7	77.9	76.6	80.0
Ovary (C56-57)	44.5	44.6	44.7	39.5	40.9	47.0	43.8	45.8	36.7	41.4
Prostate (C61)	94.5	93.7	91.0	94.4	90.6	95.0	95.2	93.3	91.9	88.3

Figure 1 further shows the variation in RER for each cancer, depicted as the RER for the four more disadvantaged quintiles compared to the least disadvantaged, including 95% confidence intervals. More variation in the RER appears for colorectal, liver and lung cancers by CD classification compared to LGA, whereas less variation is evident for uterine cancer by CD. The two sets of RERs for other cancers are fairly similar.

Figure 1: Relative excess risk of death by socioeconomic status for 10 cancers in NSW, Australia, 2004-2008, by LGA and CD



The RER of death from the each cancer by SES for each area level classification is presented in Supplementary Table 1For most cancers, the RER disparities measured at CD level were strongly significant, only becoming less so when measured by LGA (see Appendix C: supplementary table 1 for *p*-values). The RER of death of disadvantaged patients with melanoma and ovarian cancers however was significant in the CD analysis, but became insignificant in the LGA analysis. The opposite was observed for cervical and uterine cancers, where the RER of more disadvantaged patients was significant in the LGA analysis but not when measured by CD.

DISCUSSION AND CONCLUSIONS

We found that the widely used geographic unit in Australia (LGA) to classify patients by SES results in mild underestimation of the survival disparities for several cancers, compared to when SES is measured at CD level. Despite this however, the RER of death estimates derived from these survival estimates were similar in both the CD and LGA level analyses. The extremes of the SES quintiles were found to have higher agreement between the two area measures than intermediate groups, most likely because they have only one direction of potential misclassification.

This study is unique in Australia, and provides important new knowledge relevant to measuring variations in health outcomes using area-level data. Our results contribute to growing international evidence supporting the preferred use of the smallest (feasible) area units available in ecological studies measuring health outcomes, which consistently provide results more indicative of individual level effects (3-5, 8, 15-18). A logical explanation for the socioeconomic misclassification observed here is that, since the population of each CD is smaller than that of an LGA, it is more homogenous in terms of socioeconomic characteristics and thus more representative of the resident population of that area compared to LGAs (7). Appreciating the impact of geographic scale on area level health research is crucial, as it allows researchers to select the most appropriate area-level data and provides a basis for evaluating the study results (8).

Several studies have reported SES misclassification issues when investigating health related outcomes. Studies that compare large and small area-units to classify patient SES have shown similar patterns to those we report here, including studies that further compare misclassification between small area-unit and individual level classifications (3-5, 8). In Australia, assigning SES based on residential postcodes compared to CDs was found to underestimate the association between SES and several health-related outcomes (3). In England, socioeconomic disparities in breast cancer survival based on census enumeration districts were significantly larger than those based on electoral wards, which contain an average population of approximately ten times that of an enumeration districts (4). Similarly in the US, census block groups and tracts have been shown to detect similar socioeconomic disparities in cancer incidence and mortality, while some analyses

at zip-code level either failed to detect disparities or detected contradictory results (5). This was also reported more recently for prostate cancer mortality, where socioeconomic disparities at census tract and block group levels were shown to be similar to each other and both more indicative of individual level trends (8). These studies indicate that our results, though reporting only mild differences, most likely represent the true effect of socioeconomic misclassification between different geographic area-units.

The design and methodology of our study affords it many strengths. We used population-based data such that the survival experience of all patients with these major cancers in NSW is represented. The 10 major cancers included have significant public health importance in NSW in terms of both morbidity and mortality for analysis. Our study is based on a well-established statistical methods and ecological design, as recommended and used previously for measuring socioeconomic health disparities (11, 19). We used the period method of calculating patient survival to provide the most up-to-date survival rates using the latest mortality-linked data available to us (13, 20). Including adjustment for stage of disease further strengthens our analysis, since cancer stage is known to be a strong predictor of survival (21, 22). We were unable to specifically adjust for patient comorbidity in this analysis, but by using SES-specific life tables we reduced the impact of disparities in competing causes of death in the population on our relative survival calculations.

In addition, the index of area-level SES used here has been widely used in Australia in numerous studies of health outcomes and socioeconomic status (11, 23, 24) and is extensively reviewed and validated (10). The definition of the area-level socioeconomic index generally has minimal impact on survival disparities detected (4), though economic-related indicators have been shown to be most robust in detecting disparities in the US (5). Australia's universal healthcare system (theoretically) ensures equal access to health care, so indicators based on financial-disadvantage or income may be less appropriate for identifying disparities in this context.

A limitation of our study lies in our use of aggregated area-level data which even at CD level, the smallest area-unit available to us, would still carry some residual socioeconomic misclassification effects compared to individual SES measurements. Previous research has found small but residual socioeconomic misclassification between individual and small area-level analyses (3-5, 8, 25). Without access to individual socioeconomic data to compare with our CD-level analysis, we cannot quantify the extent of this remaining misclassification. Such questions are unlikely to be answered using routine administrative data collections, such as population-based cancer registries, that are not designed for detailed individual level data collections. Rather, this is an area for further research using large, population based cohorts providing data from both an area- and individual-level perspective. Further to this, the SES homogeneity of quintiles used in this study could

potentially be questioned, considering the large population each quintile represents being similar to that of a large geographic area-unit. The counter argument to this point is that, since the initial socioeconomic classification of cases was done using smaller, more accurate area-level data (either by CD or LGA), the original classification remains valid and is thus more accurate than if classification was done using an area with a population similar to that of the final aggregated quintiles.

Our analysis did not take into account correlations between geographic areas, the “nesting” of CDs within LGAs, or the impact of adjacent geographical areas. Evidence from previous studies suggests that accounting for geographic nesting would not have greatly altered our results or the socioeconomic gradients we observed (26-28). Accounting for any spatial dependence between neighbouring areas is an area of increasing research interest, and recent work in Australia has investigated the impact of spatial scales on measuring the risk of advanced breast cancer within a Bayesian framework (29). Further work incorporating both the hierarchical structure and special dependence between areas may unearth additional insights into the role of SES on cancer survival outcomes. We have also not examined any impact of using the alternative Statistical Local Area (SLA) geographic level, which also includes multiple CDs. The SLA unit has been used extensively in other Australian studies on geographical variation in cancer outcomes (30, 31). However, while some SLAs are smaller than LGAs in size, the vast majority of SLAs in NSW equated in area (and thus population) to a whole LGA in 2001 (7). Thus comparing survival disparities by these two area units would likely have produced inconclusive results.

Accurate mortality data for the NSW general population was unavailable to us at CD level. At this small area-level, a significant proportion of death counts for individual CDs were very low and thus randomised for privacy reasons. Instead we used the LGA level SES-specific population life tables to calculate relative survival for both the LGA and CD-level analyses. As a result, the accuracy of our relative survival estimates at CD level is likely to be slightly diminished and this may have impacted on our ability to detect a significant difference between the CD-and LGA-specific RER estimates.

In this study we found significant disparities in RER for ovarian cancer and melanoma when SES was assigned at CD-level, which were not detected by LGA. Previous research has reported no associations between survival from these cancers and SES in NSW (11, 32), though these studies used LGA level SES classifications and are likely to have underestimated the disparities. International literature however has reported survival disparities by SES for these cancers, which suggests our CD level analysis to be more reflective of current trends (33, 34). Conversely, we found significant disparities in survival for cervical and uterine cancers when SES was assigned by LGA-level, which were not detected at CD-level. This is despite international evidence reporting

SES disparities in survival from these cancers, including those using small-area and individual level socioeconomic information (35-37).

Patients of low SES, when measured by either area unit, more often presented with more advanced stage in this study. Similar stage disparity by SES has been reported (38), though differential stage is an unlikely cause of the survival disparities we for adjusted stage in the modelling. Despite reports of residual misclassification of stage information recorded by the Registry (39, 40), it is more likely that our findings are due to disparities in non-diagnostic factors.

Several arguments have been raised for and against area-level studies. Area-level measures are a good “building-block” for epidemiological studies, particularly those measuring health outcomes in large populations, as access to area-level health data is generally easier and more cost-effective than obtaining individual data. The population coverage is much wider for area-based such as retired persons, those with no occupation or income data and women in home-care roles. Privacy concerns surrounding patient data and anonymity are also addressed by using area-level data. Area-level studies allow large quantities of health information to be analysed, producing more reliable and generalisable results. In epidemiology, especially in large scale studies, these advantages of area-level data often easily outweigh the cost of potential biases, such as misclassification errors. Despite the potential biases, many studies have shown that area-level studies generally provide “appropriate” estimates of socioeconomic disparities in health as detected by smaller-area units or individual data (25). The risk of using larger areas, as shown here, is a more conservative estimate of these disparities.

An additional benefit of area level studies is that they allow area-contextual effects and their impact on individual health outcomes to be considered, with recent research increasingly discussing these interactions (41-43). Whilst individual SES contributes to health outcomes (44), area level SES has also been shown to be associated with individual health regardless of individual level SES (15, 45-47). The review by Frohlich and colleagues identified the two important concepts of “space” and “place” in health inequalities research (43). Recent interventions to reduce survival inequalities have not succeeded as they have not adequately addressed the role of “place” (48). This may be because space, the quantifiable attributes of an area, is more easily investigated as a potential reason for area-level health inequalities than place, being the often complex qualitative relationships and attitudes within a community. Greater success in reducing these inequalities may be achieved through future studies which focus on both space and place, and their impacts on health behaviours.

Area-level health data, at any area scale, will continue to be used in health research as valuable resource to guide policy, education and planning efforts when more accurate individual level

information is unavailable. Appreciating the impact of geographic scale on area level health research is crucial, as it allows researchers to select the most appropriate area-level data and provides a basis for evaluating the study results. Future access to small-area level health data in NSW will allow for technical improvements in epidemiological studies of SES and health-related outcomes. Our findings suggest that while there is misclassification of area-level SES when using the larger LGA area compared to CD areas, the impact of this misclassification on survival disparities in NSW is relatively small and in no consistent direction across cancer types. As such, our results suggest LGAs remain a valuable spatial unit for Australian health and social research and are appropriate for detecting area-level socioeconomic disparities in cancer survival.

REFERENCES

1. Kogevinas M, Porta M. Socioeconomic differences in cancer survival: a review of the evidence. IARC Scientific Publications. 1997(138):177-206.
2. Woods LM, Rachet B, Coleman MP. Origins of socio-economic inequalities in cancer survival: a review. Annals of Oncology. 2006;17(1):5-19.
3. Hyndman JC, Holman CSD, Hockey RL, Donovan RJ, Corti B, Rivera J. Misclassification of social disadvantage based on geographical areas: comparison of postcode and collector's district analyses. Int J Epidemiol. 1995;24:165-76.
4. Woods LM, Rachet B, Coleman MP. Choice of geographic unit influences socioeconomic inequalities in breast cancer survival. British Journal of Cancer. 2005;92(7):1279-82.
5. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: the Public Health Disparities Geocoding Project. American Journal of Epidemiology. 2002;156(5):471-82.
6. McCracken K. Into a SEIFA SES cul-de-sac? Australian & New Zealand Journal of Public Health. 2001;25(4):305-6.
7. Edwards RW. Statistical Geography Volume 1: Australian Standard Geographical Classification (ASGC) (Cat. No. 1216.0). Canberra: Australian Bureau of Statistics (ABS), 2001.
8. Wan N, Zhan FB, Cai Z. Socioeconomic disparities in prostate cancer mortality and the impact of geographic scale. Southern Medical Journal. 2011;104(8):553-9.
9. Fritz A, Percy C, Jack A, Shanmugaratnam K, Sobin L, Parkin DM, et al. International Classification of Diseases for Oncology 3rd Edition (ICD-O-3). Geneva: World Health Organization; 2000.
10. Trewin D. Technical Paper: Census of Population and Housing - Socio-Economic Indexes for Areas (SEIFA), Australia, 2001. Canberra: Australian Bureau of Statistics, 2003.
11. 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):1383-90.
12. Pohar-Perme M, Stare J, Estève J. On estimation in relative survival. Biometrics. 2012;68(1):113-20.
13. Brenner H, Soderman B, Hakulinen T. Use of period analysis for providing more up-to-date estimates of long-term survival rates: empirical evaluation among 370,000 cancer patients in Finland. International Journal of Epidemiology. 2002;31(2):456-62.
14. Dickman PW, Sloggett A, Hills M, Hakulinen T. Regression models for relative survival. Statistics in Medicine. 2004;23(1):51-64.
15. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/Ethnicity, Gender, and Monitoring Socioeconomic Gradients in Health: A Comparison of Area-Based Socioeconomic Measures—The Public Health Disparities Geocoding Project. American Journal of Public Health. 2003;93(10):1655-71.
16. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Choosing area based socioeconomic measures to monitor social inequalities in low birth weight and childhood lead poisoning: The Public Health Disparities Geocoding Project (US). Journal of Epidemiology & Community Health. 2003;57(3):186-99.
17. Tian N, Goovaerts P, Zhan FB, Wilson JG. Identification of racial disparities in breast cancer mortality: does scale matter? International Journal of Health Geographics [Electronic Resource]. 2010;9:35.
18. Weisent J, Rohrbach B, Dunn JR, Odoi A. Detection of high risk campylobacteriosis clusters at three geographic levels. Geospatial Health. 2011;6(1):65-76.
19. Berkson J, Gage RP. Calculation of survival rates for cancer. Proceedings of the Staff Meetings of the Mayo Clinic. 1950;25(11):270-86.
20. Brenner H, Gefeller O, Hakulinen T. Period analysis for 'up-to-date' cancer survival data: theory, empirical evaluation, computational realisation and applications. European Journal of Cancer. 2004;40(3):326-35.
21. Yu XQ. Socioeconomic disparities in breast cancer survival: relation to stage at diagnosis, treatment and race. BMC Cancer. 2009;9:364.

22. Yu XQ, O'Connell DL, Gibberd RW, Coates AS, Armstrong BK. Trends in survival and excess risk of death after diagnosis of cancer in 1980-1996 in New South Wales, Australia. International Journal of Cancer. 2006;119(4):894-900.
23. Brennan SL, Henry MJ, Wluka AE, Nicholson GC, Kotowicz MA, Williams JW, et al. BMD in population-based adult women is associated with socioeconomic status. J Bone Miner Res. 2009;24(5):809-15.
24. Page A, Morrell S, Taylor R. Suicide differentials in Australian males and females by various measures of socio-economic status, 1994-98. Aust N Z J Public Health. 2002;26(4):318-24.
25. Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Comparing individual- and area-based socioeconomic measures for the surveillance of health disparities: A multilevel analysis of Massachusetts births, 1989-1991. American Journal of Epidemiology. 2006;164(9):823-34.
26. Soobader MJ, LeClere FB. Aggregation and the measurement of income inequality: effects on morbidity. Social Science & Medicine.48(6):733-44.
27. Subramanian S, Duncan C, Jones K. Multilevel perspectives on modeling census data. Environment and Planning A. 2001;33(3):399-418.
28. Duncan C, Jones K, Moon G. Context, composition and heterogeneity: using multilevel models in health research. Social Science & Medicine. 1998;46(1):97-117.
29. Kang SY, McGree J, Baade P, Mengersen K. An investigation of the impact of various geographical scales for the specification of spatial dependence. Journal of Applied Statistics. 2014;41(11):2515-38.
30. Baade PD, Dasgupta P, Aitken JF, Turrell G. Geographic remoteness, area-level socioeconomic disadvantage and inequalities in colorectal cancer survival in Queensland: a multilevel analysis. BMC Cancer. 2013;13:493.
31. Dasgupta P, Cramb SM, Aitken JF, Turrell G, Baade PD. Comparing multilevel and Bayesian spatial random effects survival models to assess geographical inequalities in colorectal cancer survival: a case study. International Journal of Health Geographics [Electronic Resource]. 2014;13:36.
32. Downing A, Yu XQ, Newton-Bishop J, Forman D. Trends in prognostic factors and survival from cutaneous melanoma in Yorkshire, UK and New South Wales, Australia between 1993 and 2003. International Journal of Cancer. 2008;123(4):861-6.
33. Braaten T, Weiderpass E, Lund E. Socioeconomic differences in cancer survival: the Norwegian Women and Cancer Study. BMC Public Health. 2009;9:178.
34. Reyes-Ortiz CA, Goodwin JS, Freeman JL. The effect of socioeconomic factors on incidence, stage at diagnosis and survival of cutaneous melanoma. Medical Science Monitor. 2005;11(5):RA163-RA72.
35. Ueda K, Kawachi I, Tsukuma H. Cervical and corpus cancer survival disparities by socioeconomic status in a metropolitan area of Japan. Cancer Science. 2006;97(4):283-91.
36. Elstad JI, Torstensrud R, Lyngstad TH, Kravdal O. Trends in educational inequalities in mortality, seven types of cancers, Norway 1971-2002. European Journal of Public Health. 2012;22(6):771-6.
37. 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):4160-7.
38. Luke C, Nguyen AM, Priest K, Roder D. Female breast cancers are getting smaller, but socio-demographic differences remain. Australian & New Zealand Journal of Public Health. 2004;28(4):312-6.
39. Yu XQ, O'Connell DL, Gibberd RW, Abrahamowicz M, Armstrong BK. Misclassification of colorectal cancer stage and area variation in survival. International Journal of Cancer. 2008;122(2):398-402.
40. Luo Q, Yu XQ, Cooke-Yarborough C, Smith DP, O'Connell DL. Characteristics of cases with unknown stage prostate cancer in a population-based cancer registry. Cancer Epidemiology. 2013;37(6):813-9.
41. Diez-Roux AV, Kiefe CI, Jacobs DR, Jr., Haan M, Jackson SA, Nieto FJ, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. Annals of Epidemiology. 2001;11(6):395-405.

42. Shareck M, Kestens Y, Frohlich KL. Moving beyond the residential neighborhood to explore social inequalities in exposure to area-level disadvantage: Results from the Interdisciplinary Study on Inequalities in Smoking. Social Science & Medicine. 2014;108:106-14.
43. Frohlich KL, Corin E, Potvin L. A theoretical proposal for the relationship between context and disease. Sociology of Health & Illness. 2001;23(6):776-97.
44. Southern DA, McLaren L, Hawe P, Knudtson ML, Ghali WA, Investigators A. Individual-level and neighborhood-level income measures: agreement and association with outcomes in a cardiac disease cohort. Medical Care. 2005;43(11):1116-22.
45. Robert SA, Strombom I, Trentham-Dietz A, Hampton JM, McElroy JA, Newcomb PA, et al. Socioeconomic risk factors for breast cancer: distinguishing individual- and community-level effects. Epidemiology. 2004;15(4):442-50.
46. Chang CM, Su YC, Lai NS, Huang KY, Chien SH, Chang YH, et al. The combined effect of individual and neighborhood socioeconomic status on cancer survival rates. PLoS ONE [Electronic Resource]. 2012;7(8):e44325.
47. Reijneveld SA, Verheij RA, de Bakker DH. The impact of area deprivation on differences in health: does the choice of the geographical classification matter? Journal of Epidemiology & Community Health. 2000;54(4):306-13.
48. King D, Miranda P, Gor B, Fuchs-Young R, Chilton J, Hajek R, et al. Addressing cancer health disparities using a global biopsychosocial approach. Cancer. 2010;116(2):264-9.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

ABOUT THIS CHAPTER

This chapter presents an in-depth discussion of the research conducted and conclusions drawn from this thesis. Firstly, I summarise the main findings of the thesis and examine the strengths and limitations of the research conducted. I then discuss some potential directions for future research on cancer survival disparities, and how this may improve our understanding of survival disparities. Finally, I examine the need for ongoing monitoring of cancer survival inequalities, and bring all the findings from previous chapters together to discuss what the thesis contributes overall to new knowledge about monitoring socioeconomic inequalities in cancer survival.

SUMMARY OF FINDINGS

The papers included in this thesis have demonstrated that overall cancer survival has improved in NSW since 1996, but inequalities in survival by socioeconomic status persisted over the past decade for many cancers, despite improvements in diagnosis and treatment. Whilst misclassification of socioeconomic status may occur depending on the area-level unit used to classify patients, LGA units in NSW provide a valuable and informative measure of SES for analysing cancer survival disparities and tracking temporal trends in disparities.

As detailed in Chapter 3, the analysis of temporal trends in socioeconomic inequalities in cancer survival in NSW presents the relative survival rate and relative excess risk of death by socioeconomic status after a diagnosis of one of ten major cancers in NSW. This paper also estimates the number of additional cancer patients who could have survived to 5 years if the excess risk of death of the least disadvantaged quintile was applied to the lower four quintiles, providing an absolute measure of socioeconomic survival disparities as the number of patient lives that were “potentially extendable” to five years from diagnosis. This measure identified cancers that could achieve the greatest potential benefit from targeted health and social interventions aimed at reducing socioeconomic survival disparities. This study found that survival inequalities by area-level SES have persisted over time for many cancers in NSW, suggesting that current health strategies focussed on reducing these disparities are either not adequate or that additional factors contributing to survival disparities have not been properly identified and addressed by appropriate health strategies.

In Chapter 4, I compared the estimates of relative survival and excess risk of death when SES was classified at area-level using two area-units of different size and populations, CD and LGA, to quantify the extent to which cancer patients could be misclassified by SES between these two

area-levels, with specific reference to cancer survival data in NSW in 2004-2008. Using LGA to classify patients by SES generally resulted in slight underestimation of the relative survival compared to when SES was measured at CD level, and similar RERs were detected at both area-levels. As such, these findings suggest that LGAs are suitable for detecting appropriate trends in socioeconomic disparities in cancer survival, however attenuated, and remain a useful and valuable area-unit for health and social research in NSW. However, the misclassification effects found here require the use of LGAs and interpretation of results in future to be considered carefully with this point in mind.

STRENGTHS AND LIMITATIONS

This thesis used population-based data, with large case numbers and a long follow-up period. The data included 10 major cancer types of significant public health importance in NSW in terms of both morbidity and mortality. This data ensures the results reflect the everyday effectiveness of cancer treatments and patient management in NSW, such that the survival experience of all cancer patients in NSW is represented.

The methods of analyses used in this thesis have many strengths. Firstly, the analyses are based on a well-established statistical method and ecological study design, as recommended and used previously for measuring socioeconomic health inequalities (1, 2). The period method for calculating relative survival was employed, which includes long patient follow-up to provide the most up-to-date survival estimates (3, 4). Secondly, including adjustment for stage of disease further strengthens the analyses by accounting for lead-time bias, considering for example, the impact screening may have on the observed survival time in calculations for cancers amenable to screening detection (5). Adjustment for stage over time in chapter 3 also accounts for length bias, by limiting the distortion of relative survival estimates that may result from stage migration over time (5). Thirdly, the socioeconomic measure “Index of Education and Occupation” has been widely used in numerous studies of health outcomes and socioeconomic status in Australia (1, 6, 7) and is extensively reviewed and validated (8). Finally, the results in chapter 3 both presents two measures of socioeconomic disparity, one relative (RER) and one absolute (number of lives potentially extendable). These measures highlight the importance of socioeconomic survival disparities and demonstrates the potential public health benefits of improving cancer services (1, 9-11), whilst assisting health authorities in allocating cancer care resources to areas of greatest need.

Despite these strengths, some limitations of the data and methods use in this thesis remain. The primary limitation of the data is it’s aggregated area-unit nature, which would still carry some misclassification effects compared to individual SES measurements (12-16). The impact of patient

comorbidity on cancer survival estimates was not directly accounted for in the analyses as information on comorbid conditions are not collected by the Registry. Similarly, information on patient treatment regimes is also not collected, thus it was not possible to account for the impact of socioeconomic differences in either treatment or comorbidity on survival in this thesis. Instead, SES-group specific life tables were used to remove the effect on mortality from competing causes of death and, indirectly, the unequal distribution of comorbidity in the population. Misclassification of stage information by the Registry has been reported (17), therefore it is possible that the analyses did not fully control for cancer stage.

We constructed SES-specific life tables for each year 2004-2008 using all-cause mortality data and the corresponding population data by LGA into the SES quintiles used for classifying cancer cases, as data of all-cause mortality and general population at CD level were not available. As a result, the accuracy of our relative survival estimates at CD level is likely to be slightly diminished and this may have impacted on our ability to detect a significant difference between the CD-and LGA-specific RER estimates. Additionally, the analyses in Chapter 4 of this thesis did not take into account correlations between different geographic area-units – the "nesting" of CDs within LGAs – or the impact of adjacent geographical areas, though doing so would not have greatly altered the socioeconomic gradients observed (18-20).

FUTURE RESEARCH DIRECTIONS

There are several ways in which research monitoring socioeconomic inequalities in cancer survival could be improved in future to more accurately inform attempts to reduce the survival disparities. These include: conducting large population-based cohort studies of cancer survival which use both individual and area-level data; Availability of small area-level population mortality data; Application of varying statistical methods to similar studies to accounting for issues of area-unit adjacency and spatial dependence; and increased examination of the impact of area-contextual effects on health and their links with cancer survival inequalities.

Without access to individual socioeconomic data to compare with area-level analyses, we cannot quantify the extent of this remaining misclassification and the possible associations with cancer survival working at each level. Future studies including data on patient comorbidities, tumour characteristics, treatment and compliance with therapy are needed to clarify the extent to which clinical and patient factors may impact on survival inequalities. This is an area for future research using large, population based cohort studies that offer both area- and individual-level data socioeconomic data for comparison.

Misclassification of stage information recorded by the Registry has been reported previously (17, 21), More accurate recording of stage data by the registry, as well as tumour size and histology information, would benefit the understanding of both improvements in survival over time and the progression of survival disparities over time, by ensuring the effects of stage at diagnosis and tumour characteristics are accurately accounted for in analyses.

Privacy concerns surrounding patient data and anonymity precluded access to NSW population mortality data at an area-level smaller than LGA for analysis in Chapter 4. Future access to small-area level health data in NSW will allow for technical improvements in epidemiological studies of SES and health-related outcomes.

Accounting for spatial dependence between neighbouring areas and "nesting" effects is an area of increasing research interest, and recent work in Australia has investigated the impact of spatial scales on measuring the risk of advanced breast cancer within a Bayesian framework (22). Further work incorporating both the hierarchical structure and spatial dependence between areas may provide additional insights into the impact of SES on cancer survival.

Due to the ecological study design of the analyses in this thesis, it cannot be concluded from this research that an individual person's SES is directly associated with lower cancer survival in NSW. The larger area-level socioeconomic measures are likely to be less reflective of the characteristics of individual patients living within an areas, rather more reflective of the characteristics of the community in each area as a whole. Hence, the characteristics of the community within area-units may potentially be the basis for socioeconomic inequalities in cancer survival. Increasingly, recent literature has focused on the correlation between these area contextual effects and individual health outcomes (23-25). Whilst individual SES contributes to health outcomes (26), area level SES has also been shown to be associated with individual health regardless of individual level SES (27-30). These few studies that have compared the impact of individual and area-level SES on cancer survival report that individual and area-level SES are both independently related to cancer survival, but also interact. The concepts of "space", the measurable attributes of an area, and "place", the qualitative relationships and attitudes within a local community, were identified by Frohlich and colleagues in a review of research on health inequalities (25). They concluded from this review that there has been limited success in reducing survival inequalities because the role of space has been more easily and thoroughly addressed than the multi-layered role of Place, as a potential reason for area-level health inequalities. Future studies of cancer survival inequalities which focus on both the quantifiable "space" characteristics and more qualitative community-based "place" characteristics, such as differential access to specialised healthcare, and their impacts on health behaviours may yield greater success in highlighting reasons for, and ultimately reducing, socioeconomic inequalities in cancer survival.

CONCLUSIONS

This thesis emphasizes the importance of assessing progress toward eliminating cancer survival inequalities for two reasons. Firstly, monitoring these disparities assists the overall monitoring of improvements in cancer survival and is essential for identifying those groups more vulnerable to a poorer cancer prognosis. Secondly, monitoring survival disparities is important as it provides the opportunity to examine the impacts of the many proposed causes of socioeconomic inequalities in cancer survival.

The findings of this thesis have important implications for predicting and planning for the future needs of cancer care services in NSW, thus informing health and social policies aiming to reduce the socioeconomic inequalities in cancer survival in NSW. This thesis also contributes to the field of epidemiology by improving our understanding of the impact of using area-based measures of differing geographical precision when investigating socioeconomic inequalities in health outcomes. These findings add to growing international evidence supporting the preferred use of the smallest (feasible) area units available in ecological studies measuring health outcomes.

The analysis in Chapter 3 shows that while recent health and social policies have accompanied an increase in cancer survival overall in NSW, they have not been associated with a reduction in socioeconomic inequalities. Survival has increased over time for most individual cancers, but significant socioeconomic disparities persisted over the study period for stomach, colorectal, liver, lung, breast, and prostate cancers, whilst disparities in cervical and uterine cancers have emerged in recent years. More disadvantaged patients generally experienced poorer survival and large numbers of patient lives would be potentially extendable if these inequalities were reduced. Appreciating the impact of geographic scale on area level health research is crucial, as it allows researchers to select the most appropriate area-level data and provides a basis for evaluating the study results (12). The analysis in Chapter 4 found extensive disagreement in SES classification across all socioeconomic quintiles between data classified at LGA and CD area-levels, and particularly for more disadvantaged groups. Again, more disadvantaged patients experienced significantly lower survival at both LGA and CD classifications, though our analysis detected similar RERs at both area-levels. These findings suggest that LGAs detect appropriate, though attenuated, patterns in socioeconomic disparities in cancer survival, and remain a useful and valuable area-unit for health and social research in NSW.

REFERENCES

1. 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):1383-90.
2. Berkson J, Gage RP. Calculation of survival rates for cancer. Proceedings of the Staff Meetings of the Mayo Clinic. 1950;25(11):270-86.
3. Brenner H, Gefeller O, Hakulinen T. Period analysis for 'up-to-date' cancer survival data: theory, empirical evaluation, computational realisation and applications. European Journal of Cancer. 2004;40(3):326-35.
4. Brenner H, Soderman B, Hakulinen T. Use of period analysis for providing more up-to-date estimates of long-term survival rates: empirical evaluation among 370,000 cancer patients in Finland. International Journal of Epidemiology. 2002;31(2):456-62.
5. Yu XQ, O'Connell DL, Gibberd RW, Coates AS, Armstrong BK. Trends in survival and excess risk of death after diagnosis of cancer in 1980–1996 in New South Wales, Australia. Int J Cancer. 2006;119:894-900.
6. Brennan SL, Henry MJ, Wluka AE, Nicholson GC, Kotowicz MA, Williams JW, et al. BMD in population-based adult women is associated with socioeconomic status. J Bone Miner Res. 2009;24(5):809-15.
7. Page A, Morrell S, Taylor R. Suicide differentials in Australian males and females by various measures of socio-economic status, 1994-98. Aust N Z J Public Health. 2002;26(4):318-24.
8. Trewin D. Technical Paper: Census of Population and Housing - Socio-Economic Indexes for Areas (SEIFA), Australia, 2001. Canberra: Australian Bureau of Statistics, 2003.
9. Pokhrel A, Martikainen P, Pukkala E, Rautalahti M, Seppa K, Hakulinen T. Education, survival and avoidable deaths in cancer patients in Finland. Br J Cancer. 2010;103(7):1109-14.
10. Yu XQ, Luo Q, Smith DP, O'Connell DL, Baade PD. Geographic variation in prostate cancer survival in New South Wales. Med J Aust. 2014;200(10):586-90.
11. Yu XQ, O'Connell DL, Gibberd RW, Smith DP, Dickman PW, Armstrong BK. Estimating regional variation in cancer survival: a tool for improving cancer care. Cancer Causes Control. 2004;15(6):611-8.
12. Wan N, Zhan FB, Cai Z. Socioeconomic disparities in prostate cancer mortality and the impact of geographic scale. Southern Medical Journal. 2011;104(8):553-9.
13. Woods LM, Rachet B, Coleman MP. Choice of geographic unit influences socioeconomic inequalities in breast cancer survival. British Journal of Cancer. 2005;92(7):1279-82.
14. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: the Public Health Disparities Geocoding Project. American Journal of Epidemiology. 2002;156(5):471-82.
15. Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Comparing individual- and area-based socioeconomic measures for the surveillance of health disparities: A multilevel analysis of Massachusetts births, 1989-1991. American Journal of Epidemiology. 2006;164(9):823-34.
16. Hyndman JC, Holman CSD, Hockey RL, Donovan RJ, Corti B, Rivera J. Misclassification of social disadvantage based on geographical areas: comparison of postcode and collector's district analyses. Int J Epidemiol. 1995;24:165-76.
17. Yu XQ, O'Connell DL, Gibberd RW, Abrahamowicz M, Armstrong BK. Misclassification of colorectal cancer stage and area variation in survival. International Journal of Cancer. 2008;122(2):398-402.
18. Soobader MJ, LeClere FB. Aggregation and the measurement of income inequality: effects on morbidity. Social Science & Medicine.48(6):733-44.
19. Subramanian S, Duncan C, Jones K. Multilevel perspectives on modeling census data. Environment and Planning A. 2001;33(3):399-418.
20. Duncan C, Jones K, Moon G. Context, composition and heterogeneity: using multilevel models in health research. Social Science & Medicine. 1998;46(1):97-117.

21. Luo Q, Yu XQ, Cooke-Yarborough C, Smith DP, O'Connell DL. Characteristics of cases with unknown stage prostate cancer in a population-based cancer registry. Cancer Epidemiology. 2013;37(6):813-9.
22. Kang SY, McGree J, Baade P, Mengersen K. An investigation of the impact of various geographical scales for the specification of spatial dependence. Journal of Applied Statistics. 2014;41(11):2515-38.
23. Diez-Roux AV, Kiefe CI, Jacobs DR, Jr., Haan M, Jackson SA, Nieto FJ, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. Annals of Epidemiology. 2001;11(6):395-405.
24. Shareck M, Kestens Y, Frohlich KL. Moving beyond the residential neighborhood to explore social inequalities in exposure to area-level disadvantage: Results from the Interdisciplinary Study on Inequalities in Smoking. Social Science & Medicine. 2014;108:106-14.
25. Frohlich KL, Corin E, Potvin L. A theoretical proposal for the relationship between context and disease. Sociology of Health & Illness. 2001;23(6):776-97.
26. Southern DA, McLaren L, Hawe P, Knudtson ML, Ghali WA, Investigators A. Individual-level and neighborhood-level income measures: agreement and association with outcomes in a cardiac disease cohort. Medical Care. 2005;43(11):1116-22.
27. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/Ethnicity, Gender, and Monitoring Socioeconomic Gradients in Health: A Comparison of Area-Based Socioeconomic Measures—The Public Health Disparities Geocoding Project. American Journal of Public Health. 2003;93(10):1655-71.
28. Robert SA, Strombom I, Trentham-Dietz A, Hampton JM, McElroy JA, Newcomb PA, et al. Socioeconomic risk factors for breast cancer: distinguishing individual- and community-level effects. Epidemiology. 2004;15(4):442-50.
29. Chang CM, Su YC, Lai NS, Huang KY, Chien SH, Chang YH, et al. The combined effect of individual and neighborhood socioeconomic status on cancer survival rates. PLoS ONE [Electronic Resource]. 2012;7(8):e44325.
30. Reijneveld SA, Verheij RA, de Bakker DH. The impact of area deprivation on differences in health: does the choice of the geographical classification matter? Journal of Epidemiology & Community Health. 2000;54(4):306-13.

APPENDIX A: AUTHOR CONTRIBUTIONS AND STATEMENT OF CONSENT BY CO-AUTHORS

AUTHOR CONTRIBUTIONS TO PUBLICATIONS

Miss Julia F Stanbury (JFS) and Dr Xue Qin Yu (XQY) conceived the projects; Mr Yan Yu (YY) and JFS performed the data analyses, XQY provided oversight of the data analyses with inputs from A/Prof Peter D Baade (PDB); JFS drafted the manuscripts with important inputs from XQY and PDB; XQY, PDB and YY revised the manuscripts. All authors read and approved the final version of the manuscripts.

STATEMENT OF CONSENT FOR INCLUSION

I consent, as a co-author of the manuscripts titled “Cancer survival in New South Wales, Australia: Socioeconomic disparities remain despite overall improvements” and “Measuring socioeconomic disparities in cancer survival using different geographic area units” to the inclusion of these works, presented as Chapters 3 and 4 respectively, as components of the thesis by Miss Julia F Stanbury (JFS), submitted in fulfilment of the requirements for the Degree of Master of Philosophy in Public Health, to The University of Sydney.

Co-Author Name ……**MISS JULIA F STANBURY**…..……

Signed ……  …… Date ……**28/12/2015**……..

AUTHOR CONTRIBUTIONS AND STATEMENT OF CONSENT BY CO-AUTHORS

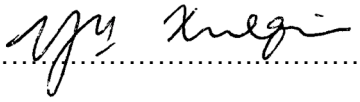
AUTHOR CONTRIBUTIONS TO PUBLICATIONS

Miss Julia F Stanbury (JFS) and Dr Xue Qin Yu (XQY) conceived the projects; Mr Yan Yu (YY) and JFS performed the data analyses, XQY provided oversight of the data analyses with inputs from A/Prof Peter D Baade (PDB); JFS drafted the manuscripts with important inputs from XQY and PDB; XQY, PDB and YY revised the manuscripts. All authors read and approved the final version of the manuscripts.

STATEMENT OF CONSENT FOR INCLUSION

I consent, as a co-author of the manuscripts titled “Cancer survival in New South Wales, Australia: Socioeconomic disparities remain despite overall improvements” and “Measuring socioeconomic disparities in cancer survival using different geographic area units” to the inclusion of these works, presented as Chapters 3 and 4 respectively, as components of the thesis by Miss Julia F Stanbury (JFS), submitted in fulfilment of the requirements for the Degree of Master of Philosophy in Public Health, to The University of Sydney.

Co-Author Name ……**DR XUE QIN YU**……

Signed ……  …….. Date ……**30/12/2015**……..

AUTHOR CONTRIBUTIONS AND STATEMENT OF CONSENT BY CO-AUTHORS

AUTHOR CONTRIBUTIONS TO PUBLICATIONS

Miss Julia F Stanbury (JFS) and Dr Xue Qin Yu (XQY) conceived the projects; Mr Yan Yu (YY) and JFS performed the data analyses, XQY provided oversight of the data analyses with inputs from A/Prof Peter D Baade (PDB); JFS drafted the manuscripts with important inputs from XQY and PDB; XQY, PDB and YY revised the manuscripts. All authors read and approved the final version of the manuscripts.

STATEMENT OF CONSENT FOR INCLUSION

I consent, as a co-author of the manuscripts titled “Cancer survival in New South Wales, Australia: Socioeconomic disparities remain despite overall improvements” and “Measuring socioeconomic disparities in cancer survival using different geographic area units” to the inclusion of these works, presented as Chapters 3 and 4 respectively, as components of the thesis by Miss Julia F Stanbury (JFS), submitted in fulfilment of the requirements for the Degree of Master of Philosophy in Public Health, to The University of Sydney.

Co-Author Name ……**A/PROF PETER D BAADE**……..……

Signed ……  …… Date ……**29/12/2015**……..

AUTHOR CONTRIBUTIONS AND STATEMENT OF CONSENT BY CO-AUTHORS

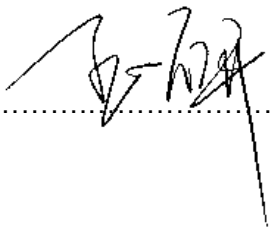
AUTHOR CONTRIBUTIONS TO PUBLICATIONS

Miss Julia F Stanbury (JFS) and Dr Xue Qin Yu (XQY) conceived the projects; Mr Yan Yu (YY) and JFS performed the data analyses, XQY provided oversight of the data analyses with inputs from A/Prof Peter D Baade (PDB); JFS drafted the manuscripts with important inputs from XQY and PDB; XQY, PDB and YY revised the manuscripts. All authors read and approved the final version of the manuscripts.

STATEMENT OF CONSENT FOR INCLUSION

I consent, as a co-author of the manuscripts titled “Cancer survival in New South Wales, Australia: Socioeconomic disparities remain despite overall improvements” and “Measuring socioeconomic disparities in cancer survival using different geographic area units” to the inclusion of these works, presented as Chapters 3 and 4 respectively, as components of the thesis by Miss Julia F Stanbury (JFS), submitted in fulfilment of the requirements for the Degree of Master of Philosophy in Public Health, to The University of Sydney.

Co-Author Name ……**MR YAN YU**……

Signed ……  …… Date ……**29/12/2015**……..

S1: Number of cancer cases and distribution by socioeconomic disadvantage in New South Wales, Australia, 1996-2000 and 2004-2008

Cancer	Number of Cases		Percentage of cases by SES disadvantage quintile, early and late periods									
			Least		Second		Third		Fourth		Most	
	1996-2000	2004-2008	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Stomach	3,912	4,711	20.8	20.2	21.6	20.4	19.9	19.7	18.4	19.0	19.3	20.6
Colorectum	28,089	44,397	21.8	20.4	22.6	21.4	19.4	19.6	16.4	17.6	19.7	21.0
Liver	1,160	2,312	25.3	22.0	21.5	20.3	15.3	16.9	19.3	20.8	18.6	20.0
Lung	15,074	18,868	18.6	17.0	20.5	19.7	20.0	20.2	19.2	20.3	21.8	22.9
Melanoma	22,293	42,347	20.3	20.2	23.4	22.5	19.8	20.4	16.4	16.8	20.1	20.1
Breast	29,869	53,657	24.5	23.9	22.1	21.7	18.7	18.7	16.5	17.1	18.3	18.6
Cervix	2,723	3,745	21.0	20.1	20.5	20.8	19.4	19.6	17.2	17.3	21.9	22.1
Uterus	3,622	6,560	22.0	21.0	22.7	21.1	19.0	19.4	17.3	18.7	19.0	19.9
Ovary	2,662	3,839	23.3	23.7	23.4	21.9	18.0	18.1	16.4	16.5	18.9	19.7
Prostate	29,830	57,823	21.7	21.0	22.1	21.5	19.8	19.8	16.4	17.4	20.0	20.3

Early period: 1996-2000. Late period: 2004-2008.

S2: Stage distribution (%) by socioeconomic status for 10 cancers in NSW, Australia, 1996-2000 and 2004-2008

Cancer		Stage distribution by SES for 10 Cancers (Row %)									
		1996-2000					2004-2008				
		Localised	Regional	Distant	Unknown	Total	Localised	Regional	Distant	Unknown	Total
Stomach		936(23.9)	1,562(39.9)	739(18.9)	675(17.3)	3,912	1,448(30.7)	1,636(34.7)	984(20.9)	643(13.6)	4,711
	Least	221(27.2)	312(38.4)	156(19.2)	124(15.3)	813	315(33.1)	308(32.4)	201(21.1)	127(13.4)	951
	Second	219(25.9)	376(44.4)	135(16.0)	116(13.7)	846	298(31.0)	341(35.4)	205(21.3)	118(12.3)	962
	Third	173(22.2)	294(37.8)	154(19.8)	157(20.2)	778	286(30.8)	323(34.8)	176(18.9)	144(15.5)	929
	Fourth	164(22.8)	284(39.4)	147(20.4)	125(17.4)	720	271(30.2)	321(35.8)	176(19.6)	129(14.4)	897
	Most	159(21.1)	296(39.2)	147(19.5)	153(20.3)	755	278(28.6)	343(35.3)	226(23.3)	125(12.9)	972
Colorectum		8,712(31.0)	13,028(46.4)	3,327(11.8)	3,022(10.8)	28,089	16,594(37.4)	18,898(42.6)	4,758(10.7)	4,147(9.3)	44,397
	Least	1,996(32.6)	2,860(46.8)	701(11.5)	559(9.1)	6,116	3,569(39.5)	3,913(43.3)	867(9.6)	690(7.6)	9,039
	Second	2,012(31.7)	2,916(45.9)	780(12.3)	648(10.2)	6,356	3,589(37.8)	4,075(43.0)	986(10.4)	835(8.8)	9,485
	Third	1,636(30.0)	2,623(48.1)	615(11.3)	577(10.6)	5,451	3,290(37.7)	3,667(42.1)	910(10.4)	852(9.8)	8,719
	Fourth	1,410(30.5)	2,159(46.7)	556(12.0)	494(10.7)	4,619	2,768(35.4)	3,306(42.3)	955(12.2)	787(10.1)	7,816
	Most	1,658(29.9)	2,470(44.5)	675(12.2)	744(13.4)	5,547	3,378(36.2)	3,937(42.2)	1,040(11.1)	983(10.5)	9,338
Liver		371(32.0)	79(6.8)	141(12.2)	569(49.1)	1,160	1,020(44.1)	175(7.6)	352(15.2)	765(33.1)	2,312
	Least	120(40.8)	24(8.2)	32(10.9)	118(40.1)	294	232(45.7)	42(8.3)	79(15.6)	155(30.5)	508
	Second	64(25.7)	20(8.0)	34(13.7)	131(52.6)	249	203(43.3)	36(7.7)	75(16.0)	155(33.0)	469
	Third	48(27.1)	12(6.8)	23(13.0)	94(53.1)	177	184(47.1)	32(8.2)	57(14.6)	118(30.2)	391
	Fourth	71(31.7)	13(5.8)	25(11.2)	115(51.3)	224	220(45.7)	29(6.0)	75(15.6)	157(32.6)	481
	Most	68(31.5)	10(4.6)	27(12.5)	111(51.4)	216	181(39.1)	36(7.8)	66(14.3)	180(38.9)	463
Lung		3,293(21.8)	3,185(21.1)	4,218(28.0)	4,378(29.0)	15,074	5,024(26.6)	3,541(18.8)	6,162(32.7)	4,141(21.9)	18,868
	Least	622(22.1)	675(24.0)	857(30.5)	655(23.3)	2,809	892(27.9)	614(19.2)	1,116(34.9)	579(18.1)	3,201
	Second	738(23.9)	701(22.7)	849(27.5)	796(25.8)	3,084	1,002(27.0)	674(18.2)	1,200(32.4)	833(22.5)	3,709
	Third	648(21.5)	549(18.2)	795(26.4)	1,020(33.9)	3,012	990(26.0)	724(19.0)	1,216(32.0)	875(23.0)	3,805
	Fourth	638(22.1)	594(20.6)	808(28.0)	850(29.4)	2,890	1,005(26.2)	719(18.7)	1,192(31.1)	920(24.0)	3,836
	Most	647(19.7)	666(20.3)	909(27.7)	1,057(32.2)	3,279	1,135(26.3)	810(18.8)	1,438(33.3)	934(21.6)	4,317

Cancer		Stage distribution by SES for 10 Cancers (Row %)									
		1996-2000					2004-2008				
		Localised	Regional	Distant	Unknown	Total	Localised	Regional	Distant	Unknown	Total
Melanoma		19,872(89.1)	849(3.8)	771(3.5)	801(3.6)	22,293	37,146(87.7)	2,137(5.0)	1,265(3.0)	1,799(4.2)	42,347
	Least	4,074(89.9)	152(3.4)	151(3.3)	155(3.4)	4,532	7,530(88.0)	411(4.8)	250(2.9)	366(4.3)	8,557
	Second	4,627(88.9)	193(3.7)	195(3.7)	191(3.7)	5,206	8,406(88.4)	460(4.8)	275(2.9)	366(3.8)	9,507
	Third	3,978(90.0)	171(3.9)	130(2.9)	142(3.2)	4,421	7,575(87.7)	432(5.0)	274(3.2)	353(4.1)	8,634
	Fourth	3,231(88.6)	149(4.1)	142(3.9)	124(3.4)	3,646	6,194(86.9)	405(5.7)	214(3.0)	315(4.4)	7,128
	Most	3,962(88.3)	184(4.1)	153(3.4)	189(4.2)	4,488	7,441(87.3)	429(5.0)	252(3.0)	399(4.7)	8,521
Breast		16,111(53.9)	9,480(31.7)	965(3.2)	3,313(11.1)	29,869	29,862(55.7)	17,813(33.2)	1,809(3.4)	4,173(7.8)	53,657
	Least	4,152(56.8)	2,183(29.9)	224(3.1)	749(10.2)	7,308	7,357(57.4)	4,167(32.5)	360(2.8)	924(7.2)	12,808
	Second	3,560(53.9)	2,146(32.5)	200(3.0)	693(10.5)	6,599	6,497(55.7)	3,954(33.9)	373(3.2)	844(7.2)	11,668
	Third	2,962(53.2)	1,822(32.7)	171(3.1)	617(11.1)	5,572	5,591(55.7)	3,338(33.3)	322(3.2)	786(7.8)	10,037
	Fourth	2,600(52.8)	1,604(32.6)	157(3.2)	561(11.4)	4,922	4,953(54.0)	3,127(34.1)	332(3.6)	759(8.3)	9,171
	Most	2,837(51.9)	1,725(31.5)	213(3.9)	693(12.7)	5,468	5,464(54.8)	3,227(32.4)	422(4.2)	860(8.6)	9,973
Cervix		1,492(54.8)	594(21.8)	112(4.1)	525(19.3)	2,723	2,128(56.8)	793(21.2)	162(4.3)	662(17.7)	3,745
	Least	306(53.6)	153(26.8)	27(4.7)	85(14.9)	571	434(57.6)	177(23.5)	26(3.5)	116(15.4)	753
	Second	296(53.0)	125(22.4)	21(3.8)	117(20.9)	559	435(55.8)	165(21.2)	39(5.0)	141(18.1)	780
	Third	289(54.7)	104(19.7)	21(4.0)	114(21.6)	528	420(57.1)	141(19.2)	27(3.7)	147(20.0)	735
	Fourth	270(57.6)	88(18.8)	24(5.1)	87(18.6)	469	376(57.9)	134(20.6)	25(3.9)	114(17.6)	649
	Most	331(55.5)	124(20.8)	19(3.2)	122(20.5)	596	463(55.9)	176(21.3)	45(5.4)	144(17.4)	828
Uterus		2,289(63.2)	578(16.0)	233(6.4)	522(14.4)	3,622	4,338(66.1)	1,101(16.8)	405(6.2)	716(10.9)	6,560
	Least	515(64.6)	138(17.3)	61(7.7)	83(10.4)	797	961(69.8)	222(16.1)	86(6.3)	107(7.8)	1,376
	Second	527(64.2)	130(15.8)	50(6.1)	114(13.9)	821	899(65.1)	234(16.9)	104(7.5)	145(10.5)	1,382
	Third	430(62.5)	116(16.9)	38(5.5)	104(15.1)	688	842(66.1)	216(17.0)	66(5.2)	149(11.7)	1,273
	Fourth	395(62.9)	101(16.1)	31(4.9)	101(16.1)	628	783(64.0)	214(17.5)	80(6.5)	147(12.0)	1,224
	Most	422(61.3)	93(13.5)	53(7.7)	120(17.4)	688	853(65.4)	215(16.5)	69(5.3)	168(12.9)	1,305

Cancer		Stage distribution by SES for 10 Cancers (Row %)									
		1996-2000					2004-2008				
		Localised	**Regional**	**Distant**	**Unknown**	**Total**	**Localised**	**Regional**	**Distant**	**Unknown**	**Total**
Ovary		571(21.5)	418(15.7)	1,329(49.9)	344(12.9)	2,662	1,053(27.4)	622(16.2)	1,749(45.6)	415(10.8)	3,839
	Least	151(24.3)	111(17.9)	291(46.9)	68(11.0)	621	276(30.3)	155(17.0)	388(42.6)	92(10.1)	911
	Second	142(22.8)	93(15.0)	309(49.7)	78(12.5)	622	239(28.5)	136(16.2)	386(46.0)	79(9.4)	840
	Third	105(21.9)	70(14.6)	240(50.1)	64(13.4)	479	194(27.9)	127(18.2)	300(43.1)	75(10.8)	696
	Fourth	73(16.7)	71(16.2)	230(52.6)	63(14.4)	437	153(24.1)	81(12.8)	319(50.3)	81(12.8)	634
	Most	100(19.9)	73(14.5)	259(51.5)	71(14.1)	503	191(25.2)	123(16.2)	356(47.0)	88(11.6)	758
Prostate		12,478(41.8)	1,445(4.8)	1,329(4.5)	14,578(48.9)	29,830	28,865(49.9)	3,388(5.9)	1,377(2.4)	24,193(41.8)	57,823
	Least	3,123(48.2)	415(6.4)	263(4.1)	2,674(41.3)	6,475	6,873(56.5)	887(7.3)	249(2.0)	4,162(34.2)	12,171
	Second	2,953(44.8)	302(4.6)	299(4.5)	3,044(46.1)	6,598	6,572(52.9)	813(6.5)	275(2.2)	4,770(38.4)	12,430
	Third	2,234(37.8)	267(4.5)	230(3.9)	3,172(53.7)	5,903	5,327(46.5)	566(4.9)	258(2.3)	5,304(46.3)	11,455
	Fourth	1,908(39.1)	198(4.1)	219(4.5)	2,558(52.4)	4,883	4,647(46.2)	467(4.6)	244(2.4)	4,695(46.7)	10,053
	Most	2,260(37.8)	263(4.4)	318(5.3)	3,130(52.4)	5,971	5,446(46.5)	655(5.6)	351(3.0)	5,262(44.9)	11,714

S2: Relative excess risk of death by socioeconomic status for 10 cancers in NSW, Australia, 2004-2008, LGA and CD

Cancer	Relative excess risk of death* and (95% confidence interval)											
	LGA						CD					
	Least	Second	Third	Fourth	Most	*p-value*§	Least	Second	Third	Fourth	Most	*p-value*§
Stomach	1.00	1.05 (0.90, 1.22)	1.25 (1.08, 1.46)	1.18 (1.01, 1.38)	1.31 (1.13, 1.52)	*0.0007*	1.00	1.08 (0.93, 1.27)	1.09 (0.93, 1.28)	1.19 (1.02, 1.38)	1.31 (1.13, 1.51)	*0.004*
Colorectum	1.00	1.06 (0.97, 1.16)	1.11 (1.02, 1.21)	1.12 (1.02, 1.22)	1.17 (1.07, 1.27)	*0.006*	1.00	1.07 (0.98, 1.18)	1.20 (1.09, 1.31)	1.25 (1.14, 1.36)	1.35 (1.24, 1.48)	*<0.0001*
Liver	1.00	1.10 (0.92, 1.31)	1.38 (1.15, 1.65)	1.33 (1.12, 1.58)	1.33 (1.12, 1.59)	*0.0005*	1.00	1.25 (1.03, 1.50)	1.42 (1.17, 1.72)	1.30 (1.08, 1.56)	1.67 (1.40, 2.00)	*<0.0001*
Lung	1.00	1.12 (1.05, 1.20)	1.18 (1.11, 1.26)	1.19 (1.12, 1.27)	1.26 (1.19, 1.34)	*<0.0001*	1.00	1.09 (1.02, 1.17)	1.20 (1.13, 1.29)	1.27 (1.19, 1.36)	1.30 (1.22, 1.38)	*<0.0001*
Melanoma	1.00	0.88 (0.71, 1.08)	0.95 (0.77, 1.16)	0.99 (0.80, 1.23)	0.94 (0.76, 1.16)	*0.76*	1.00	0.95 (0.76, 1.17)	0.92 (0.73, 1.15)	1.11 (0.90, 1.37)	1.21 (0.98, 1.48)	*0.05*
Breast	1.00	1.29 (1.10, 1.50)	1.38 (1.17, 1.61)	1.28 (1.09, 1.52)	1.23 (1.05, 1.45)	*0.002*	1.00	1.25 (1.06, 1.46)	1.29 (1.10, 1.52)	1.34 (1.15, 1.57)	1.23 (1.04, 1.45)	*0.004*
Cervix	1.00	1.06 (0.72, 1.56)	1.07 (0.71, 1.61)	1.19 (0.79, 1.78)	1.69 (1.19, 2.41)	*0.008*	1.00	0.96 (0.64, 1.45)	1.08 (0.73, 1.59)	1.40 (0.97, 2.01)	1.07 (0.75, 1.53)	*0.27*
Uterus	1.00	1.38 (0.98, 1.95)	2.17 (1.55, 3.03)	1.64 (1.16, 2.34)	1.33 (0.93, 1.91)	*0.0001*	1.00	0.99 (0.71, 1.39)	1.19 (0.85, 1.67)	1.22 (0.88, 1.70)	1.18 (0.85, 1.64)	*0.55*
Ovary	1.00	1.00 (0.83, 1.21)	1.15 (0.94, 1.40)	1.22 (1.00, 1.48)	1.08 (0.90, 1.31)	*0.23*	1.00	1.13 (0.93, 1.37)	0.98 (0.80, 1.21)	1.37 (1.13, 1.67)	1.20 (0.99, 1.46)	*0.005*
Prostate	1.00	1.36 (1.09, 1.70)	1.54 (1.23, 1.93)	1.32 (1.04, 1.66)	1.38 (1.11, 1.71)	*0.005*	1.00	1.34 (1.06, 1.68)	1.36 (1.07, 1.72)	1.41 (1.12, 1.77)	1.55 (1.24, 1.92)	*0.003*

*Adjusted for sex, year of follow-up, age group and stage at diagnosis in a Poisson model
§ Wald test for the effect of SES quintiles in the Poisson model