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Is place or person more important in determining higher rural cancer mortality? A data-linkage study to compare individual versus area-based measures of deprivation

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Abstract

Data from Northeast Scotland for 11,803 cancer patients (diagnosed 2007-13) were linked to UK Censuses to explore relationships between hospital travel-time, timely-treatment and one-year-mortality, adjusting for both area and individual-level socioeconomic status (SES). Adjusting for area-based SES, those living >60 minutes from hospital received timely-treatment more often than those living <15 minutes. Substituting individual-level SES changed little. Adjusting for area-based SES those living >60 minutes from hospital died within one year more often than those living <15 minutes. Again, substituting individual-level SES changed little. In Northeast Scotland distance to services, rather than individual SES, likely explains poorer rural cancer survival.

Background and objective

The Northeast and Aberdeen Scottish Cancer and Residence (NASCAR) study found rural-dwellers are treated quicker but more likely to die within a year of a cancer diagnosis. A potential confounder of the relationship between geography and cancer mortality is socioeconomic status (SES). We linked the original NASCAR cohort to the UK Censuses of 2001 and 2011, at an individual level, to explore the relationship between travel time to key healthcare facilities, timely cancer treatment and one-year mortality adjusting for both area and individual-level markers of socioeconomic status.

Methods

A data linkage study of 11803 patients examined the association between travel times, timely treatment and one-year mortality with adjustment for area, and for individual-level, markers of socioeconomic status.

Results

Following adjustment for area-based SES measures those living more than 60 minutes from the cancer treatment centre were significantly more likely to be treated within 62 days of GP referral than those living within 15 minutes (Odds Ratio [OR]) 1.41; 95% (Confidence Interval [CI]) 1.23 , 1.60]. Replacing area-based with individual-level SES measures from UK Censuses made little impact on the results [OR 1.39; 95% CI 1.22, 1.57].

Following adjustment for area-based SES measures of socioeconomic status those living more than 60 minutes from the cancer treatment centre were significantly more likely to die within one year than those living closer by [OR 1.22; 95% CI 1.08, 1.38]. Again, replacing area-based with individual-level SES measures from UK Censuses made little impact on the result [OR 1.20; CI 1.06, 1.35].

Conclusions

Distribution of individual measures of socioeconomic status did not differ significantly between rural and urban cancer patients. The relationship between distance to service, timely treatment and one-year survival were the same adjusting for both area-based and individual SES. Overall, it seems that distance to services, rather than personal characteristics, influences poorer rural cancer survival.

Keywords

cancer; rurality; geography; data-linkage; delay; primary care; treatment; mortality; census

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Highlights

- Rural cancer patients in Northeast Scotland die sooner despite quicker treatment
- UK National Censuses were linked to clinical data to explore this paradox
- Analyses adjusted for both area-based deprivation and individual socioeconomic status
- The paradoxical results did not alter adjusting for either type of measure
- Distance to services seems to determine poorer rural cancer survival in Northeast Scotland

Introduction

Rurality is associated with poorer cancer outcomes but the reasons why are obscure [1]. We recently conducted a systematic review of global literature including 39 studies that explored the relationship between rurality and cancer mortality [2]. The majority of included studies found rural residents were less likely to survive cancer. A meta-analysis of 11 studies that had controlled for socioeconomic status, found that rural dwellers were 5% less likely to survive cancer than equivalent urban counterparts [2].

A limitation of most existing research into rurality and cancer outcomes is that studies rely on small area-level categorizations of geography and socioeconomic status based on the area or sector in which individuals live [2, 3]. In Scotland, the Scottish Index of Multiple Deprivation (SIMD) divides the whole of Scotland into 6,976 datazones with approximately equal population but varying size and degrees of urbanization [4]. Thus two individuals who are socially very different, but living close by, could be assigned the same socioeconomic status [5, 6]. For example, in Aberdeen city datazone S01006572 West End North (part) is assigned SIMD deprivation decile 5 (least deprived). The datazone comprises several adjacent residential streets with a total population of 969 individuals, 1.5% (n=15) of whom are classified as income or employment deprived. In contrast datazone S01006979 Ythsie (part) comprises several square miles of rural Aberdeenshire and is also assigned SIMD quintile 5. In this datazone however, of a population of 888 individuals, 7.8% (n=70) are recorded as income or employment deprived [4]. Care also needs to be employed when using area-based measures to avoid ecological fallacy, that is bias occurring because an association observed at an aggregate or group level may not exist among the group individuals [7]. Consequently, using an area-based measure of socioeconomic circumstance in studies of cancer outcomes in individuals might mean that the statistical analyses do not adequately adjust for potential confounding by the socioeconomic characteristics which could be influential on individuals' cancer journeys. The effect of this could be to falsely inflate the importance of physical geography in determining a rural disadvantage in cancer outcomes.

The route to diagnosis and treatment for almost all people diagnosed with symptomatic cancer in Scotland will begin with consultation with a general practitioner (GP) [8]. Depending on the clinical features at presentation the GP can then either admit the patient directly to hospital or refer them to see a secondary care specialist at a hospital. Throughout Scotland GPs will prioritize such referrals as routine referrals, non-specific urgent referrals or "Urgent – Suspected Cancer" referrals according to the Scottish Referral Guidelines for Suspected Cancer [9]. The referral route used will subsequently influence the time interval until the patient is first seen at a secondary care clinic for further investigation, and ultimately the time it takes them to be diagnosed and treated.

To explore the impact of residential geography on the routes to diagnosis and treatment the Northeast of Scotland and Aberdeen Cancer and Residence (NASCAR) study analysed associations between travelling time, time to treatment and one-year mortality for 12,339 people resident in Northeast Scotland and diagnosed with one of eight common cancers between 2007 and 2014 [10]. The NASCAR findings were unexpected – mainland patients with greater than 60 minutes travelling time from their nearest cancer centre [OR 1.42; 95%CI 1.25–1.61] and those living on an island [OR 1.32; 95%CI 1.09–1.59] were more likely to commence cancer treatment within Scottish Government target times of 62 days from GP referral and within 31 days of their cancer diagnosis date [11]. Island patients were also more likely to have their diagnosis and treatment started on the same or next day [OR 1.72; 95%CI 1.31–2.25]. Paradoxically however, compared to living within 5 minutes travel of a cancer centre, living greater than 30 minutes travelling time to a cancer centre on the mainland was associated with reduced survival to one year (30–59 minutes [Hazard Ratio (HR) 1.21; 95% Confidence Interval (CI) 1.05–1.41], >60 minutes [HR 1.18; 95%CI 1.03–1.36]) but living on an island was not associated with poorer one-year mortality [10].

Previous researchers have suggested that physical geography confers poorer access to healthcare facilities in rural areas which, in turn, underpins geographical cancer outcome inequality [12, 13]. NASCAR partially addressed this issue since the main analysis examined patients' actual travelling times to key healthcare facilities using geographical information systems (GIS) technology [14]. NASCAR also accounted for socioeconomic status in the analyses but used the area-based Scottish Index of Multiple Deprivation to assign each individual to the quintile of deprivation which corresponded to their residential postcode [15]. As illustrated in the example above, using area-based measures of deprivation in comparison of urban and rural cancer outcomes is problematic, since an individual's socioeconomic status could differ from the area-based measure. This could lead to overestimating the importance of physical geography and underestimating the importance of personal characteristics and circumstances in producing a rural cancer disadvantage.

The UK Census aims to collect extensive personal demographic data characterizing every person resident in the UK every 10 years [16, 17]. In particular, the census seeks information about each individual's home and family environment, employment, and access to transport. The census also collects information about individuals' ethnicity and religious affiliation. We linked the NASCAR cohort to the 2011 UK Census where possible, and failing that the 2001 UK Census, to obtain individual-level socioeconomic measures for each included subject. We aimed to explore the

relative importance of place over person in determining rural disadvantage in cancer outcomes.

Methods

The NASCAR Census cohort was constructed by linking individuals from the NASCAR cohort to information that they had provided to the UK National Census of 2011 (or 2001 if 2011 was unavailable).

Data sources

NASCAR has been previously described previously and is a novel linked longitudinal dataset comprising over 12,000 individuals from Northeast Scotland diagnosed with one of eight common cancers (colorectal, lung, breast, prostate, melanoma, oesophago-gastric, cervical, ovarian) from 2007 to 2014 [10]. The primary data source for NASCAR is the NHS Grampian Cancer Care Pathway (CCPd) database which comprises information about individuals' journey to cancer diagnosis in NHS Grampian, and two island communities NHS Orkney and NHS Shetland. All three diagnosis centres lead to treatment at a single cancer treatment centre (Aberdeen Royal Infirmary). The CCPd records information about referral, diagnosis, subsequent investigations and secondary care appointments, intra-secondary care referrals, investigations, hospital admissions and discharges, operations, and treatment. The accuracy of the CCPd has been validated [10]. Using residential postcodes (geo-reference for postcode centroid), we assigned the Scottish Index of Multiple Deprivation (SIMD) and the Scottish Government Urban-Rural Classification to the whole CCPd cohort dataset [15, 18]. The SIMD data come from a variety of different sources and data providers quality assure data before providing them to the Office of the Chief Statistician and Performance (OCSP) [19]. The OCSP also carries out further checks to ensure the data are fit for purpose. This combined dataset was then linked to the Scottish Cancer Registry (SMR06), which records information on cancer type, date of diagnosis, stage at diagnosis, treatment received and date [20]. Data quality of the Scottish Cancer Registry is monitored using routine indicators, computer validations and ad hoc studies of data accuracy and completeness of ascertainment [21–23]. Further linkage was made to hospital episode data relating to all inpatient and day cases discharged from Scottish acute hospitals (Scottish Morbidity Record 01 (SMR01)). The data quality is regularly assessed and validated [24]. Using these data, a Charlson co-morbidity index (CCI) was calculated for each patient [25]. Death registry data from the General Registry Office for Scotland (GROS) provided information relating to all principal and secondary causes of death.

For each individual within the dataset, postcodes for home residence, GP practice, cancer diagnosis and cancer treatment centre were available. To model travel times to key healthcare facilities used during each individuals cancer diagnostic pathway (GP practice, cancer diagnosis centre, and cancer treatment centre), mainland road networks from place of residence were calculated using Network Analyst extension in ArcGIS V10.2 (ESRI: Environmental Systems Research Institute, Redlands, CA, USA). A travelling time was not calculated for island patients, and island was used a distinct category.

Our analyses investigated the relationship between rurality, distance and travelling times to key healthcare facilities (GP practice, hospitals of diagnosis and treatment) and outcomes (receipt of timely treatment based on Scottish Government targets, which are within 62 days of GP referral and within 31 days of diagnosis [26]) and one year mortality. Multivariable logistic regression adjusted for potential confounding variables, including: age; sex; urban/rural; deprivation; urgency/referral status; cancer type; procedure type; CCI score; treatment type; and metastatic cancer.

Data from UK Censuses on all variables which could potentially influence timely cancer treatment and cancer mortality were obtained for each individual in the NASCAR cohort. Census population results go through a rigorous quality assurance process [27]. For each individual, information was sought on: ethnic group; country of birth; religion; marital status; general health; disability; long-term illness; deprivation; economic activity; highest qualification; occupation; hours worked per week; mode of travel to work or study; family type; living arrangements; carers in house and hours providing care per week; car and van availability; home circumstances; and housing type.

Data linkage

The Information Services Division (ISD) is a division of National Services Scotland, part of NHS Scotland. ISD provides health information, health intelligence, statistical services and advice that support the NHS in progressing quality improvement in health and care and facilitates robust planning and decision making. The electronic Data Research and Innovation Service (eDRIS) team are part of the Information Services Division and support Administrative Data Research – Scotland (ADR-Scotland) linkage projects.

The original NASCAR cohort was approved by the Privacy Advisory Committee of ISD Scotland (Reference number 0942/14). The cohort was constructed in collaboration between eDRIS and the Data Management Team of the NHS Grampian/University of Aberdeen Data Safe Haven (DaSH). Following secure transfer eDRIS linked CCPd data using the community health index (CHI), a unique identifier for all residents in Scotland [28]. This allows all the records from multiple data sets from primary care, secondary care, and specialist disease registries to be linked [24]. Data extraction and linkage were carried out by eDRIS and DaSH. Data were pseudo-anonymised by the DaSH team (by removal of CHI and application of a unique NASCAR ID) and placed in DaSH, which provides a secure virtual research environment, before release to our research group for analysis.

Subsequently, the NASCAR Census project received approvals from the NHS Grampian Caldicott Guardian (CG/2018/31), the Public Benefit and Privacy Panel (PBPP) of Scottish Government (1718-0012), and the ADR-Scotland (PROJ-166). The DaSH team reapplied CHI numbers to the original NASCAR cohort which was subsequently transferred securely back to eDRIS. In collaboration between eDRIS and ADR-Scotland, the requested UK Census variables were linked to the original cohort using the CHI number which was then subsequently removed and replaced with a new

anonymised NASCAR Census study ID. Data were stored and analysed within the National Safe Haven, a secure virtual environment maintained by Public Health Scotland where the project data were uploaded and accessed by the research team using the dedicated ADR-Scotland secure datalink [29]. The NASCAR Census cohort consisted of the individuals which had been linked to the Census (2011 or 2001).

Statistical Analyses

General principles

All analysis was undertaken using STATA v15. There were no missing data in the key NASCAR variables as described previously [10].

Descriptive analysis of NASCAR-Census cohort

Individuals from the original NASCAR cohort who could not be linked to the Census were excluded. Individuals who resided in a communal facility were also excluded. The frequency and percentage distribution of both NASCAR and Census variables were described for the whole cohort of the current study.

Association between Census variables and treatment and mortality outcomes

The frequency and proportion of each category within the Census variables were described across the following outcomes: [1] within and without timely treatment (i.e. treatment started within 62 days of GP referral); [2] treatment within 31 days of diagnosis; [3] one-year all-cause mortality from date of GP referral as recorded in the CCPd. Chi-squared tests were used to identify any associations between each Census variable and each outcome. Using univariable binary logistic regression, the unadjusted OR and 95% CI of timely treatment, treatment within 31 days, and one-year mortality was calculated for each categorical Census variable.

Association between travelling time and treatment and mortality outcomes

The relationship between different categories of travelling time from subjects' home to their GP surgery (<5 mins; 5–9.9 mins; 10–14.9 mins; >15.0 mins; island-resident) and their cancer treatment centre (<15 mins; 15–29.9 mins; 30–59.9 mins; >60 mins; island-resident) were then compared for timely treatment, treatment within 31 days of diagnosis and one year mortality. First, the univariate OR and 95% CI of each outcome was calculated for each category of travelling time (to GP and cancer treatment centre) using binary logistic regression, with the category closest to the relevant healthcare facility being the reference.

Next, four successive binary logistic regression models were performed to sequentially adjust for different potential confounders. In the first model sociodemographic variables alone were added: age; sex; SIMD; urban-rural classification; and the Census variables found to be significant univariately (ethnic group, hours in main job, heating, country of birth, housing type). In the second model, the same adjustments made in the original NASCAR analysis were repeated on the current cohort, which included: age; sex; SIMD; urban-rural classification; referral status (screening, other, routine, urgent, urgent-suspected cancer); cancer type; treatment received; CCI; metastatic cancer [8]. In the third model, the individual-level Census variables found to have a significant association ($p<0.05$) with one of the outcomes (ethnic group, hours in main job, heating, birth in UK and housing type) were added to model 2. For the fourth model SIMD was removed so that the model comprised the original NASCAR variables and the individual-level Census variables which were significant univariately.

Results

Completeness of linkage

There were 12339 patients in the original NASCAR cohort of which 401 could not be matched to data in either the 2001 or 2011 National UK Censuses (Figure 1). Participants ($n = 135$) resident in a communal establishment (e.g. a nursing home) were also excluded since it was not possible to determine for how long individuals had resided or would reside there. The final cohort for analysis comprised 11803 individual patients (Table 1 for patient and pathway characteristics).

Description of sample

The NASCAR Census cohort is described in Table 2 and was 98.1% white with 96.9% born in the UK. Adherence to a religion was stated by 67.8% and 62.4% were married. Good general health was reported by 59.5% with 1653 (14.0%) having two or more comorbidities. Only 56 (0.5%) had four dimensions of deprivation. Current employment was reported by 34.3% and 66.8% were living as a couple. Homeownership was reported by 72.2% and only 21.4% did not have a car.

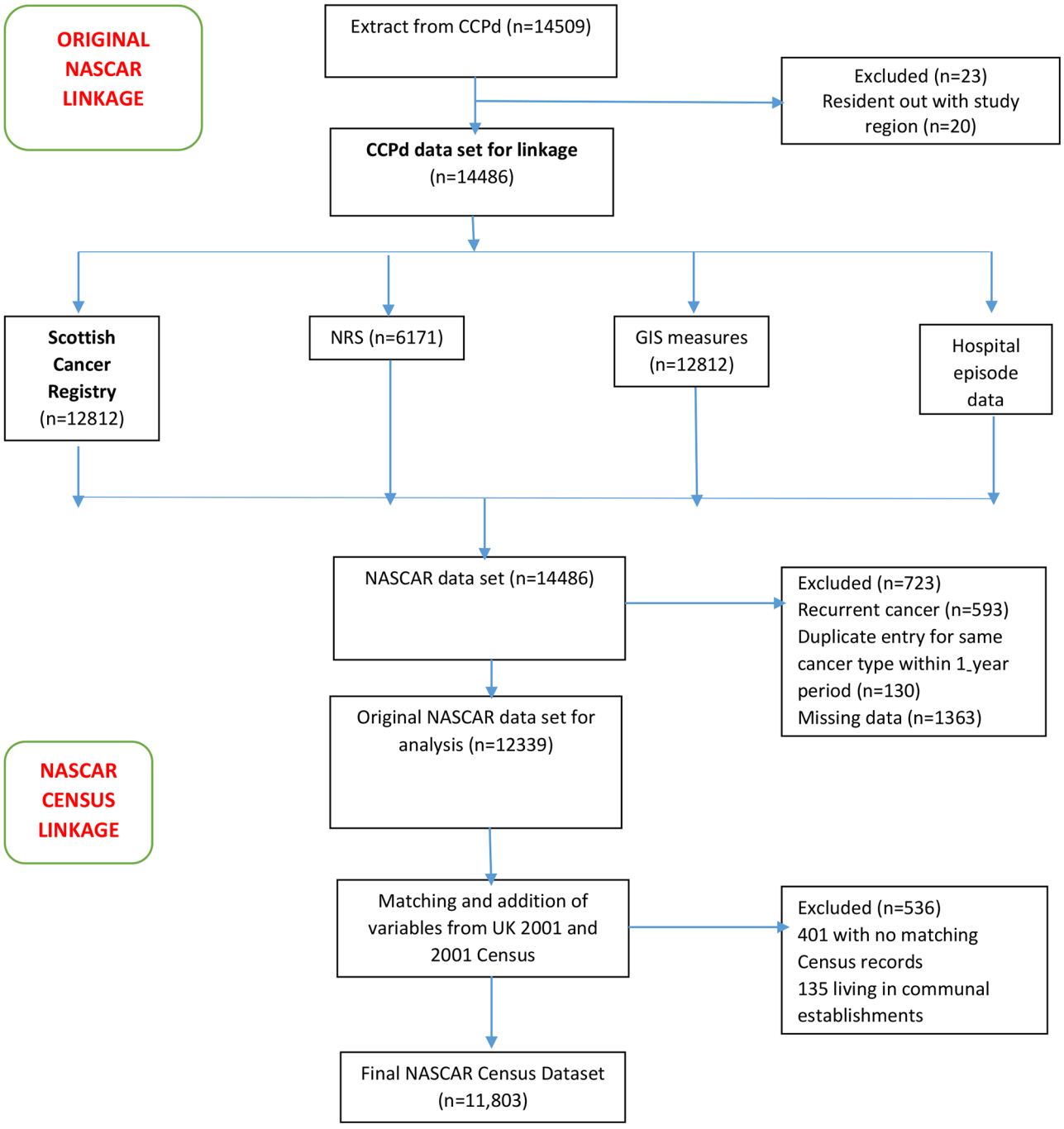
Association between Census variables, timely treatment and mortality

Across the whole sample non-UK born white subjects were significantly more likely to receive timely treatment than Scottish born white subjects (OR 1.61; (95% CI 1.09–2.39) (Table 3). People working more than 15 hours per week were significantly less likely to receive timely treatment than those working less than 15 hours, the odds being lowest for those working more than 49 hours (OR 0.79; (95% CI 0.67–0.93). Those with heating in their homes were 2.34 times (95% CI 1.84–2.99) more likely to receive timely treatment. Compared to manager/senior officials, those working in skilled trades (OR 1.26; (95% CI 1.05–1.50)) and personal services (1.28; (95% CI 1.04–1.56)) were significantly more likely to begin treatment within the target time of 62 days.

Compared to those working fewer than 15 hours per week, those working more than 49 hours were 0.82 times (95% CI 0.70–0.96) less likely to begin treatment within 31 days of diagnosis (Table 4).

None of the added Census variables were associated with an increased risk of mortality at one year (Table 5).

Figure 1: Flow diagram of study population



CCPd = Cancer Care Pathway Database (NHS Grampian); GIS = Geographic Information Systems; NASCAR = Northeast and Aberdeen Scottish Cancer and Residence; NRS = National Records of Scotland.

Timely treatment and travelling times

Table 6 reports the results of univariable and multivariable binary logistic regression models analysing associations between travelling times to GP and cancer treatment centre and timely treatment outcomes. Travelling time to the GP surgery was not strongly associated with timely treatment, except that island-dwellers were significantly more likely to be treated within 31 days of diagnosis compared to those in all mainland categories. Those living more than 60 minutes travelling time from the cancer centre, and on an island, were significantly more likely to be treated within 62 days of GP referral and within 31 days of diagnosis. This association was observed in the unadjusted model. Making adjustments for sociodemographic factors (model 1) did not strengthen the association. In the three models (2–4) which also adjusted for patients' route to diagnosis, the cancer type and whether it has metastasized at the point of diagnosis, the type of cancer

treatment received, and patients' underlying co-morbidities, the association was strengthened. Substituting area-based measures of SES (model 2) with individual measures (model 3 and 4) of SES did not change the strength of the observed associations.

Mortality and travelling times

Table 7 reports the results of univariable and multivariable binary logistic regression models analysing associations between travelling time to GP and cancer treatment centre and mortality outcomes. There were no significant associations between travelling times to the GP surgery, overall all-cause mortality, overall all-cause one-year mortality, or cancer-specific one-year mortality. In the unadjusted models travelling time to the cancer centre was not associated with any of the three mortality outcomes and this was not changed by adjusting for socioeconomic factors (model 1). When patients' route to diagnosis, the cancer type and whether it has metastasized at the point of diagnosis, the type of cancer treatment received and patients' underlying co-morbidities were also adjusted for (models 2–4), those living more than 30 minutes travel from a cancer centre were significantly more likely to die overall and within one year from both all and cancer-specific causes. Replacing area-based (model 2) with individual (models 3 and 4) measures of SES did not strengthen the associations. Living on an island was not associated with increase mortality in any of the adjusted models (1–4).

Conclusions

Main findings

In univariable statistical models, subjects' travelling time to their cancer treatment centre was not associated with receipt of timely treatment. This remained the case when adjustments were made for both area-based and individual-level measures of SES. When cancer-related factors were added to models, those living on an island or with a more than 30 minute journey to their cancer centre were significantly more likely to receive treatment within Scottish Government targets, and were more likely to receive their diagnosis and treatment on the same day if they live on an island. Substituting individual-level for area-based measures of SES did not meaningfully change the associations. Similarly, mortality outcomes showed no association with travelling times to the cancer treatment centre in univariable models, which remained the case when adjustments were made for area-based and individual-level markers of SES. Adjustments for cancer-related factors revealed a significantly increased mortality risk across all three mortality measures for mainland subjects living more than 60 minutes from their cancer treatment centre. Again, substituting individual-level for area-based measures of SES did not meaningfully change the association. Travel times to individuals' GP surgery was not associated with outcomes in either univariable or multivariable models.

There was also a notable general trend in all adjusted models, albeit non-significant, suggesting that the best survival outcomes (overall and cancer-specific) occurred for those living within 15 minutes of the cancer centre.

Strengths and limitations

The NASCAR Census cohort/dataset provides comprehensive data from a large cohort of people diagnosed with cancer in Northeast Scotland from 2007 to 2013. Extensive information about characteristics, routes to diagnosis, outcomes, travelling times from key healthcare facilities, and socio-demographics of residential area have been linked with individual socio-demographic information from the UK Censuses of 2001 and 2011. Using individual socio-demographic information, we have been able to make adjustments for the particular characteristics of individuals. The range of socio-demographic information we have been able to add, and to adjust for, provides compelling additional evidence for the fundamental importance of residential geography in an individual patient's cancer journey.

The NASCAR Census study is one of the first in Scotland to have linked an existing clinical cohort to data from the UK Census. The linkage was remarkably complete with only 401 (3%) cases being lost likely due to incomplete Census returns rather than data errors [30]. Using high quality and validated electronic clinical datasets via established data linkage methods allowed a high degree of completeness and accuracy. Thus, for the benefit of future researchers we have demonstrated, given the appropriate permissions, the feasibility of making these linkages.

This study enables, for the first time, a consideration around concerns about residual confounding from using an area-based measure of deprivation in studies of exploring the impact of geography on processes of cancer care. There have been previous concerns that rural postcodes are sufficiently large, and their residents sufficiently diverse as to introduce major socioeconomic confounding in studies of this type. Our data provide reassurance that, at least in Scotland, individuals' postcodes provide an acceptable proxy for their individual socioeconomic status.

The population of Northeast Scotland is relatively affluent, and the rural population here may not represent the rural population of the rest of Scotland and the wider UK. The possibility remains that the phenomena demonstrated by NASCAR are produced by conditions of local geography and health service provision and that the situation would be different elsewhere. For example, in future, increasingly sophisticated software may enable variables such as traffic volume, road conditions and local issues of healthcare supply and demand to be included in analyses. Further, we explored time-to-treatment as one of our outcomes but considering the natural course of the cancers studied other parameters such as time to diagnosis and detailed treatment received could be equally important.

A further limitation is the fact that the UK National Census occurs every ten years. It is possible, therefore, that an individual's personal circumstances, including socioeconomic status could vary during that time in ways which would not be captured by the Census. A further limitation is the limited follow-up period enabled in the NASCAR cohort, which may be insufficient to capture differential effects of geography and SES acting on those surviving cancer for longer.

This study is important, if incremental, in that it strongly suggests that physical location is more important than individual characteristics of people of rural-dwellers and island residents in influencing their cancer journey and outcomes.

Context with other literature

Our study suggests that area-based indicators of socio-economic status capture, within cancer outcome models, the individual status of individuals within these areas. A study based in nine counties in the Southwest of England concluded that the Index of Multiple Deprivation had a strong relation to individuals' health. [31] A more recent study exploring the Index of Multiple Deprivation in England found greater heterogeneity in key indicators of deprivation in rural areas than is suggested by the original indices, suggesting that existing area-based measures may be less suitable for comparing rural and urban populations [32]. However, the Scottish Index of Multiple Deprivation (SIMD) is based upon smaller output areas with a smaller population and there are differences in the content of the constituent domains [33, 34]. A study based on 10,359 participants aged 40–59 in the Scottish Heart Health Study also concluded that area-based measures of deprivation showed similar degrees of association with coronary heart disease CHD as measures based on individuals' occupation [3] Against the context of increasing regulatory and cost burdens around data-linkage, our study also supports the argument that SIMD is an acceptable proxy for individual social status in Scotland.

With this in mind our data suggest that individual social deprivation is not the main determinant of poorer rural cancer outcomes. At first glance, this would appear to contrast with a report from the National Cancer Registration and Analysis service which explored English cancer incidence and mortality in England from 2004–2006 [35]. The NCRAS analysis found variation in cancer incidence and mortality between rural and urban areas concluding that observed difference resulted from differential distribution of socioeconomic deprivation between country and city. However, a study based upon 18,568 women diagnosed with breast cancer in Queensland, Australia between 1997 and 2006 found that area-level disadvantage was associated with breast cancer mortality independently of individual characteristics [36].

The importance of patients' location relative to specialist cancer and diagnostic facilities has been highlighted before. A study which explored the association between local populations' mean travelling times to their cancer treatment centre across the whole of England found that longer average travel times were associated with worse mortality from breast, lung and colorectal cancer after adjustment for age, sex, year and area deprivation, in line with our own finding of a trend to better survival for those living within 15 minutes of the cancer centre [37]. In further work by the same authors increased travelling time to a GP in England was associated with increased risk of an emergency or post-mortem cancer diagnosis [13].

Two national Danish studies have recently highlighted the complex relationship between cancer patients' location, diagnosis and mortality [38, 39]. Amongst 37,872 Danish cancer patients diagnosed during 2006–16, longer travelling distance was associated with a longer diagnostic interval, early stage at diagnosis for hard to diagnose cancers, and later stage for easier to diagnose cancers. Direct comparison with NASCAR is difficult due to the differing methods employed and intervals measured by the Danish investigators, but the overall patterns of diagnosis appear different. Both sets of studies, however, imply that specific local circumstances of geography and health service organization impact cancer diagnosis in specific local ways. In this context, it is important to consider that some European studies have not demonstrated a rural-urban cancer survival inequality. A 2014 German study compared age-standardised five-year survival using 11 population-based cancer registries and found similar survival for urban and rural cancer patients [40]. A recent data-linkage study of 3,718 patients with colorectal cancer, diagnosed between 2007 and 2013 in Northern Sweden, one of the most sparsely populated areas in Europe, found no association between travel time to nearest hospital and survival [41]. A Norwegian study also found no evidence of under-treatment or poorer survival for more remote patients amongst 288 men with metastatic prostate cancer in Nordland County [42].

Nevertheless, most studies conducted in the developed world suggest a rural cancer disadvantage which is complex and multifactorial. Further research from different perspectives is needed to unpick the causes [1]. For example, a study published in 2008 by investigators in Dumfries and Galloway did not explore pathway delays or mortality but did report reduced hospital admissions and bed-days for cancer patients with longer travelling times, suggesting less intense treatment or management of complications as a potential mechanism for our NASCAR findings [43]. A more recent US study found similar outcomes for rural and urban cancer patients who were enrolled in oncology trials [44]. Together, these studies suggest that regional and health service organization and provision could be at least as important as the characteristics of individual patients in determining how geography impacts on cancer outcomes.

Implications

Analysis of the NASCAR-Census dataset has important implications for the relationship between residential geography and cancer in Northeast Scotland.

First, the rural "paradox" remains whether adjustments are made for area-based or individual-level markers of socioeconomic status. Those living most remote from a cancer centre are more likely to receive their treatment within Scottish Government targets but, despite this, have a greater risk of mortality than those living closer by.

Second, in the NASCAR Census study the models have been adjusted for area-based and individual level markers of socioeconomic status, both together and separately, with neither appearing to be strongly associated with the outcomes under study. This strongly suggests that sociodemographic characteristics are not the cause of geographical cancer outcome inequality in Northeast Scotland.

Travelling times were not associated with outcomes in univariate models or when adjustments were made for SES. It was only when cancer-related factors were added to the models that the paradoxical associations between travelling times and time to begin cancer treatment and mortality were revealed. Together, this strongly suggests that the

mortality disadvantage in the most remote patients arises after treatment has begun.

Aside from geographical considerations our results suggest that other hitherto unrecognized inequalities could be imposed by the way in which cancer services are organized. For example, it was striking that people working fewer hours were significantly more likely to receive timely treatment. This has considerable implications for how appointment systems currently operate and perhaps suggest that greater availability of weekend or evening appointments could redress this balance. It is probably also worth pointing out that the greatest barriers to timely treatment appeared to occur for those in senior management positions, and those working more than 49 hours per week. This finding perhaps highlights how people in highly pressurized senior positions may focus less on their own well-being.

In conclusion, physical geography and its impact on cancer care appears to drive a disadvantage for all rural cancer patients irrespective of their individual socio-economic circumstances. Further qualitative and quantitative research is required to compare and contrast what happens to people after they have been diagnosed with cancer and how where they live influences treatment choices and care received after the point of diagnosis. It makes sense that, where possible, such research in based upon whole-nation samples and cohorts to allow for the potential of regional variation in the impact of geography on cancer service provision and resultant cancer outcomes. The authors plan to begin a whole-Scotland analysis exploring these issues in the upcoming SCOTSCAR study. In this way the root causes of geographical cancer inequality can be determined, and the most promising interventions elucidated.

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Statement of conflicts of interest

None declared

Ethics statement and study approvals

Formal ethical approval was not required for either the original NASCAR study or the NASCAR Census study since both replied on completely anonymised routinely collected data with no requirement to contact patients. The original NASCAR cohort was approved by the Privacy Advisory Committee of ISD Scotland (Reference number 0942/14). Subsequently, the NASCAR Census project received approvals from the NHS Grampian Caldicott Guardian (CG/2018/31), the Public Benefit and Privacy Panel (PBPP) of Scottish Government (1718-0012), and the ADR-Scotland (PROJ-166).

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References

1. Murchie P, Adam R, Wood R, Fielding S. Can we understand and improve poorer cancer survival in rural-dwellers? BJGP Open 2019; https://doi.org/10.3399/bjgpopen19X101646. National Cancer Registration and Analysis Service (NCRAS) 2010. Available at http://www.ncin.org.uk/publications/data_briefings/rurality (Accessed 04/12/19)

2. Carriere R, Adam R, Fielding S, Barlas R, Ong Y, Murchie P. Rural dwellers are less likely to survive cancer – An international review and meta-analysis. J Health Place 2018;53:219–227

3. Woodward M. Small area statistics as markers for personal social status in the Scottish heart health study. J Epidemiol Community Health 1996;50:570–576

4. Scottish Government 2020. Scottish Index of Multiple Deprivation 2020. https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/ [Accessed 2nd December 2020]

5. Kou K, Baade PD, Guo X, Gatton M, Cramb S, Lu Z, Fu Z, Chui K, Xu A, Sun J. Area socioeconomic status is independently associated with esophageal cancer mortality in Shandong, China. Sci Rep 2019;9:6388. https://doi.org/10.1038/s41598-019-42774-x

6. Cox J. Poverty in rural areas is more hidden but no less real than in urban areas. Brit Med J 1998;316:722–30

7. Porta M (2008) In: A Dictionary of epidemiology, 5th edition. Porta M (ed). Oxford: Oxford University Press. p75

8. Murchie P, Adam R, McNair E, Swann R, Witt J, Wood R, Weller D. Cancer diagnosis in Scottish primary care: results from the National Cancer Diagnosis Audit. Eur J Cancer Care. 2020;00:e13234. https://doi.org/10.1111/ecc.13234

9. Scottish Government. (2018). Scottish referral guidelines for suspected cancer. NHS Scotland, 2019. http://www.cancerreferral.scot.nhs.uk/ [Accessed 2nd December 2020]

10. Turner M, Fielding S, Ong Y, Dibben C, Feng Z, Brewster DH, Black C, Lee A, Murchie P. A cancer geography paradox? Poorer cancer outcomes with longer

travelling times to healthcare facilities despite prompter diagnosis and treatment: a data-linkage study. Brit J Cancer 2017;117:439-449 – Published Online June 22nd - https://doi.org/10.1038/bjc.2017.180

11. ISD Scotland (2010). https://www.isdscotland.org/Health-Topics/Waiting-Times/Cancer/ [Accessed 2nd December 2020]

12. Campbell NC, Elliott AM, Sharp L, Ritchie LD, Cassidy J, Little J. Rural factors and survival from cancer: analysis of Scottish cancer registrations. Brit J Cancer 2000;82:1863-1866.

13. Murage P, Bachmann MO, Crawford SM, McPhail S, Jones A. Geographical access to GPs and modes of cancer diagnosis in England: a cross-sectional study Family Practice 2018; https://doi.org/10.1093/fampra/cmy077

14. Higgs G (2009) The role of GIS for health utilization studies: literature review. Health Serv Outcomes Res Method 9: 84–99.

15. The Scottish Government (2016) The Scottish Index of Multiple Deprivation. The Scottish Government: Edinburgh, UK. Available at: http://www.gov.scot/Topics/Statistics/SIMD [Accessed 2nd December 2020].

16. Office for National Statistics; General Register Office for Scotland; Northern Ireland Statistics and Research Agency (2005): 2001 Census aggregate data (Edition: 2005). UK Data Service. http://doi.org/10.5257/census/aggregate-2001-1

17. Office for National Statistics; National Records of Scotland; Northern Ireland Statistics and Research Agency (2016): 2011 Census aggregate data. UK Data Service (Edition: June 2016). http://doi.org/10.5257/census/aggregate-2011-1

18. The Scottish Government (2014) Scottish Government Urban Rural Classification. The Scottish Government: Edinburgh, UK. Available at: http://www.gov.scot/Topics/Statistics/About/Methodology/UrbanRuralClassification [Accessed 2nd December 2020].

19. Scottish Government 2020. About Statistics in Scotland – Chief Statistician and Data Officer. https://www2.gov.scot/Topics/Statistics/About/ChiefStatistician [Accessed 2nd December 2020].Information Services Division (2017a) Scottish Cancer Registry. ISD Scotland, NHS NSS: Edinburgh, UK. Available at: http://www.isdscotland.org/Health-Topics/Cancer/Scottish-Cancer-Registry.asp [Accessed 2nd December 2020]

20. Brewster D, Crichton J, Muir C (1994) How accurate are Scottish cancer registration data? Br J Cancer 70: 954–959.

21. Brewster DH, Stockton D, Harvey JC, Mackay M (2002) Reliability of cancer registration data in Scotland, 1997. Eur J Cancer 38: 414–417.

22. Information Services Division (2017b) Quality of Cancer Registration Data in Scotland. ISD Scotland, NHS NSS: Edinburgh, UK. Available at: http://www.isdscotland.org/Health-Topics/Cancer/Cancer%20Registration%20Data%20Quality%20in%20Scotland.pdf [Accessed 2nd December 2020].

23. ScottisH Informatics Project (SHIP) 2003. Available at: http://www.scot-ship.ac.uk/overview [Accessed 2nd December 2020].

24. Information Services Division (2012) Assessment of SMR01 Data 2010–2011. Scotland Report, May 2012. ISD Scotland, NHS NSS: Edinburgh, UK.

25. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40: 373–383.

26. Scottish Government 2018. Cancer waiting times standards in Scotland: clinical review. https://www.gov.scot/publications/clinical-review-cancer-waiting-times-cwt-standards-scotland/pages/3/ [Accessed 2nd December 2020].

27. National Records of Scotland (2013). 2011 Census in Scotland: Population and Household Estimates – Quality Assurance Process. https://www.scotlandscensus.gov.uk/documents/censusresults/release1c/rel1cqualityassurance.pdf [Accessed 2nd December 2020].

28. Information Services Division (2020) ISD Scotland Data Dictionary. Data Dictionary A-Z Chi Number. https://www.ndc.scot.nhs.uk/Dictionary-A-Z/Definitions/index.asp?ID=128&Title=CHI%20Number [Accessed 2nd December 2020].

29. Public Health Scotland (2020). Use of the National Safe Haven. https://www.isdscotland.org/Products-and-Services/EDRIS/Use-of-the-National-Safe-Haven/ [Accessed 2nd December 2020].

30. Scotland's Census. Shaping our future. National Records of Scotland, 2018. https://www.scotlandscensus.gov.uk/edit-and-imputation [Accessed 2nd December 2020].

31. Jordan H, Roderick P, Martin D. The index of multiple deprivation 2000 and accessibility effects on health. J Epidemiol Community Health 2004;58:250–157. http://doi.org/10.1136/jceh.2003.013011

32. Fecht D, Jones A, Hill T, Lindfield T, Thomson R, Hansell AL, Shukla R. Inequalities in rural communities: adapting national deprivation indices for rural settings. J Public Health 2017;40:419–425. http://doi.org/10.1093/pubmed/fdx048

33. Abel GA, Barclay ME, Payne RA. Adjusted indices of multiple deprivation to enable comparisons within and between constituent countries of the UK including an illustration using mortality rates. BMJ Open

2016;6:e012750. http://doi.org/10.1136/bmjopen-2016-012750

34. Scotland's Census 2018. Household deprivation classification. https://www.scotlandscensus.gov.uk/variables-classification/household-deprivation-classification-0 [Accessed 2nd December 2020].

35. National Cancer Registration and Analysis Service (2010). The effect of rurality on cancer incidence and mortality. http://www.ncin.org.uk/publications/data_briefings/rurality [Accessed 2nd December 2020]..

36. 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 Res Treat 2012;132:701–710. http://doi.org/10.1007/s10549-011-1899-y

37. Murage P, Crawford SM, Bachman M, Jones A. Geographical disparities in access to cancer management and treatment services in England. Health Place 2016;42:11–18. http://doi.org/10.1016/j.healthplace.2016.08.014

38. Virgilsen LF, Møller H, Vedsted P. Cancer diagnostic delays and travel distance to health services: A nationwide cohort study in Denmark. Cancer Epidemiol 2019;59:115–122. http://doi.org/10.1016/j.canep.2019.01.018#

39. Virgilsen LF, Møller H, Vedsted P. Travel distance to cancer-diagnostic facilities and tumour stage. Health Place 2019;60:102208. http://doi.org/10.1016/j.healthplace.2019.102208.

40. Nennecke A, Geiss K, Hentschel S, Vettorazzi E, Jansen L, Eberle A, Holleczek B, Gondos A, Brenner H; GEKID cancer survival working group. Survival of cancer patients in urban and rural areas of Germany–a comparison. Cancer Epidemiol. 2014 Jun;38(3):259–65. http://doi.org/10.1016/j.canep.2014.02.011. Epub 2014 Mar 27. PMID: 24680643.

41. Sjöström O, Dahlin AM, Silander G, Syk I, Melin B, Hellquist BN. Travel time to care does not affect survival for patients with colorectal cancer in northern Sweden: A data linkage study from the Risk North database. PLoS One. 2020 Aug 5;15(8):e0236799. http://doi.org/10.1371/journal.pone.0236799. PMID: 32756574; PMCID: PMC7406033.

42. Nieder C, Dalhaug A, Haukland E, Norum J. Management of patients with metastatic prostate cancer (mPC) in a rural part of North Norway with a scattered population: does living near the department of oncology translate into a different pattern of care and survival? Int J Circumpolar Health. 2019 Dec;78(1):1620086. https://doi.org/10.1080/22423982.2019.1620086. PMID: 31120400; PMCID: PMC6534221.

43. Unger JM, Moseley A, Symington B, Chavez-MacGregor M, Ramsey SD, Hershman DL. Geographic Distribution and Survival Outcomes for Rural Patients With Cancer Treated in Clinical Trials. JAMA Netw Open. 2018 Aug 3;1(4):e181235. http://doi.org/10.1001/jamanetworkopen.2018.1235. PMID: 30646114; PMCID: PMC6324281.

44. Baird G, Flynn R, Baxter G, Donnelly M, Lawrence J. Travel time and cancer care: an example of the inverse care law? Rural and Remote Health 2008; 8: 1003. Available: www.rrh.org.au/journal/article/1003 [Accessed 2nd December 2020].

Table 1: Patient and pathway characteristics at time of referral (12339 patients in NASCAR, 401 could not be matched to CENSUS, 135 in communal establishments excluded)

	NASCAR Census sample N=11803
	n (%)
Sex	
Male	5187 (43.9)
Female	6616 (56.1)
Age at diagnosis	
Mean (Standard Deviation)	67.5 (13.1)
Vital status at 5th December 2014	
Alive	7214 (61.1)
Dead	4589 (38.9)
Deprivation (quintiles based on SIMD)	
SIMD Q1 (most)	575 (4.9)
SIMD Q2	1455 (12.3)
SIMD Q3	2749 (23.3)
SIMD Q4	3510 (29.7)
SIMD Q5 (least)	3514 (29.8)
Urgency/referral status	
USC	3059 (25.9)
Urgent	2124 (18.0)
Routine	1348 (11.4)
Screening	1793 (15.2)
Emergency	1554 (13.2)
Others	1925 (16.3)
Cancer Type	
Breast	3599 (30.5)
Ovarian	312 (2.6)
Cervical	127 (1.1)
Prostate	1912 (16.2)
Melanoma	543 (4.6)
Lung	1660 (14.1)
Oesophagastric	979 (8.3)
Colorectal	2671 (22.6)
Vital status by cancer type	
	Alive at 5th December 2014 / **Dead at 5th December 2014**
Breast	2971 (82.6) / 628 (17.4)
Ovarian	164 (52.6) / 148 (47.4)
Cervical	102 (80.3) / 25 (19.7)
Prostate	1472 (77.0) / 440 (23.0)
Melanoma	442 (81.4) / 101 (18.6)
Lung	341 (20.5) / 1319 (79.5)
Oesophagastric	200 (20.4) / 779 (79.6)
Colorectal	1522 (56.9) / 1149 (43.1)
Charlson comorbidity index (CCI)	
0	8175 (69.3)
1	2073 (17.6)
2	835 (7.1)
3	375 (3.2)
4	206 (1.7)
5	87 (0.7)
6+	52 (0.4)
Charlson comorbidity conditions (CCI)	
Acute MI	719 (6.1)

Continued

Table 1: Continued

	NASCAR Census sample N=11803
	n (%)
Cerebral vascular accident	463 (3.9)
Congestive heart failure	412 (3.5)
Connective tissue disorder	188 (1.6)
Dementia	125 (1.1)
Diabetes without long-term complications	942 (8.0)
Mild or moderate liver disease	37 (0.3)
peptic ulcer	277 (2.3)
Peripheral vascular disease	501 (4.2)
Pulmonary disease	1343 (11.4)
Diabetes with long term complications	74 (0.6)
Paraplegia	56 (0.5)
Renal disease	568 (4.8)
Severe liver disease	13 (0.1)
HIV	<10 (<0.1)
Diagnostic procedure	
Imaging	2018 (17.1)
Endoscopy/endoscopic biopsy	5523 (46.8)
Operative biopsy/surgery	3693 (31.3)
Other	569 (4.8)
Main treatment type	
Surgery	6023 (51.0)
Chemotherapy/radiotherapy	4733 (40.1)
Other	1047 (8.9)
Metastatic cancer	
Yes	1306 (11.1)
No	10497 (88.9)

Table 2: Census characteristics of NASCAR Census cohort

	NASCAR Census cohort N=11803
Variable	**N (%)**
Ethnic group	
White-Scottish	10219 (86.6)
White-other UK/Irish	1365 (11.6)
White-other European	137 (1.2)
Non-white	82 (0.7)
Country of birth	
United Kingdom	11434 (96.9)
Non-UK	369 (3.1)
Religion	
None	3020 (25.6)
Declared	8001 (67.8)
Not stated	782 (6.6)
Marital status	
Single	993 (8.4)
Married	7364 (62.4)
Separated/Divorced/Widowed/Surviving	3446 (29.2)
General health	
Good	7020 (59.5)
Fair	3444 (29.2)
Bad	1339 (11.3)
Disability	
No	6952 (58.9)
Yes	4851 (41.1)
Long term illnesses (adults)	
None	5767 (48.9)
1	4383 (37.1)
2+	1653 (14.0)
Deprivation[1]	
None	2968 (25.1)
1 dimension	4572 (38.7)
2 dimensions	3495 (29.6)
3 dimensions	712 (6.0)
4 dimensions	56 (0.5)
Economically active	
Employed	4052 (34.3)
Not employed	7751 (65.7)
Highest qualification	
None	5267 (44.6)
Standard grade/GCSE	2005 (17.0)
Post16-nondegree	1557 (13.2)
Degree/professional qual	2570 (21.8)
No code required	404 (3.4)
Occupation	
Managers/senior officials	797 (6.8)
Professional occupations	1499 (12.7)
Associated professional technical occupations	844 (7.2)
Admin/secretarial	1392 (11.8)
Skilled trades	1601 (13.6)
Personal services	898 (7.6)
Sales/customer service	794 (6.7)
Process, plant, machines	1023 (8.7)
Elementary occupation	1594 (13.5)
No occupation	1361 (11.5)

Continued

Table 2: Continued

Variable	NASCAR Census cohort N=11803 N (%)
Hours per week in main job	
<=15	1048 (8.9)
16–30	2415 (20.5)
31–48	6041 (51.2)
49+	1725 (14.6)
Not applicable	574 (4.9)
Travel to work	
No place of work	7718 (65.4)
Work at home	607 (5.1)
Public transport	347 (2.9)
Car/motorbike	2554 (21.6)
other	577 (4.9)
Family type	
Single	3293 (27.9)
Lone parent	560 (4.7)
Couple no children	6184 (52.4)
Couple children	1766 (15.0)
Living arrangements	
Couple	7882 (66.8)
Single	833 (7.1)
Previous couple (separated, divorced, widowed, surviving)	3088 (26.2)
Carers in house	
No carers	9541 (80.8)
At least one	2262 (19.2)
Hours providing care for others per week	
Not a carer	10440 (88.5)
1–19hrs/week	751 (6.4)
20–49 hrs/week	186 (1.6)
50+ hrs/week	426 (3.6)
Number of cars in household	
None	2529 (21.4)
1	5665 (48.0)
2+	3609 (30.6)
Accommodation	
Detached	4475 (37.9)
Semi detached	3427 (29.0)
Terraced	1902 (16.1)
Purpose built flat	1799 (15.2)
Other	200 (1.7)
Heating	
No	311 (2.6)
Yes	11492 (97.4)
Housing type	
Owned outright	6360 (53.9)
Mortgaged	2225 (18.9)
Rented	2912 (24.7)
Other	306 (2.6)

[1]The dimensions of deprivation used to classify households are indicators based on four selected household characteristics. A household is deprived in a dimension if they meet one or more of the following conditions: employment: where any member of a household, who is not a full-time student, is either unemployed or long-term sick, education: no person in the household has at least level 2 education (see highest level of qualification), and no person aged 16-18 is a full-time student, health and disability: any person in the household has general health that is 'bad' or 'very bad' or has a long term health problem, and housing: the household's accommodation is either overcrowded, with an occupancy rating -1 or less, or is in a shared dwelling, or has no central heating. A household is classified as being deprived in none, or one to four of these dimensions in any combination (Scotland's Census, 2018).

Table 3: Census characteristics by TIMELY TREATMENT (Treatment began within 62 days of GP referral)

		OUTWITH TARGET (column) N = 3996	WITHIN TARGET (column) N = 7807	WITHIN TARGET (Row) N = 7807	CHI	Unadjusted odds ratio	
Variable	**N**	**n (%)**	**n (%)**	**(%)**	**p-value**		**95% confidence interval**
Ethnic group					**0.045**		
White-Scottish	10219	3462 (86.6)	6757 (86.6)	(66.1)		1.00	
White-Other UK/Irish	1365	467 (11.7)	898 (11.5)	(65.8)		0.98	(0.87, 1.10)
White-other European	137	33 (0.8)	104 (1.3)	(75.9)		1.61	(1.09, 2.39)
Non-white	82	34 (0.9)	48 (0.6)	(58.5)		0.72	(0.46, 1.12)
Country of birth					0.571		
United Kingdom	11434	3866 (96.7)	7568 (96.9)	(66.2)		1.00	
Non-UK	369	130 (3.3)	239 (3.1)	(64.8)		0.94	(0.76, 1.17)
Religion					0.812		
None	3020	1020 (25.5)	2000 (25.6)	(66.2)		1.00	
Declared	8001	2703 (67.6)	5298 (67.9)	(66.2)		1.00	(0.91, 1.09)
Not stated	782	273 (6.8)	509 (6.5)	(65.1)		0.95	(0.81, 1.12)
Marital status					0.262		
Single	993	316 (7.9)	677 (8.7)	(68.2)		1.00	
Married	7364	2488 (62.3)	4876 (62.5)	(66.2)		0.91	(0.79, 1.05)
Separated/Divorced/Widowed/Surviving	3446	1192 (29.8)	2254 (28.9)	(65.4)		0.88	(0.76, 1.03)
General Health					0.739		
Good	7020	2369 (59.3)	4651 (59.6)	(66.3)		1.00	
Fair	3444	1161 (29.1)	2283 (29.2)	(66.3)		1.00	(0.92, 1.09)
Bad	1339	466 (11.7)	873 (11.2)	(65.2)		0.95	(0.84, 1.08)
Disability					0.802		
No	6952	2360 (59.1)	4592 (58.8)	(66.1)		1.00	
Yes	4851	1636 (40.9)	3215 (41.2)	(66.3)		1.01	(0.93, 1.09)
Long term illnesses (adults)					0.739		
None	5767	1940 (48.5)	3827 (49.0)	(66.4)		1.00	
1	4383	1483 (37.1)	2900 (37.1)	(66.2)		0.99	(0.91, 1.08)
2+	1653	573 (14.3)	1080 (13.8)	(65.3)		0.96	(0.85, 1.07)
Deprivation[1]					0.881		
None	2968	1006 (25.2)	1962 (25.1)	(66.1)		1.00	
1 dimension	4572	1558 (39.0)	3014 (38.6)	(65.9)		0.99	(0.90, 1.09)
2 dimensions	3495	1166 (29.2)	2329 (29.8)	(66.6)		1.02	(0.92, 1.14)
3 dimensions	712	249 (6.2)	463 (5.9)	(65.0)		0.95	(0.80, 1.13)
4 dimensions	56	17 (0.4)	39 (0.5)	(69.6)		1.18	(0.66, 2.09)
Economically active					0.166		
Employed	4052	1338 (33.5)	2714 (34.8)	(67.0)		1.00	
Not employed	7751	2658 (66.5)	5093 (65.2)	(65.7)		0.94	(0.87, 1.02)
Highest qualification					0.895		
None	5267	1802 (45.1)	3465 (44.4)	(65.8)		1.00	
Standard grade/GCSE	2005	663 (16.6)	1342 (17.2)	(66.9)		1.05	(0.94, 1.17)
Post 16 non-degree	1557	520 (13.0)	1037 (13.3)	(66.6)		1.04	(0.92, 1.17)
Degree/professional qualification	2570	876 (21.9)	1694 (21.7)	(65.9)		1.01	(0.91, 1.11)
No code required	404	135 (3.4)	269 (3.4)	(66.6)		1.04	(0.84, 1.28)
Occupation					0.104		
Managers/senior official	797	293 (7.3)	504 (6.5)	(63.2)		1.00	
Professional occupation	1499	525 (13.1)	974 (12.5)	(65.0)		1.08	(0.90, 1.29)
Associated professional/technical occupation	844	303 (7.6)	541 (6.9)	(64.1)		1.04	(0.85, 1.27)
Admin/secretarial	1392	456 (11.4)	936 (12.0)	(67.2)		1.19	(0.99, 1.43)
Skilled trades	1601	506 (12.7)	1095 (14.0)	(68.4)		1.26	(1.05, 1.50)
Personal services	898	281 (7.0)	617 (7.9)	(68.7)		1.28	(1.04, 1.56)
Sales/customer service	794	258 (6.5)	536 (6.9)	(67.5)		1.21	(0.98, 1.49)
Process, plant, machines	1023	355 (8.9)	668 (8.6)	(65.3)		1.09	(0.90, 1.33)
Elementary occupation	1594	559 (14.0)	1035 (13.3)	(64.9)		1.08	(0.90, 1.28)
No occupation	1361	460 (11.5)	901 (11.5)	(66.2)		1.14	(0.95, 1.37)
Hours per week in main job					**0.049**		
<=15	1048	317 (7.9)	731 (9.4)	(69.8)		1.00	
16–30	2415	842 (21.1)	1573 (20.1)	(65.1)		0.81	(0.69 , 0.95)
31–48	6041	2030 (50.8)	4011 (51.4)	(66.4)		0.86	(0.74, 0.99)
49+	1725	613 (15.3)	1112 (14.2)	(64.5)		0.79	(0.67, 0.93)
Not applicable	574	194 (4.9)	380 (4.9)	(66.2)		0.85	(0.68, 1.06)

Continued

Table 3: Continued

Variable	N	OUTWITH TARGET (column) N = 3996 n (%)	WITHIN TARGET (column) N = 7807 n (%)	WITHIN TARGET (Row) N = 7807 (%)	CHI p-value	Unadjusted odds ratio	95% confidence interval
Travel to work					0.638		
No place of work	7718	2646 (66.2)	5072 (65.0)	(65.7)		1.00	
Work at home	607	197 (4.9)	410 (5.3)	(67.5)		1.08	(0.91,1.30)
Public transport	347	116 (2.9)	231 (3.0)	(66.6)		1.04	(0.83, 1.30)
Car/motorbike	2554	838 (21.0)	1716 (22.0)	(67.2)		1.07	(0.97, 1.17)
Other	577	199 (5.0)	378 (4.8)	(65.5)		0.99	(0.83, 1.18)
Family type					0.160		
Single	3293	1121 (28.1)	2172 (27.8)	(66.0)		1.00	
Lone parent	560	190 (4.8)	370 (4.7)	(66.1)		1.01	(0.83, 1.21)
Couple no children	6184	2049 (51.3)	4135 (53.0)	(66.9)		1.04	(0.95, 1.14)
Couple children	1766	636 (15.9)	1130 (14.5)	(64.0)		0.92	(0.81, 1.03)
Living arrangements					0.177		
Couple	7882	2656 (66.5)	5226 (66.9)	(66.3)		1.00	
Single	833	263 (6.6)	570 (7.3)	(68.4)		1.10	(0.94, 1.28)
Previous defined as couple	3088	1077 (27.0)	2011 (25.8)	(65.1)		0.95	(0.87, 1.04)
Carers in house					0.447		
None	9541	3242 (81.1)	6299 (80.7)	(66.0)		1.00	
At least one	2262	754 (18.9)	1508 (19.3)	(66.7)		1.03	(0.93, 1.13)
Hours providing care for others per week					0.852		
Not a carer	10440	3533 (88.4)	6907 (88.5)	(66.2)		1.00	
1–19 hrs/week	751	262 (6.6)	489 (6.3)	(65.1)		0.95	(0.82, 1.11)
20–49 hrs/week	186	59 (1.5)	127 (1.6)	(68.3)		1.10	(0.81, 1.50)
50+ hrs/week	426	142 (3.6)	284 (3.6)	(66.7)		1.02	(0.83, 1.26)
Number of cars in household					0.791		
None	2529	869 (21.7)	1660 (21.3)	(65.6)		1.00	
1	5665	1903 (47.6)	3762 (48.2)	(66.4)		1.03	(0.94, 1.14)
2+	3609	1224 (30.6)	2385 (30.5)	(66.1)		1.02	(0.92, 1.14)
Accommodation					0.373		
Detached	4475	1525 (38.2)	2950 (37.8)	(65.9)		1.00	
Semi detached	3427	1125 (28.2)	2302 (29.5)	(67.2)		1.06	(0.96, 1.16)
Terraced	1902	643 (16.1)	1259 (16.1)	(66.2)		1.01	(0.90, 1.13)
Purpose built flat	1799	639 (16.0)	1160 (14.9)	(64.5)		0.94	(0.84, 1.05)
Other	200	64 (1.6)	136 (1.7)	(68.0)		1.10	(0.81, 1.49)
Heating					0.136		
No	311	93 (2.3)	218 (2.8)	(70.1)		1.00	
Yes	11492	3903 (97.7)	7589 (97.2)	(66.0)		2.34	(1.84, 2.99)
Housing type					0.603		
Owned outright	6360	2162 (54.1)	4198 (53.8)	(66.0)		1.00	
Mortgaged	2225	765 (19.1)	1460 (18.7)	(65.6)		0.98	(0.89, 1.09)
Rented	2912	975 (24.4)	1937 (24.8)	(66.5)		1.02	(0.93, 1.12)
Other	306	94 (2.4)	212 (2.7)	(69.3)		1.16	(0.91, 1.49)

[1] The dimensions of deprivation used to classify households are indicators based on four selected household characteristics. A household is deprived in a dimension if they meet one or more of the following conditions: employment: where any member of a household, who is not a full-time student, is either unemployed or long-term sick, education: no person in the household has at least level 2 education (see highest level of qualification), and no person aged 16–18 is a full-time student, health and disability: any person in the household has general health that is 'bad' or 'very bad' or has a long term health problem, and housing: the household's accommodation is either overcrowded, with an occupancy rating −1 or less, or is in a shared dwelling, or has no central heating. A household is classified as being deprived in none, or one to four of these dimensions in any combination (Scotland's Census, 2018).

Table 4: Census characteristics by treatment within 31 days of diagnosis

	Total	Not within 31 days (column) N=5341	Within 31 days (column) N=6462	Within target (row)	Chi	Unadjusted odds ratio	95% C.I.	
Variable	**N**	**N (%)**	**N (5)**	**(%)**	**p-value**	**OR**	**lower**	**upper**
Ethnic group					0.454			
White-Scottish	10219	4634 (86.8)	5585 (86.4)	(54.7)		1.00		
White-Other UK/Irish	1365	606 (11.3)	759 (11.7)	(55.6)		1.04	0.93	1.16
White-other European	137	58 (1.1)	79 (1.2)	(57.7)		1.13	0.80	1.59
Non-white	82	43 (0.8)	39 (0.6)	(47.6)		0.75	0.49	1.16
Country of birth					0.998			
United Kingdom	11434	5174 (96.9)	6260 (96.9)	(54.7)		1.00		
Non-UK	369	167 (3.1)	202 (3.1)	(54.7)		1.00	0.81	1.23
Religion					0.437			
None	3020	1340 (25.1)	1680 (26.0)	(55.6)		1.00		
Declared	8001	3653 (68.4)	4348 (67.3)	(54.3)		0.95	0.87	1.03
Not stated	782	348 (6.5)	434 (6.7)	(55.5)		0.99	0.85	1.17
Marital status					0.816			
Single	993	446 (8.4)	547 (8.5)	(55.1)		1.00		
Married	7364	3349 (62.7)	4015 (62.1)	(54.5)		0.98	0.86	1.12
Separated/Divorced/Widowed/Surviving	3446	1546 (28.9)	1900 (29.4)	(55.1)		1.00	0.87	1.15
General Health					0.561			
Good	7020	3165 (59.3)	3855 (59.7)	(54.9)		1.00		
Fair	3444	1582 (29.6)	1862 (28.8)	(54.1)		0.97	0.89	1.05
Bad	1339	594 (11.1)	745 (11.5)	(55.6)		1.03	0.92	1.16
Disability					0.405			
No	6952	3168 (59.3)	3784 (58.6)	(54.4)		1.000		
Yes	4851	2173 (40.7)	2678 (41.4)	(55.2)		1.03	0.96	1.11
Long term illness (adults)					0.722			
none	5767	2619 (49.0)	3148 (48.7)	(54.6)		1.00		
1	4383	1964 (36.8)	2419 (37.4)	(55.2)		1.02	0.95	1.11
2+	1653	758 (14.2)	895 (13.9)	(54.1)		0.98	0.88	1.1
Deprivation[1]					0.796			
None	2968	1357 (25.4)	1611 (24.9)	(54.3)		1.00		
1 dimension	5572	2066 (38.7)	3506 (54.3)	(62.9)		1.02	0.93	1.12
2 dimensions	3495	1576 (29.5)	1919 (29.7)	(54.9)		1.03	0.93	1.13
3 dimensions	712	321 (6.0)	391 (6.1)	(54.9)		1.03	0.87	1.21
4 dimensions	56	21 (0.4)	35 (0.5)	(62.5)		1.40	0.81	2.42
Economically active					0.358			
Employed	4052	1810 (33.9)	2242 (34.7)	(55.3)		1.00		
Not employed	7751	3531 (66.1)	4220 (65.3)	(54.4)		0.96	0.89	1.04
Highest qualification					0.099			
None	5267	2382 (44.6)	2885 (44.6)	(54.8)		1.00		
Standard grade/GCSE	2005	868 (16.3)	1137 (17.6)	(56.7)		1.08	0.98	1.20
Post 16 non-degree	1557	709 (13.3)	848 (13.1)	(54.5)		0.99	0.88	1.11
Degree/professional qual	2570	1210 (22.7)	1360 (21.0)	(52.9)		0.93	0.84	1.02
No code required	404	172 (3.2)	232 (3.6)	(57.4)		1.11	0.91	1.37
Occupation					0.779			
Managers/senior officials	797	366 (6.9)	431 (6.7)	(54.1)		1.00		
Professional occupation	1499	717 (13.4)	782 (12.1)	(52.2)		0.93	0.78	1.10
Associated professional/technical occupations	844	379 (7.1)	465 (7.2)	(55.1)		1.04	0.86	1.26
Admin/secretarial	1392	614 (11.5)	778 (12.0)	(55.9)		1.08	0.90	1.28
Skilled trades	1601	721 (13.5)	880 (13.6)	(55.0)		1.04	0.87	1.23
Personal services	898	399 (7.5)	499 (7.7)	(55.6)		1.06	0.88	1.29
Sales/customer service	794	357 (6.7)	437 (6.8)	(55.0)		1.04	0.85	1.27
Process, plant, machines	1023	466 (8.7)	557 (8.6)	(54.4)		1.02	0.84	1.22
Elementary occupation	1594	713 (13.3)	881 (13.6)	(55.3)		1.05	0.88	1.24
No occupation	1361	609 (11.4)	752 (11.6)	(55.3)		1.05	0.88	1.25

Continued

Table 4: Continued

	Total	Not within 31 days (column) N=5341	Within 31 days (column) N=6462	Within target (row)	Chi	Unadjusted odds ratio	95% C.I.	
Variable	**N**	**N (%)**	**N (5)**	**(%)**	**p-value**	**OR**	**lower**	**upper**
Hours per week in main job					0.111			
<=15	1048	442 (8.3)	606 (9.4)	(57.8)		1.00		
16-30	2415	1093 (20.5)	1322 (20.5)	(54.7)		0.88	0.76	1.02
31-48	6041	2745 (51.4)	3296 (51.0)	(54.6)		0.88	0.77	1.00
49+	1725	813 (15.2)	912 (14.1)	(52.9)		0.82	0.70	0.96
Not applicable	574	248 (4.6)	326 (5.0)	(56.8)		0.96	0.78	1.18
Travel to work					0.521			
No place of work	7718	3512 (65.8)	4206 (65.1)	(54.5)		1.00		
Work at home	607	262 (4.9)	345 (5.3)	(56.8)		1.10	0.93	1.30
Public transport	347	154 (2.9)	193 (3.0)	(55.6)		1.05	0.84	1.30
Car/motorbike	2554	1138 (21.3)	1416 (21.9)	(55.4)		1.04	0.95	1.14
other	577	275 (5.1)	302 (4.7)	(52.3)		0.92	0.77	1.09
Family type					0.576			
Single	3293	1489 (27.9)	1804 (27.9)	(54.8)		1.00		
Lone parent	560	246 (4.6)	314 (4.9)	(56.1)		1.05	0.88	1.26
Couple no children	6184	2782 (52.1)	3402 (52.6)	(55.0)		1.01	0.93	1.10
Couple children	1766	824 (15.4)	942 (14.6)	(53.3)		0.94	0.84	1.06
Living arrangements					0.811			
Couple	7882	3574 (66.9)	4308 (66.7)	(54.7)		1.00		
Single	833	368 (6.9)	465 (7.2)	(55.8)		1.05	0.91	1.21
Previous defined as couple	3088	1399 (26.2)	1689 (26.1)	(54.7)		1.00	0.92	1.09
Carers in house					0.498			
None	9541	4303 (80.6)	5238 (81.1)	(54.9)		1.00		
At least one	2262	1038 (19.4)	1224 (18.9)	(54.1)		0.97	0.88	1.06
Hours providing care for others per week			0.323					
Not a carer	10440	4715 (88.3)	5725 (88.6)	(54.8)		1.00		
1-19hrs/week	751	359 (6.7)	392 (6.1)	(52.2)		0.90	0.76	1.04
20-49 hrs/week	186	76 (1.4)	110 (1.7)	(59.1)		1.19	0.89	1.60
50+ hrs/week	426	191 (3.6)	235 (3.6)	(55.2)		1.01	0.83	1.23
Number of cars in household					0.820			
None	2529	1133 (21.2)	1396 (21.6)	(55.2)		1.00		
1	5665	2579 (48.3)	3086 (47.8)	(54.5)		0.97	0.88	1.07
2+	3609	1629 (30.5)	1980 (30.6)	(54.9)		0.99	0.89	1.09
Accommodation					0.554			
Detached	4475	2043 (38.3)	2432 (37.6)	(54.3)		1.00		
Semi detached	3427	1509 (28.3)	1918 (29.7)	(56.0)		1.07	0.98	1.17
Terraced	1902	877 (16.4)	1025 (15.9)	(53.9)		0.98	0.88	1.09
Purpose built flat	1799	821 (15.4)	978 (15.1)	(54.4)		1.00	0.90	1.17
Other	200	91 (1.7)	109 (1.7)	(54.5)		1.01	0.76	1.34
Heating					0.176			
No	311	129 (2.4)	182 (2.8)	(58.5)		1.00		
Yes	11492	5212 (97.6)	6280 (97.2)	(54.6)		0.85	0.68	1.07
Housing type					0.650			
Owned outright	6360	2870 (53.7)	3490 (54.0)	(54.9)		1.00		
Mortgaged	2225	995 (18.6)	1230 (19.0)	(55.3)		1.02	0.92	1.12
Rented	2912	1328 (24.9)	1584 (24.5)	(54.4)		0.98	0.90	1.07
Other	306	148 (2.8)	158 (2.4)	(51.6)		0.88	0.70	1.1

[1]The dimensions of deprivation used to classify households are indicators based on four selected household characteristics. A household is deprived in a dimension if they meet one or more of the following conditions: employment: where any member of a household, who is not a full-time student, is either unemployed or long-term sick, education: no person in the household has at least level 2 education (see highest level of qualification), and no person aged 16-18 is a full-time student, health and disability: any person in the household has general health that is 'bad' or 'very bad' or has a long term health problem, and housing: the household's accommodation is either overcrowded, with an occupancy rating -1 or less, or is in a shared dwelling, or has no central heating. A household is classified as being deprived in none, or one to four of these dimensions in any combination (Scotland's Census, 2018).

Table 5: Census characteristics by all cause one-year mortality

	Alive N=8380	Dead 1 year N=2271		Dead (row)	Unadjusted odds ratio (OR)	95% confidence interval	
Variable	**N (%)**	**N (%)**	**p-value**	**%**	**OR**	**lower**	**upper**
Ethnic group			0.755				
White-Scottish	7236 (86.3)	1971 (86.8)		21.4	1.00		
White-Other UK/Irish	987 (11.8)	257 (11.3)		20.7	0.96	0.85	1.10
White-other European	94 (1.1)	29 (1.3)		23.6	1.12	0.78	1.62
Non-white	63 (0.8)	14 (0.6)		18.2	0.81	0.48	1.37
Country of birth			0.128				
United Kingdom	8106 (96.7)	2211 (97.4)		21.4	1.00		
Non-UK	274 (3.3)	60 (2.6)		18.0	0.82	0.64	1.06
Religion			0.330				
None	2187 (26.1)	558 (24.6)		20.3	1.00		
Declared	5642 (67.3)	1558 (68.6)		21.6	1.08	0.98	1.18
Not stated	551 (6.6)	155 (6.8)		22.0	1.09	0.91	1.31
Marital status			0.832				
Single	712 (8.5)	184 (8.1)		20.5	1.00		
Married	5213 (62.2)	1421 (62.6)		21.4	1.04	0.89	1.22
Separated/Divorced/Widowed/Surviving	2455 (29.3)	666 (29.3)		21.3	1.04	0.88	1.22
General Health			0.982				
Good	4982 (59.5)	1355 (59.7)		21.4	1.00		
Fair	2440 (29.1)	657 (28.9)		21.2	0.99	0.90	1.09
Bad	958 (11.4)	259 (11.4)		21.3	0.99	0.87	1.14
Disability			0.977				
No	4916 (58.7)	1333 (58.7)		21.3	1.00		
Yes	3464 (41.3)	938 (41.3)		21.3	1.00	0.92	1.09
Long term illness (adults)			0.420				
none	4071 (48.6)	1127 (49.6)		21.7	1.00		
1	3129 (37.3)	814 (35.8)		20.6	0.95	0.86	1.04
2+	1180 (14.1)	330 (14.5)		21.9	1.01	0.89	1.14
Deprivation[1]			0.155				
None	2130 (25.4)	564 (24.8)		20.9	1.00		
1 dimension	3183 (38.0)	906 (39.9)		22.2	1.06	0.96	1.18
2 dimensions	2488 (29.7)	671 (29.5)		21.2	1.02	0.91	1.14
3 or 4 dimensions	579 (6.9)	130 (5.5)		22.4	0.88	0.73	1.07
Economically active			0.435				
Employed	2871 (34.3)	798 (35.1)		21.7	1.00		
not employed	5509 (65.7)	1473 (64.9)		21.1	0.97	0.86	1.06
Highest qualification			0.205				
None	3733 (44.5)	1013 (44.6)		21.3	1.00		
Standard grade/GCSE	1411 (16.8)	417 (18.4)		22.8	1.09	0.97	1.22
Post 16 non-degree	1116 (13.3)	277 (12.2)		19.9	0.91	0.80	1.05
Degree/professional qual	1832 (21.9)	499 (22.0)		21.4	1.00	0.90	1.12
No code required	288 (3.4)	65 (2.9)		18.4	0.85	0.66	1.09
Occupation			0.996				
Managers/senior officials	563 (6.7)	156 (6.9)		21.7	1.00		
Professional occupations	1080 (12.9)	284 (12.5)		20.8	0.95	0.78	1.15
Associated professional/technical occupations	588 (7.0)	163 (7.2)		21.7	0.99	0.80	1.24
Admin/secretarial	997 (11.9)	272 (12.0)		21.4	0.98	0.80	1.19
Skilled trades	1118 (13.3)	318 (14.0)		22.1	1.02	0.84	1.24
Personal services	648 (7.7)	176 (7.7)		21.4	0.97	0.79	1.21
Sales/customer service	573 (6.8)	156 (6.9)		21.4	0.97	0.78	1.21
Process, plant, machines	728 (8.7)	193 (8.5)		21.0	0.96	0.78	1.18
Elementary occupation	1119 (13.4)	306 (13.5)		21.5	0.98	0.81	1.19
No occupation	966 (11.5)	247 (10.5)		20.4	0.93	0.76	1.14
Hours in main job			0.534				
<=15	753 (9.0)	192 (8.5)		20.3	1.00		

Continued

Table 5: Continued

	Alive N=8380	Dead 1 year N=2271		Dead (row)	Unadjusted odds ratio (OR)	95% confidence interval	
Variable	**N (%)**	**N (%)**	**p-value**	**%**	**OR**	**lower**	**upper**
16–30	1702 (20.3)	497 (21.9)		22.6	1.12	0.95	1.32
31–48	4304 (51.4)	1157 (50.9)		21.2	1.05	0.90	1.22
49+	1219 (14.5)	320 (14.1)		20.8	1.02	0.85	1.22
Not applicable	402 (4.8)	105 (4.6)		20.7	1.02	0.80	1.30
Travel to work			0.544				
No place of work	5491 (65.5)	1461 (64.3)		21.0			
Work at home	418 (5.0)	118 (5.2)		22.0	1.05	0.87	1.27
Public transport	236 (2.8)	78 (3.4)		24.8	1.20	0.96	1.51
Car/motorbike	1824 (21.8)	505 (22.2)		21.7	1.03	0.94	1.15
other	411 (4.9)	109 (4.8)		21.0	0.99	0.81	1.20
Family type			0.226				
Single	2340 (27.9)	636 (28.0)		21.4	1.00		
Lone parent	405 (4.8)	99 (4.4)		19.6	0.91	0.74	1.13
Couple no children	4358 (52.0)	1222 (53.8)		21.9	1.03	0.93	1.13
Couple children	1277 (15.2)	314 (13.8)		19.7	0.92	0.80	1.05
Living arrangements			0.905				
Couple	5585 (66.6)	1523 (67.1)		21.4	1.00		
Single	590 (7.0)	161 (7.1)		21.4	1.00	0.85	1.18
Previous identify as couple	2205 (26.3)	587 (25.8)		21.0	0.98	0.90	1.08
Carers in house			0.449				
No carers	6775 (80.8)	1820 (80.1)		21.2	1.00		
At least one	1605 (19.2)	451 (19.9)		21.9	1.05	0.95	1.16
Hours providing care for others per week			0.400				
Not a carer	7419 (88.5)	1997 (87.9)		21.2	1.00		
1–19hrs/week	517 (6.2)	161 (7.1)		23.7	1.15	0.98	1.34
20–49 hrs/week	134 (1.6)	32 (1.4)		19.3	0.90	0.63	1.27
50+ hrs/week	310 (3.7)	81 (3.6)		20.7	0.98	0.78	1.22
Number of cars in household			0.992				
None	1799 (21.5)	488 (21.5)		21.3	1.00		
1	4008 (47.8)	1083 (47.7)		21.3	0.99	0.89	1.11
2+	2573 (30.7)	700 (30.8)		21.4	1.00	0.89	1.12
Accommodation			0.652				
Detached	3155 (37.6)	875 (38.5)		21.7	1.00		
Semi detached	2448 (29.2)	645 (28.4)		20.9	0.96	0.87	1.07
Terraced	1350 (16.1)	372 (16.4)		21.6	0.99	0.88	1.13
Purpose built flat	1295 (15.5)	336 (14.8)		20.6	0.95	0.84	1.07
Other	132 (1.6)	43 (1.9)		24.6	1.15	0.85	1.56
Heating			0.307				
No	232 (2.8)	54 (2.4)		18.9	1.00		
Yes	8148 (97.2)	2217 (97.6)		21.4	1.15	0.88	1.51
Housing type			0.341				
Owned outright	4490 (53.6)	1220 (53.7)		21.4	1.00		
Mortgaged	1583 (18.9)	421 (18.5)		21.0	0.98	0.88	1.09
Rented	2073 (24.7)	581 (25.6)		21.9	1.03	0.93	1.13
Other	234 (2.8)	49 (2.2)		17.3	0.79	0.59	1.05

[1]The dimensions of deprivation used to classify households are indicators based on four selected household characteristics. A household is deprived in a dimension if they meet one or more of the following conditions: employment: where any member of a household, who is not a full-time student, is either unemployed or long-term sick, education: no person in the household has at least level 2 education (see highest level of qualification), and no person aged 16–18 is a full-time student, health and disability: any person in the household has general health that is 'bad' or 'very bad' or has a long term health problem, and housing: the household's accommodation is either overcrowded, with an occupancy rating -1 or less, or is in a shared dwelling, or has no central heating. A household is classified as being deprived in none, or one to four of these dimensions in any combination (Scotland's Census, 2018).

Table 6: Patient outcomes and relationships of travelling time from home to GP and cancer treatment centre

Outcome = Timely treatment (treatment began within 62 days of GP referral)						
	Travelling time (minutes)	**<5.0**	**5.0–9.9**	**10.0–14.9**	**>15.0**	**Islands**
Time from home to GP practice	N	6165	2989	1016	758	875
	N event (%)	4134 (67.1)	1934 (64.7)	642 (63.2)	492 (64.9)	605 (69.1)
	Unadjusted OR (95% CI)	1.00	0.90 (0.82, 0.99)	0.84 (0.73, 0.97)	0.91 (0.78, 1.06)	1.10 (0.94, 1.28)
	Adjusted[1] OR (95%CI)	1.00	0.90 (0.82, 0.99)	0.83 (0.72, 0.96)	0.91 (0.77 (1.08)	1.07 (0.91, 1.26)
	Adjusted[2] OR (95%CI)	1.00	0.89 (0.80, 0.99)	0.84 (0.72, 0.99)	0.85 (0.71, 1.02)	1.03 (0.86, 1.23)
	Adjusted[3] OR (95%CI)	1.00	0.89 (0.80, 0.98)	0.84 (0.72, 0.99)	0.85 (0.71, 1.03)	1.02 (0.86, 1.22)
	Adjusted[4] OR (95%CI)	1.00	0.89 (0.80, 0.98)	0.84 (0.72, 0.99)	0.86 (0.71, 1.03)	1.04 (0.87, 1.24)
	Travelling time (minutes)	**<15.0**	**15.0–29.9**	**30.0–59.9**	**>60.0**	**Islands**
Time from home to cancer treatment centre	N	3920	1695	2404	2909	875
	N event (%)	2524 (64.4)	1129 (66.6)	1566 (65.1)	1983 (68.2)	605 (69.1)
	Unadjusted OR (95% CI)	1.00	1.10 (0.97, 1.24)	1.03 (0.93, 1.15)	**1.18 (1.07, 1.31)**	**1.24 (1.06, 1.45)**
	Adjusted[1] OR (95%CI)	1.00	**1.16 (1.02. 1.32)**	1.10 (0.97, 1.25)	**1.26 (1.12, 1.42)**	**1.32 (1,11, 1.58)**
	Adjusted[2] OR (95%CI)	1.00	1.06 (0.92, 1.23)	1.11 (0.97, 1.28)	**1.41 (1.23, 1.60)**	**1.32 (1.09, 1.60)**
	Adjusted[3] OR (95%CI)	1.00	1.07 (0.93, 1.23)	1.12 (0.98, 1.29)	**1.42 (1.24, 1.62)**	**1.33 (1.09, 1.61)**
	Adjusted[4] OR (95%CI)	1.00	1.09 (0.85, 1.25)	1.13 (0.98, 1.29)	**1.39 (1.22, 1.57)**	**1.31 (1.09, 1.59)**
Outcome = Treatment within 31 days of diagnosis						
	Travelling time (minutes)	**<5.0**	**5.0–9.9**	**10.0–14.9**	**>15.0**	**Islands**
Time from home to GP practice	N	6165	2989	1016	758	875
	N event (%)	3384 (54.9)	1603 (53.6)	562 (55.3)	388 (51.2)	525 (60.0)
	Unadjusted OR (95% CI)	1.00	0.95 (0.87, 1.04)	1.02 (0.89. 1.16)	0.86 (0.74, 1.00)	**1.23 (1.07, 1.42**)
	Adjusted[1] OR (95%CI)	1.00	0.96 (0.87, 1.05)	1.05 (0.91, 1.20)	0.91 (0.77, 1.07)	**1.22 (1.05, 1.42)**
	Adjusted[2] OR (95%CI)	1.00	0.98 (0.89, 1.08)	1.14 (0.98, 1.33)	0.88 (0.74, 1.04)	**1.24 (1.05, 1.46)**
	Adjusted[3] OR (95%CI)	1.00	0.98 (0.89, 1.08)	1.14 (0.98, 1.32)	0.88 (0.74, 1.05)	**1.24 (1.06, 1.46)**
	Adjusted[4] OR (95%CI)	1.00	0.98 (0.89, 1.07)	1.14 (0.98, 1.32)	088 (0.74, 1.05)	**1.26 (1.07, 1.48)**
	Travelling time (minutes)	**<15.0**	**15.0–29.9**	**30.0–59.9**	**>60.0**	**Islands**
Time from home to cancer treatment centre	N	3920	1695	2404	2909	875
	N event (%)	2088 (53.3)	927 (54.7)	1274 (53.0)	1648 (56.7)	525 (60.0)
	Unadjusted OR (95% CI)	1.00	1.06 (0.94, 1.19)	0.99 (0.89, 1.09)	**1.15 (1.04, 1.26)**	**1.32 (1.13, 1.53)**
	Adjusted[1] OR (95%CI)	1.00	1.12 (0.99, 1.27)	1.03 (0.91, 1.17)	**1.15 (1.03, 1.29)**	**1.35 (1.14, 1.59)**
	Adjusted[2] OR (95%CI)	1.00	1.09 (0.96, 1.25)	1.01 (0.89, 1.15)	**1.20 (1.07, 1.36)**	**1.36 (1.14, 1.62)**
	Adjusted[3] OR (95%CI)	1.00	1.10 (0.96, 1.25)	1.02 (0.90, 1.15)	**1.20 (1.07, 1.36)**	**1.36 (1.14, 1.63)**
	Adjusted[4] OR (95%CI)	1.00	1.10 (0.97, 1.25)	1.02 (0.90, 1.15)	**1.21 (1.08, 1.35)**	**1.37 (1.15, 1.63)**

Continued

Table 6: Continued

Outcome = Diagnosis and treatment started on same or next day						
	Travelling time (minutes)	**<5.0**	**5.0–9.9**	**10.0–14.9**	**>15.0**	**Islands**
Time from home to GP practice	N	6165	2989	1016	758	875
	N event (%)	941 (15.3)	443 (14.8)	125 (12.3)	123 (16.2)	181 (20.7)
	Unadjusted OR (95% CI)	1.00	0.97 (0.85, 1.09)	0.78 (0.64, 0.95)	1.08 (0.88, 1.32)	**1.45 (1.21, 1.73)**
	Adjusted[1] OR (95%CI)	1.00	0.95 (0.84, 1.07)	0.73 (0.59, 0.90)	0.99 (0.80, 1.23)	**1.38 (1.15, 1.67)**
	Adjusted[2] OR (95%CI)	1.00	0.99 (0.85, 1.17)	0.78 (0.60, 1.02)	0.96 (0.72, 1.27)	**1.60 (1.25, 2.05)**
	Adjusted[3] OR (95%CI)	1.00	0.99 (0.85, 1.17)	0.77 (0.59, 1.00)	0.96 (0.73. 1.28)	**1.59 (1.24, 2.04)**
	Adjusted[4] OR (95%CI)	1.00	0.99 (0.84, 1.16)	0.77 (0.59, 1.00)	0.96 (0.72, 1.27)	**1.63 (1.28, 2.09)**
	Travelling time (minutes)	**<15.0**	**15.0–29.9**	**30.0–59.9**	**>60.0**	**Islands**
Time from home to cancer treatment centre	N	3920	1695	2404	2909	875
	N event (%)	546 (13.9)	261 (15.4)	357 (14.9)	468 (16.1)	181 (20.7)
	Unadjusted OR (95% CI)	1.00	1.12 (0.96, 1.32)	1.08 (0.93, 1.24)	**1.18 (1.04, 1.35)**	**1.61 (1.33, 1.94)**
	Adjusted[1] OR (95%CI)	1.00	1.09 (0.92, 1.30)	1.06 (0.90, 1.25)	1.15 (0.98, 1.34)	**1.59 (1.29, 1.96)**
	Adjusted[2] OR (95%CI)	1.00	1.11 (0.89, 1.38)	0.95 (0.77, 1.18)	1.13 (0.93, 1.37)	**1.74 (1.32, 2.29)**
	Adjusted[3] OR (95%CI)	1.00	1.12 (0.90, 1.39)	0.95 (0.77, 1.18)	1.13 (0.92, 1.37)	**1.74 (1.32, 2.29)**
	Adjusted[4] OR (95%CI)	1.00	1.10 (0.89, 1.36)	0.96 (0.78, 1.18)	1.19 (0.98, 1.43)	**1.81 (1.39, 2.37)**

(GP = general practitioner; OR = odds ratio; CI = confidence interval).

[1] sociodemographic factors only: age at diagnosis, sex, SIMD, UR code, + Census variables: ethnic group, hours main job, heating, country of birth, housing-type.

[2] Repeat NASCAR on reduced Census sample (n = 11803) adjusted for age, sex, SIMD UR code, urgency/referral status, cancer type, procedure type, Charlson comorbidity index (CCI) score, treatment type and metastatic cancer.

[3] Analysis as model 2 but now including Census variables (ethnic group, hours in main job, heating, birth in UK and housing type), n = 11803.

[4] as model 3 but without SIMD deprivation.

Table 7: Patient mortality outcomes with travelling time from home to GP and cancer treatment centre

Outcome = Overall all-cause mortality (n = 11803)						
	Travelling time (minutes)	**<5.0**	**5.0–9.9**	**10.0–14.9**	**>15.0**	**Islands**
Time for home to GP practice	N	6165	2989	1016	758	875
	N event (%)	1873 (30.4)	837 (28.0)	267 (26.3)	201 (26.5)	245 (28.0)
	Unadjusted OR (95% CI)	1.00	0.91 (0.83, 0.98)	0.84 (0.74, 0.95)	0.83 (0.72, 0.96)	0.91 (0.80, 1.04)
	Adjusted[1] OR (95%CI)	1.00	0.93 (0.85, 1.01)	1.02 (0.89, 1.16)	0.79 (0.68, 0.92)	0.92 (0.80, 1.06)
	Adjusted[2] OR (95%CI)	1.00	0.93 (0.85, 1.01)	1.01 (0.88, 1.16)	0.79 (0.68, 0.92)	0.92 (0.80, 1.06)
	Adjusted[3] OR (95%CI)	1.00	0.93 (0.86, 1.01)	1.01 (0.89, 1.16)	0.79 (0.68, 0.92)	0.92 (0.80, 1.05)
	Adjusted[4] OR (95%CI)	1.00	0.92 (0.84, 1.00)	0.92 (0.81, 1.06)	0.98 (0.84, 1.15)	0.92 (0.80, 1.05)
	Travelling time (minutes)	**< 15.0**	**15.0–29.9**	**30.0–59.9**	**>60.0**	**Islands**
Time from home to cancer treatment centre	N	3920	1695	2404	2909	875
	N event (%)	1157 (29.5)	440 (26.0)	693 (28.8)	888 (30.5)	245 (28.0)
	Unadjusted OR (95% CI)	1.00	0.85 (0.76, 0.95)	0.96 (0.88, 1.06)	1.04 (0.96, 1.14)	0.94 (0.82, 1.08)
	Adjusted[1] OR (95%CI)	1.00	0.97 (0.86, 1.09)	**1.16 (1.04, 1.30)**	**1.21 (1.09, 1.33)**	1.08 (0.93, 1.26)
	Adjusted[2] OR (95%CI)	1.00	0.97 (0.86, 1.09)	**1.16 (1.04, 1.29)**	**1.21 (1.09, 1.34)**	1.08 (0.93, 1.26)
	Adjusted[3] OR (95%CI)	1.00	0.95 (0.85, 1.06)	**1.14 (1.02, 1.27)**	**1.18 (1.07, 1.30)**	1.05 (0.90, 1.21)
	Adjusted4 OR (95%CI)	1.00	1.05 (0.93, 1.78)	**1.09 (0.98, 1.21)**	**1.06 (0.96, 1.17)**	1.00 (0.86, 1.17)
Outcome = All-cause mortality to one year (n = 10651)						
	Travelling time (minutes)	**<5.0**	**5.0–9.9**	**10.0–14.9**	**>15.0**	**Islands**
Time from home to GP practice	N	5548	2702	915	680	806
	N event (%)	1256 (22.6)	550 (20.4)	166 (18.1)	123 (18.1)	176 (21.8)
	Unadjusted OR (95% CI)	1.00	0.89 (0.80, 0.98)	0.78 (0.66, 0.92)	0.77 (0.64, 0.92)	0.96 (0.82, 1.13)
	Adjusted[1] OR (95%CI)	1.00	0.90 (0.76, 1.06)	0.98 (0.80, 1.18)	0.97 (0.82, 1.15)	0.90 (0.81, 1.00)
	Adjusted[2] OR (95%CI)	1.00	0.91 (0.82, 1.01)	1.01 (0.85, 1.19)	0.74 (0.61, 0.90)	0.97 (0.82, 1.14)
	Adjusted[3] OR (95%CI)	1.00	0.91 (0.82, 1.00)	1.00 (0.84, 1.18)	0.74 (0.61, 0.90)	0.96 (0.82, 1.14)
	Adjusted[4] OR (95%CI)	1.00	0.92 (0.83, 1.02)	1.01 (0.85, 1.19)	0.73 (0.61, 0.89)	0.97 (0.82, 1.14)
	Travelling time (minutes)	**<15.0**	**15.0–29.9**	**30.0–59.9**	**>60.0**	**Islands**
Time from home to cancer treatment centre	N	3537	1542	2156	2610	806
	N event (%)	774 (21.9)	287 (18.6)	445 (20.6)	589 (22.6)	176 (21.8)
	Unadjusted OR (95% CI)	1.00	0.83 (0.72, 0.95)	0.93 (0.82, 1.04)	1.04 (0.93, 1.15)	0.99 (0.85, 1.18)
	Adjusted[1] OR (95%CI)	1.00	1.10 (0.96, 1.26)	1.05 (0.93, 1.19)	1.08 (0.90, 1.29)	1.12 (0.97, 1.30)
	Adjusted[2] OR (95%CI)	1.00	1.05 (0.91, 1.22)	**1.24 (1.09, 1.42)**	**1.22 (1.08,1.38)**	1.18 (0.99, 1.42)
	Adjusted[3] OR (95%CI)	1.00	1.05 (0.91, 1.21)	**1.24 (1.09, 1.42)**	**1.23 (1.09, 1.39)**	1.18 (0.99, 1.42)
	Adjusted[4] OR (95%CI)	1.00	0.97 (0.84, 1.11)	**1.19 (1.04, 1.35)**	**1.20 (1.06, 1.35)**	1.13 (0.95, 1.35)

Continued

Table 7: Continued

Outcome = Cancer-specific mortality to one year (n = 10651)						
	Travelling time (minutes)	**<5.0**	**5.0–9.9**	**10.0–14.9**	**>15.0**	**Islands**
Time from home to GP practice	N	5548	2702	915	680	806
	N event (%)	1127 (20.3)	499 (18.5)	155 (16.9)	114 (16.8)	155 (19.2)
	Unadjusted OR (95% CI)	1.00	0.90 (0.81, 1.00)	0.81 (0.68, 0.96)	0.79 (0.65, 0.96)	0.95 (0.80, 1.12)
	Adjusted[1] OR (95%CI)	1.00	0.91 (0.81, 1.01)	0.93 (0.78, 1.10)	0.99 (0.81, 1.21)	0.95 (0.80, 1.13)
	Adjusted[2] OR (95%CI)	1.00	0.92 (0.82, 1.02)	1.06 (0.89, 1.26)	0.74 (0.61, 0.91)	0.94 (0.79, 1.12)
	Adjusted[3] OR (95%CI)	1.00	0.91 (0.82, 1.02)	1.05 (0.88, 1.25)	0.74 (0.61, 0.91)	0.94 (0.79, 1.12)
	Adjusted[4] OR (95%CI)	1.00	0.93 (0.83, 1.04)	1.06 (0.89, 1.26)	0.74 (0.61, 0.91)	0.94 (0.79, 1.12)
	Travelling time (minutes)	**<15.0**	**15.0–29.9**	**30.0–59.9**	**>60.0**	**Islands**
Time from home to cancer treatment centre	N	3537	1542	2156	2610	806
	N event (%)	697 (19.7)	261 (16.9)	406 (18.8)	531 (20.3)	155 (19.2)
	Unadjusted OR (95% CI)	1.00	0.84 (0.73, 0.96)	0.94 (0.83, 1.06)	1.04 (0.93, 1.16)	0.98 (0.82, 1.16)
	Adjusted[1] OR (95%CI)	1.00	1.12 (0.96, 1.31)	1.10 (0.96, 1.27)	1.05 (0.92, 1.19)	1.05 (0.87, 1.27)
	Adjusted[2] OR (95%CI)	1.00	1.05 (0.90, 1.23)	**1.25 (1.08, 1.43)**	**1.22 (1.07, 1.39)**	1.14 (0.95, 1.38)
	Adjusted[3] OR (95%CI)	1.00	1.05 (0.89, 1.22)	**1.24 (1.08, 1.43)**	**1.22 (1.08, 1.39)**	1.14 (0.94, 1.38)
	Adjusted[4] OR (95%CI)	1.00	0.97 (0.84, 1.13)	**1.19 (1.04, 1.37)**	**1.19 (1.05, 1.35)**	1.09 (0.91, 1.31)

(GP = general practitioner; OR = odds ratio; CI = confidence interval)

[1] sociodemographic factors only: age at diagnosis, sex, SIMD, UR code, + Census variables: ethnic group, hours main job, heating, country of birth, housing-type.

[2]Repeat NASCAR on reduced Census sample (n =11803) adjusted for age, sex, urban/rural code 2, deprivation, urgency/referral status, cancer type, procedure type, Charlson comorbidity index (CCI) score, treatment type and metastatic cancer.

[3] Analysis including Census variables (ethnic group, hours in main job, heating, birth in UK and housing type), n = 11803.

[4] as model 2 but without SIMD deprivation.