Cancer incidence, treatment, and survival in the prison population compared with the general population in England: a population-based, matched cohort study

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Summary

Background The growing and ageing prison population in England makes accurate cancer data of increasing importance for prison health policies. This study aimed to compare cancer incidence, treatment, and survival between patients diagnosed in prison and the general population.

Methods In this population-based, matched cohort study, we used cancer registration data from the National Cancer Registration and Analysis Service in England to identify primary invasive cancers and cervical cancers in situ diagnosed in adults (aged ≥18 years) in the prison and general populations between Jan 1, 1998, and Dec 31, 2017. Ministry of Justice and Office for National Statistics population data for England were used to calculate age-standardised incidence rates (ASIR) per year and age-standardised incidence rate ratios (ASIRR) for the 20-year period. Patients diagnosed with primary invasive cancers (ie, excluding cervical cancers in situ) in prison between Jan 1, 2012, and Dec 31, 2017 were matched to individuals from the general population and linked to hospital and treatment datasets. Matching was done in a 1:5 ratio according to 5-year age group, gender, diagnosis year, cancer site, and disease stage. Our primary objectives were to compare the incidence of cancer (1998–2017); the receipt of treatment with curative intent (2012–17 matched cohort), using logistic regression adjusted for matching variables (excluding cancer site) and route to diagnosis; and overall survival following cancer diagnosis (2012–17 matched cohort), using a Cox proportional hazards model adjusted for matching variables (excluding cancer site) and route to diagnosis, with stratification for the receipt of any treatment with curative intent.

Findings We identified 2015 incident cancers among 1964 adults (1556 [77·2%] men and 459 [22·8%] women) in English prisons in the 20-year period up to Dec 31, 2017. The ASIR for cancer for men in prison was initially lower than for men in the general population (in 1998, ASIR 119·33 per 100 000 person-years [95% CI 48·59–219·16] *vs* 746·97 per 100 000 person-years [742·31–751·66]), but increased to a similar level towards the end of the study period (in 2017, 856·85 per 100 000 person-years [675·12–1060·44] *vs* 788·59 per 100 000 person-years [784·62–792·57]). For women, the invasive cancer incidence rate was low and so ASIR was not reported for this group. Over the 20-year period, the incidence of invasive cancer for men in prison increased (incidence rate ratio per year, 1·05 [95% CI 1·04–1·06], during 1999–2017 compared with 1998). ASIRRs showed that over the 20-year period, overall cancer incidence was lower in men in prison than in men in the general population (ASIRR 0·76 [95% CI 0·73–0·80]). The difference was not statistically significant for women (ASIRR 0·83 [0·68–1·00]). Between Jan 1, 2012, and Dec 31, 2017, patients diagnosed in prison were less likely to undergo curative treatment than matched patients in the general population (274 [32·3%] of 847 patients *vs* 1728 [41·5%] of 4165; adjusted odds ratio (OR) 0·72 [95% CI 0·60–0·85]). Being diagnosed in prison was associated with a significantly increased risk of death on adjustment for matching variables (347 deaths during 2021·9 person-years in the prison cohort *vs* 1626 deaths during 10 944·2 person-years in the general population; adjusted HR 1·16 [95% CI 1·03–1·30]); this association was partly explained by stratification by curative treatment and further adjustment for diagnosis route (adjusted HR 1·05 [0·93–1·18]).

Interpretation Cancer incidence increased in people in prisons in England between 1998 and 2017, with patients in prison less likely to receive curative treatments and having lower overall survival than the general population. The association with survival was partly explained by accounting for differences in receipt of curative treatment and adjustment for diagnosis route. Improved routine cancer surveillance is needed to inform prison cancer policies and decrease inequalities for this under-researched population.

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Research in context

Evidence before this study

People in prison have poorer physical and mental health than the general population. Most research on prison health has focussed on communicable disease, mental health, and substance use, rather than on non-communicable diseases such as cancer, which affect ageing populations. We searched Web of Science, Scopus, CINAHL, MEDLINE, and PsycINFO for publications in English available between March 1, 2019, and June 30, 2023, using the search terms, "prison", "incarcerated", "jail", "prisoner", "offender", "inmate", "cancer", "neoplasm", "malignancy", "oncology", "tumour", "carcinoma", "healthcare", "diagnosis", "illness", and "experiences". Our search found no studies of cancer incidence and none of cancer survival for any national prison population.

Added value of this study

Our study using national English cancer registry data showed that the number of cancer diagnoses and its overall incidence

in prisons increased during the 20-year period from Jan 1, 1998, to Dec 31, 2017. Data on diagnoses made between Jan 1, 2012, and Dec 31, 2017, when information on treatment had improved due to the routine receipt of detailed data from English hospital trusts, showed that people with cancer diagnosed in prison were less likely to receive treatments with curative intent and had lower overall survival than those in the general population. For overall survival, almost half of the association was explained by stratification by treatment with curative intent.

Implications of all the available evidence

To our knowledge, this study provides the first national-level data to inform cancer policies for the early detection, diagnosis, and treatment of cancer for the entire adult prison population. Our study also highlights the need for active surveillance and investigation to ensure equitable access to cancer services.

Introduction

The UK has the largest prison population in western Europe and one of the highest rates of individuals serving life sentences.[1] In England and Wales, the prison population has doubled in size since 1990, and remained steady during the past decade,[2,3] with around 88 000 people now being incarcerated at any one time.[4] These individuals often have considerable health needs and prison health research has so far focussed on studying mental health conditions, substance abuse, and infectious diseases.[5,6] Non-communicable diseases are not well studied, despite evidence that the English prison population is ageing rapidly and has health behaviours that increase the risk of these conditions.[5,7] Key risk factors for cancer, such as smoking, drug and alcohol use, obesity, and viral infections, are more prevalent in prison populations than in the general population.[5,6] Additionally, reports by the Independent Prison Ombudsman of England and Wales have highlighted that there is no strategic approach to meeting the health needs of the growing number of older people in prison.[8] The proportion of adults older than 50 years in prison increased from 7% in 2002 to 17% in 2020.[3] Cancer is therefore a public health problem of increasing importance for prison health services, and accurate data are needed to plan cancer prevention, screening, diagnostic and treatment services, and the care of patients in prison.

A recent WHO review found no studies reporting cancer incidence in national prison populations, with most previous studies reporting data for single regional states or prisons and associated screening programmes.[9] Another review of US studies found 16 papers reporting cancer prevalence or mortality in prison, compared with one reporting incidence.[10] In England, cancer diagnoses

made in prison are not published as part of routine cancer surveillance, but cancer registry[11] and National Health Service (NHS) treatment data[12] can be used to identify diagnoses and procedures by using the unique residential postcodes of prisons from which patients were admitted to hospital. Previous use of this method identified 158 incident cancer diagnoses between 1986 and 2005 in people incarcerated in seven adult prisons in London.[11] In that study, lung cancer was the most common diagnosis in men and cervical cancer in situ the most common in women,[11] consistent with US regional population-based studies.[10] A study of men in prison between 2000 and 2012 in Ontario, Canada, found that lung, prostate, colorectal, and head and neck cancers were more common in those men than in the general male population.[13] Lung, cervical, and liver cancers were also more common among women in prison than in the female general population.[13] However, most studies of cancer in prison have investigated cancer prevalence, mortality, or screening.[9,10] No national population-based studies have used comprehensive cancer registry data to investigate whether cancer incidence, treatment, and survival differs for people in prison compared with the general population.[9,10]

Accurate information on the increasing cancer burden in prison and on patient outcomes is important for informing national cancer policies for this population. The NHS is responsible for the funding and provision of primary health care in UK prisons, which is guided by the principle of equivalence of care, whereby individuals in prison are entitled to the same range and quality of services that they would receive in the community.[14] Patients requiring secondary or tertiary care are referred to NHS hospitals for outpatient appointments or admission. In the present study, we used national data to

describe the incidence of cancers diagnosed among adults older than 18 years in all prisons in England compared with the general population over a 20-year period. We also analysed receipt of treatment and the overall survival of adults with cancers diagnosed in prison in 2012–17, compared with the general population.

Methods

Study population and data sources

We did a population-based, matched cohort study using national cancer registration data in England. Comprehensive NHS cancer registration records are made in England by the National Cancer Registration and Analysis Service (NCRAS), which is part of the National Disease Registration Service (NDRS) within NHS England.[15] To assess cancer incidence, we identified all diagnoses of primary invasive cancers, excluding non-melanoma skin cancer (International Classification of Diseases, Tenth Revision [ICD-10], code C44), but including diagnoses of cervical cancer in situ (ICD-10 code D06) in individuals aged 18–120 years with known gender (male or female) between Jan 1, 1998, and Dec 31, 2017. The UK Ministry of Justice provided information on all English prisons active for any portion of time during Jan 1, 1998, and Dec 31, 2017. We used publicly available prison postcodes, and periods in which they were active, to identify all cancer diagnoses made for people registered at these postcodes at the time of diagnosis.

To analyse the receipt of treatment with curative intent and overall survival among people diagnosed with cancer in prison compared with those in the general population, we identified a matched cohort for years when the capture of treatment data became nationally mandated and improved (2012–17), in datasets for radiotherapy (National Radiotherapy Dataset [RTDS])[16] and systemic anticancer treatment (Systemic Anti-Cancer Therapy Dataset [SACT]).[17] First, we identified individuals aged 18–120 years with known gender (male or female) and a first primary invasive cancer diagnosed in prison between Jan 1, 2012, and Dec 31, 2017. We excluded death certificate-only registrations (five [0·6%] of 888). Second, for the identified patients (n=883), we randomly selected five individuals from the NCRAS cancer registry who were not diagnosed at prison postcodes (ie, the general population), matched on 5-year age group at diagnosis, gender, year of diagnosis, cancer site (three-digit ICD-10 code), and disease stage at diagnosis. An SQL script was written in Oracle SQL Developer for matching and random selection. There were four patients in prison for whom no matching patients could be identified in the general population, and these were excluded from further analysis. 22 patients in prison with fewer than five matching patients were included. 32 patients in prison with missing vital status dates were excluded from analysis, along with matched cases. The final cohort for treatment

and survival analyses consisted of 847 prison cases and 4165 general population cases.

Hospital episode statistics (HES) data[18] were used to identify surgical resections and comorbidities. Information on systemic anticancer therapy and radiotherapy treatment was derived from the SACT and RTDS, respectively.[16,17] The cause and date of death for deceased patients were obtained from the UK Office for National Statistics.[19]

The NCRAS data included in this study were collected and analysed under the National Disease Registries Directions 2021,[20] made in accordance with sections 254(1) and 254(6) of the 2012 Health and Social Care Act.[21] The National Disease Registration Service has special permission to collect cancer data direct from the NHS. In all instances, patients have the right to opt-out of disease registration and can ask to remove their information from the registration service.

Procedures

To calculate incidence rates, we used Office for National Statistics population tables for the general population, and mid-year estimates provided by the Ministry of Justice for the prison population. Incidence rates were expressed per 100 000 person-years. Data were stratified by diagnosis year, gender (male or female), and age group at diagnosis (18–20 years, 21–24 years, 25–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, and ≥80 years). Due to differences in age bands between the Office for National Statistics and Ministry of Justice datasets, prison age categories of 18–20 years and 21–24 years were created with use of the rectangular assumption that the population within a specific age group is equally distributed at each single age.[22] Prison security categories were assigned with a list of prisons from September, 2012, checked against publicly available data via an internet search, including information from the Ministry of Justice and prison websites, in May, 2022.

We collected information on disease stage, patient age and gender, ethnicity, comorbidity, and route to cancer diagnosis. The cancer registry-defined disease stage combines all relevant information available to give a single anatomical stage at diagnosis per the TNM classification system. NCRAS collects age at diagnosis with the recording of a tumour and person-stated gender (male, female, or indeterminate) rather than sex, as per the NHS data dictionary.[23] Ethnicity is recorded in the cancer registry from different data sources, including self-report, and takes the most frequently reported ethnicity. We used the following main ethnicity groupings in our analyses: White, Mixed (anyone who identifies with more than one ethnic background), combined Asian and Chinese, Black, Other, and missing. Charlson comorbidity scores were derived from the diagnosis fields of the inpatient HES data (from ≤27 months to >3 months before the date of diagnosis), with use of ICD-10 codes and a scoring method derived from Quan et al.[24] 3 months

For the **Office for National Statistics tables** see https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

For more on **Oracle SQL Developer** see https://www.oracle.com/database/sqldeveloper/

before diagnosis was excluded to avoid including comorbidities caused by the incident cancer; and a cutoff of 27 months was used to cover a period of 2 years. Routes to cancer diagnosis included seven categories that were based on Cancer Waiting Times and HES datasets. These were (1) screen detected via breast, cervical, or bowel screening programmes; (2) 2-week wait (urgent general practitioner [GP] referrals with a suspicion of cancer); (3) GP or outpatient referral (routine and urgent referrals where the referral was not via a 2-week wait referral); (4) other outpatient (elective route starting with an outpatient appointment—either consultant to consultant referral, other referral, self-referral, dental referral, or unknown referral); (5) inpatient elective (no earlier information could be found before booked or planned admission from a waiting list); (6) emergency presentation (via emergency department, emergency GP referral, emergency consultant outpatient referral, emergency transfer, or emergency admission or attendance); or (7) unknown (no data available from inpatient or outpatient HES or on cancer waiting times or screening).[25]

We linked all cancer registry patient data to the HES, RTDS, and Cancer Waiting Times datasets using standardised tumour-level data linkage tables from the NDRS, which are based on algorithms that take into account NHS number (if available), date of birth, gender, and postcode at diagnosis. Inpatient and day-case HES-linked data were used to derive information on surgical resections with curative intent. Surgical procedures were identified as major surgery, with use of specific codes from the Office of Population Censuses and Surveys Classification of Interventions and Procedures version 4 (OPCS-4) NHS information standard for main cancer sites with relevant periods (31 days before until 183 days after diagnosis).[26] Because not all cancer sites have defined OPCS-4 codes, curative surgery could not be identified for a fifth of tumours (appendix p 5). To identify radiotherapy treatment, linkage to the RTDS was done with use of the NDRS linkage tables and ICD-10 code.[16] Any radiotherapy attendance with a start date 31 days before and until 183 days (ie, 6 months) after the date of diagnosis and recorded as having curative intent was included, as the generally accepted period for the main curative treatments of surgery, radiotherapy, and chemotherapy to be started. To identify systemic anticancer therapy, linkage to the SACT dataset was done with patient NHS number (if available) and matching to the ICD-10 code of their tumour.[17] Any systemic anticancer therapy with an earliest drug cycle, regimen, or administration start date 31 days before until 183 days after date of diagnosis and recorded as having curative intent was included. In cases where no linkage was established with the HES, RTDS, and SACT datasets, we assumed no treatment was received.

Outcomes

The primary objectives of this study were to compare cancer incidence, receipt of treatment with curative intent (systemic anticancer therapy, radiotherapy, or surgical resection, or any of these three treatment types), and overall survival between people diagnosed in prison and those in the general population. Secondary objectives were to assess the size of the prison population and to compare the diagnosis stage distribution and receipt of curative treatment between patients with cancer in different security categories of prisons and the general population.

Statistical analysis

Age-standardised incidence rates (ASIRs) per year and 95% CIs were calculated with use of the 2013 European Standard Population using the Dobson method.[27] For women, the numbers were small meaning 95% CIs were wide by year, thus ASIRs per year are not presented for this group. To assess the trend over time in the male prison population, we calculated incidence rate ratio per year for the period 1999–2017 with 1998 as the baseline, using Poisson regression adjusted for age. Age was imputed as a continuous variable, providing age-adjusted incidence rate ratio averaged over the 19 years in comparison with baseline. We also ran the Poisson model for cancers in women, but have not presented incidence rate ratio herein, in accord with the reporting of ASIR. To compare the incidence rate of cancers diagnosed in prison with those diagnosed in the general population, we calculated ASIR ratios (ASIRRs), with 95% CIs calculated using Byar's approximation.[27] For the period 1998–2017, we added the yearly cancer incidence (actual number of cancers diagnosed within a year by the age groups used for standardisation), and added the yearly person-years by the age groups used for standardisation, to compute rate, then converted to a ratio by comparing the prison cohort with the general population cohort. We presented ASIRR for the 20-year period for men and women.

Descriptive analyses to explore baseline characteristics between the two matched cohorts were done, with differences assessed with global χ^2 tests, except for age, which was assessed with the Mann–Whitney U test. Logistic regression was done to calculate odds ratios (ORs) and 95% CIs for the likelihood of patients in prison receiving curative treatment compared with matched patients in the general population. Logistic regression models were adjusted for matching variables (excluding cancer site; and with modification of age bounds): ie, gender (male, female), age group at diagnosis (18–20 years, 21–24 years, 25–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, ≥80 years), disease stage (I, II, III, IV, missing), and diagnosis year (2012–17). Ethnicity, comorbidity, and route to diagnosis were considered as confounding factors, but only route to diagnosis was found to improve the model fit with use of the Akaike information criterion; thus, route to diagnosis was adjusted for in a second

model along with matching variables. Route to diagnosis was modelled as the seven aforementioned categories. The same models were applied to assess the receipt of curative treatment by people diagnosed with cancer in an open, closed, or high-security prison compared with matched counterparts in the general population.

To investigate whether overall survival differed between the matched cohorts, survival time was calculated from the date of diagnosis or start date of treatment for those undergoing treatment with curative intent until the date of death or latest tracing with the Office for National Statistics (as of Feb 6–11, 2019), whichever came first. Survival estimates for people diagnosed in prison and matched patients in the general population were computed with the Kaplan–Meier methodology and the difference tested by log-rank test. Cox proportional hazards modelling was used to calculate hazard ratio (HR) and 95% CI for the risk of death in the prison population compared with the general population. Models were adjusted for the matching variables (excluding cancer site, and with the modified age categories) and extended to include stratification for the receipt of any treatment with curative intent (ie, surgery, radiotherapy, or systemic anticancer therapy) to assess the impact of such treatment. The same models were further adjusted for route to diagnosis. The Cox proportional hazards assumptions were assessed via visual inspection of the log–log plots, and scaled Schoenfeld residuals. Assumptions were met for matched variables, but not for the receipt of treatment with curative intent, which is why models included stratification for curative treatment.

It is of interest to know whether disease stage at diagnosis varies between people diagnosed in prison and the general population. Therefore, for the 847 patients with cancer in prison, we did a post-hoc analysis in which we randomly matched cases with general population counterparts on 5-year age group, gender, cancer site, and diagnosis year, but not tumour stage (resulting in n=4604 general population cases), and compared the resulting stage distribution, including missing stage, using a χ^2 test. Random matching was done with an SQL script.

With regard to data linkage in the treatment and survival analyses, substantially more people diagnosed in prison did not have an NHS number (26 [3·1%] of 847) compared with those in the general population (five [0·1%] of 4165). Therefore, we did post-hoc sensitivity analyses for the receipt of treatment and survival analyses by including only people with an NHS number, to assess the potential bias resulting from a lower chance of being linked to the treatment datasets.

Throughout the analyses, the probability of type I error was set at 5% or less. All statistical analyses were done with Stata (version 17.0). Statistical significance was interpreted from 95% CIs.

Role of the funding source

The funders approved the study approach, but had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Overall, we identified 2015 incident cases of premalignant cervical and malignant tumours in 1964 adults in prison during the 20-year period from Jan 1, 1998, to Dec 31, 2017. 1556 (77·2%) of the tumours were diagnosed in men and 459 (22·8%) in women. More than half of the invasive cancers in men were prostate (296 [19·0%] of 1556), lung (230 [14·8%]), colon and rectal (87 and 60 [9·4% combined]), testis (114 [7·3%]), and bladder (63 [4·0%]) cancers. Most diagnoses in women were cervical cancer in situ (350 [76·3%] of 459). Cervical cancer (22 [4·8%]) and breast cancer (24 [5·2%]) each accounted for a similar percentage of all diagnoses, and 22 (20·2%) and 24 (22·0%) of 109 invasive tumours, respectively. The prison population increased in size, with the number of men rising from 60 252 in 1998 to 77 825 in 2017 (29·2% increase). The number of women in prison was lower than the number of men overall, but also increased, from 3139 to 4007 during the same period (27·7% increase). The number of tumours diagnosed in prison increased from 19 tumours to 171 tumours over the same period, representing a 9-times (800%) increase. The proportion of people in prison older than 50 years doubled, from 16·8% (10 095 of 60 252 men) and 17·2% (540 of 3139 women) in 1998, to 33·6% (26 140 of 77 825 men) and 35·4% (1418 of 4007 women) in 2017.

The ASIR for cancer for men in prison was lower than in men in the general population during the early study period (in 1998, ASIR 119·33 per 100 000 person-years [95% CI 48·59–219·16] vs 746·97 per 100 000 person-years [742·31–751·66]), but increased to a similar level towards the end of the period (in 2017, 856·85 per
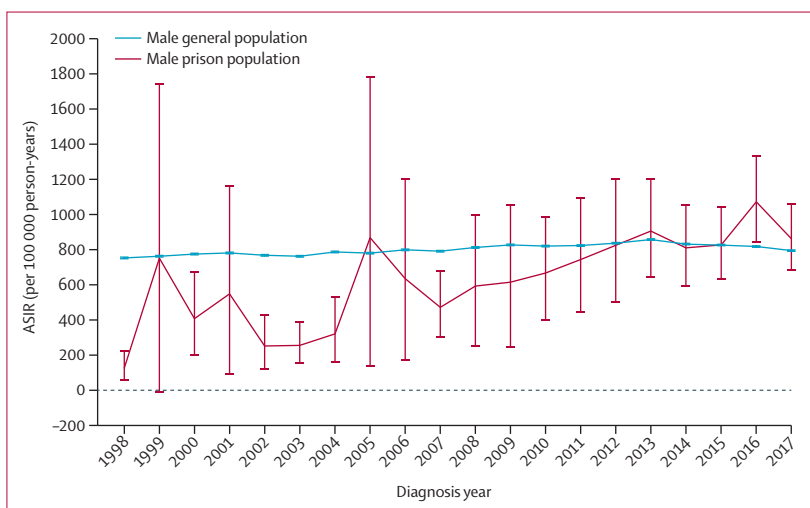
Figure 1: **ASIRs for cancer in men in the general and prison populations in England by diagnosis year**
Vertical bars denote 95% CIs. ASIR=age-standardised incidence rate.

100 000 person-years [675·12–1060·44] *vs* 788·59 per 100 000 person-years [784·62–792·57]; figure 1). Over the study period, the incidence of invasive cancer for men in prison increased (incidence rate ratio per year, 1·05 [95% CI 1·04–1·06], during 1999–2017 compared with 1998). The ASIRRs showed that over the 20-year period, overall cancer incidence was lower in men in prison than in men in the general population (ASIRR 0·76 [95% CI 0·73–0·80]). The difference was not statistically significant for women (ASIRR 0·83 [0·68–1·00]; figure 2). ASIRRs for the most common male cancers showed statistically significantly lower rates of colon (0·65 [0·52–0·80]), rectal (0·74 [0·57–0·96]), prostate (0·79 [0·70–0·89]), and testicular (0·66 [0·55–0·80]) cancer in the prison population, but no difference for bladder (0·99 [0·76–1·27]) or lung (1·08 [0·95–1·23]) cancer. Because invasive cancers were infrequent in women in prison (109 [23·7%] of 459 tumours), ASIRRs for individual invasive cancer sites in women were not calculated. However, cervical cancer in situ was diagnosed around twice as often in prison as in the general population (ASIRR 2·13 [1·91–2·36]; figure 2).

Table 1 gives an overview of the matched cohorts of 847 patients in prison and 4165 patients in the general population, showing that the matching on age, gender, disease stage, comorbidity score and diagnosis year worked well. We observed differences in ethnicity, with fewer individuals of Asian and Chinese ethnicity and more of Black, Mixed or Other ethnicity in the prison cohort than in the general population. The route to cancer diagnosis among the prison population was less likely to have occurred via a 2-week wait referral, screening, or GP or outpatient referral than among those in the general population. In the post-hoc analysis in which we randomly matched the 847 patients in prison with 4604 counterparts in the general population on age, gender, tumour site, and diagnosis year, but not tumour stage, we found no difference in the frequency of stage IV tumours among people diagnosed in prison than in the general population (235 [27·7%] of 847 *vs* 1184 [25·7%] of 4604; p=0·067).
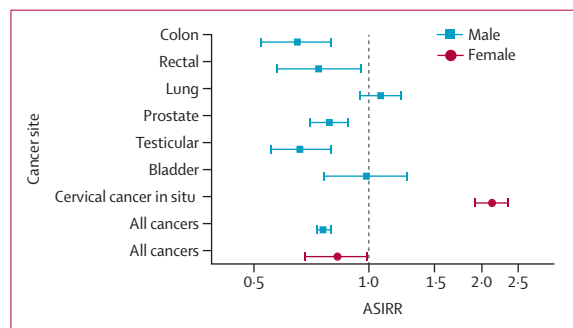
Figure 2: ASIRR for common cancers and for all cancers combined in English prisons compared with the general population by gender between Jan 1, 1998, and Dec 31, 2017

ASIRRs for infrequent cancers not shown. The x-axis is on log scale. Vertical dashed line represents an ASIRR of 1 (ie, no difference between the two populations). ASIRR=age-standardised incidence rate ratio.

We calculated ORs for the receipt of any treatment with curative intent (surgery, radiotherapy, or systemic anticancer therapy) in the 847 people diagnosed with cancer in prison, compared with the 4165 matched people

	Patients with cancer in the general population (n=4165)	Patients with cancer in prison (n=847)	p value
Gender	..	..	0·94*
Male	3931 (94·4%)	800 (94·5%)	..
Female	234 (5·6%)	47 (5·5%)	..
Age, years, median (IQR)	58 (48–68)	58 (47–67)	0·15†
Ethnicity	..	..	<0·0001*
White	3588 (86·1%)	672 (79·3%)	..
Mixed	19 (0·5%)	14 (1·7%)	..
Asian and Chinese	132 (3·2%)	13 (1·5%)	..
Black	96 (2·3%)	39 (4·6%)	..
Other	63 (1·5%)	26 (3·1%)	..
Missing	267 (6·4%)	83 (9·8%)	NA
Cancer stage at diagnosis	..	..	1·0*
I	994 (23·9%)	201 (23·7%)	..
II	524 (12·6%)	106 (12·5%)	..
III	660 (15·8%)	135 (15·9%)	..
IV	1172 (28·1%)	235 (27·7%)	..
Missing	815 (19·6%)	170 (20·1%)	NA
Diagnosis year	..	..	1·0*
2012	500 (12·0%)	101 (11·9%)	..
2013	617 (14·8%)	126 (14·9%)	..
2014	677 (16·3%)	138 (16·3%)	..
2015	719 (17·3%)	146 (17·2%)	..
2016	842 (20·2%)	171 (20·2%)	..
2017	810 (19·4%)	165 (19·5%)	..
Treatment with curative intent	..	..	<0·0001*
No	2437 (58·5%)	573 (67·7%)	..
Yes	1728 (41·5%)	274 (32·3%)	..
Charlson comorbidity score	..	..	0·086*
0	3489 (83·8%)	684 (80·8%)	..
1–2	499 (12·0%)	117 (13·8%)	..
≥3	177 (4·2%)	46 (5·4%)	..
Route to diagnosis	..	..	<0·0001*
2-week wait	1536 (36·9%)	228 (26·9%)	..
Emergency presentation	712 (17·1%)	179 (21·1%)	..
General practitioner or outpatient referral	1131 (27·2%)	210 (24·8%)	..
Inpatient elective	109 (2·6%)	25 (3·0%)	..
Other outpatient	444 (10·7%)	103 (12·2%)	..
Screen detected	65 (1·6%)	4 (0·5%)	..
Unknown	168 (4·0%)	98 (11·6%)	..

*p values based on χ² test. †p values based on Mann–Whitney U test.

Table 1: Characteristics of patients diagnosed with cancer in English prisons compared with matched patients in the general population, 2012–17

	Total number	Any treatment		Surgery		Radiotherapy		Systemic anticancer treatment	
		Number of patients	Adjusted OR (95% CI)	Number of patients	Adjusted OR (95% CI)	Number of patients	Adjusted OR (95% CI)	Number of patients	Adjusted OR (95% CI)
General population	4165	1728 (41·5%)	1 (ref)	1228 (29·5%)	1 (ref)	486 (11·7%)	1 (ref)	303 (7·3%)	1 (ref)
Prison population (model 1)	847	274 (32·3%)	0·63 (0·53–0·75)	187 (22·1%)	0·64 (0·53–0·78)	80 (9·4%)	0·78 (0·60–1·01)	51 (6·0%)	0·79 (0·57–1·08)
Prison population (model 2)	847	274 (32·3%)	0·72 (0·60–0·85)	187 (22·1%)	0·73 (0·60–0·88)	80 (9·4%)	0·85 (0·65–1·10)	51 (6·0%)	0·85 (0·62–1·17)

Logistic regression models adjusted for cohort matching variables (gender, age category, disease stage, and diagnosis year) in model 1, and additionally adjusted for route to diagnosis in model 2. OR=odds ratio.

Table 2: Likelihood of receipt of treatment with curative intent for patients diagnosed with cancer in English prisons compared with matched patients in the general population, 2012–17

diagnosed in the general population (table 2). With adjustment for cohort matching variables (excluding cancer site), people in the prison population were less likely to undergo any treatment with curative intent than the general population (274 [32·3%] of 847 patients *vs* 1728 [41·5%] of 4165; adjusted OR 0·63 [95% CI 0·53–0·75]). When analysed by type of treatment, the difference was statistically significant only for major surgical resections (187 [22·1%] patients who received surgery in the prison cohort *vs* 1228 [29·5%] in the general population cohort; adjusted OR 0·64 [0·53–0·78]). Further adjustment for route to diagnosis attenuated these associations, but they remained statistically significant (any treatment, adjusted OR 0·72 [0·60–0·85]; and surgical resections, adjusted OR 0·73 [0·60–0·88]). In the post-hoc sensitivity analysis in which we only considered patients with an NHS number, we found that the ORs were slightly attenuated (appendix p 3).

Analysis by prison security category was limited by the small number of people with cancer in each setting (76 people in open prisons, 74 in high-security prisons, and 697 in other prison settings), but indicated that individuals diagnosed in an open prison seemed least likely to undergo any treatment with curative intent (21 [27·6%] of 76 *vs* 1728 [41·5%] of 4165; adjusted OR 0·50 [95% CI 0·29–0·86]; full data not shown).

The overall survival of people diagnosed with cancer in prison was significantly lower than in those diagnosed in the general population (log-rank p=0·042; figure 3). 1-year survival was 71·1% (95% CI 67·9–74·1) among patients diagnosed in prison compared with 74·3% (72·9–75·6) among those in the general population. 5-year survival estimates were 54·3% (50·3–58·1) and 56·5% (54·7–58·1), respectively. With adjustment for cohort matching variables (excluding cancer site), being diagnosed with cancer in prison was associated with a small but significantly increased risk of death (347 deaths during 2021·9 person-years in the prison cohort *vs* 1626 deaths during 10944·2 person-years in the general population cohort; adjusted HR 1·16 [95% CI 1·03–1·30];
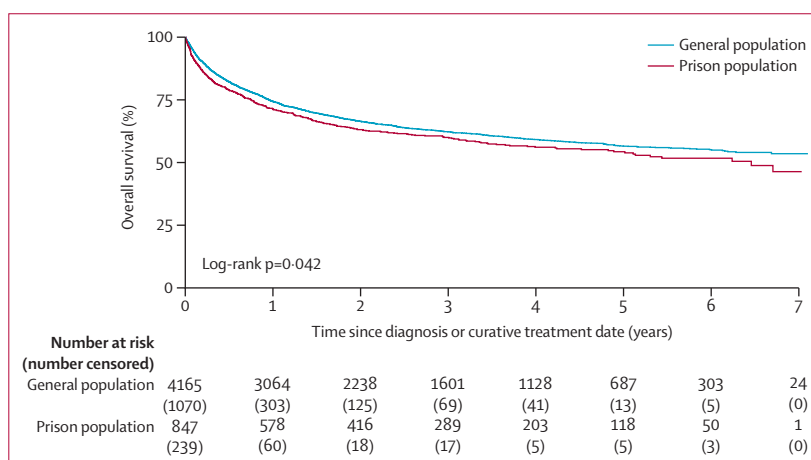
Figure 3: Kaplan–Meier curves of overall survival in patients diagnosed with cancer in the prison and general populations in England between Jan 1, 2012 and Dec 31, 2017
Follow-up started from the date of diagnosis or the start of treatment with curative intent if received until the date of death or latest tracing (as of Feb 6–11, 2019).

table 3). Stratification by treatment with curative intent showed that differences in treatment explained almost half the increased risk (adjusted HR 1·09 [95% CI 0·97–1·23]). Additional adjustment for diagnosis route attenuated the association further (adjusted HR 1·05, 95% CI 0·93–1·18). In the post-hoc sensitivity analysis in which we only considered patients with an NHS number, we found that the HRs were similar to those in the main analysis (appendix p 4).

Discussion
To our knowledge, this is the first study of cancer incidence, treatment, and survival in an entire national prison population. We used comprehensive cancer registration data in England to establish cancer diagnoses made in prisons, based on postcode, between Jan 1, 1998 and Dec 31, 2017. In accordance with a growing and ageing prison population, we observed an increasing number of cancers diagnosed over this period. The ASIRs in men showed that cancer incidence

	Number of deaths; person-years	Model A: adjusted HR (95% CI)	Model B: adjusted HR (95% CI)	Model C: adjusted HR (95% CI)	Model D: adjusted HR (95% CI)
Population					
General population	1626; 10 944·2	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Prison population	347; 2021·9	1·16 (1·03–1·30)	1·09 (0·97–1·23)	1·09 (0·97–1·23)	1·05 (0·93–1·18)
Route to diagnosis					
2-week wait	NA	..	..	1 (ref)	1 (ref)
Emergency presentation	NA	..	..	3·05 (2·72–3·43)	2·76 (2·45–3·10)
General practitioner or outpatient referral	NA	..	..	1·03 (0·91–1·17)	0·98 (0·86–1·12)
Inpatient elective	NA	..	..	1·34 (1·02–1·77)	1·22 (0·93–1·61)
Other outpatient	NA	..	..	1·34 (1·14–1·57)	1·31 (1·11–1·54)
Screen-detected	NA	..	..	0·34 (0·15–0·77)	0·38 (0·17–0·86)
Unknown	NA	..	..	1·19 (0·95–1·50)	1·03 (0·82–1·30)

Cox proportional hazards modelling, adjusted for cohort matching variables (gender, age category, disease stage, and diagnosis year) in model A; for cohort matching variables and stratified by treatment with curative intent in model B; for cohort matching variables and route to diagnosis in model C; and for cohort matching variables and route to diagnosis, stratified by treatment with curative intent, in model D. NA=not applicable.

Table 3: Risk of death for patients diagnosed with cancer in English prisons compared with matched patients in the general population, 2012–17

in men in prison increased from being initially lower than in the general population to becoming similar to it. Given the higher prevalence of risk factors in the prison population compared with the general population, notably a higher smoking rate,[6] this ASIR increase probably reflects increasing awareness of cancer and improving diagnosis within the prison health-care setting. We observed that cancer diagnoses in patients in prison were less likely to result from the 2-week wait, screening, or GP or outpatient referral routes than in the general population and more likely to result from emergency admissions.

Notably, women in prison were around twice as likely to be diagnosed with cervical cancer in situ than those in the general population. Furthermore, a fifth of the invasive cancers in women in prisons were cervical cancer. A high rate of cervical cancer in this population has previously been reported[28] and the finding that cancer in patients in prison is less likely to be screen-detected emphasises this high and undiagnosed burden as an important public health issue. Invasive cervical cancer can be effectively prevented by vaccination and screening and our findings suggest that health services are failing to reach this vulnerable group.

Among people with cancer in the recent prison cohort between Jan 1, 2012, and Dec 31, 2017, we found a significantly lower receipt of curative treatment than in matched individuals diagnosed with similar cancers in the general population. We hypothesise that barriers to curative treatment in prison might relate to the organisation of clinical care due to security measures, unavailability of staff, inadequate communication between health professionals within prisons and hospitals or between health professionals and prison staff, or patient choice and unavailability of information. For example, people are often moved between prisons, and if they are diagnosed and released from prisons far

away from their usual place of residence, they could be lost to follow-up without representing to cancer services nearer to home).[29,30] The information patients receive about treatment and their willingness to undergo it also needs further exploration.

The overall survival from cancers diagnosed in prison was lower than for cancers diagnosed in the general population. Although some confounding seems to arise from diagnostic route, almost half of the survival discrepancy can be explained by lower receipt of curative treatment among the prison population. We focussed on treatment with curative intent, which is most often surgery, but could not identify potentially curative surgical procedures for all cancers in this study. This means that for the cancers for which relevant OPCS-4 codes were not identified, potentially curative treatment was missing from the analysis. However, because we matched patients on cancer site, the missing data affects cancers in both the prison and general populations, and might attenuate the effect on overall findings. Because NHS number was important for the matching algorithm for the retrieval of RTDS data and surgery information and necessary for matching to SACT data, we did sensitivity analyses in which we only included people with an NHS number. This slightly attenuated the associations, but HRs remained similar in the survival analysis.

Although this study benefits from comprehensive cancer registration data, the capture of curative treatment and complete death registration data in England and Wales[19] has some limitations. Although we matched patients on cancer site, we could not adjust for it in our analyses, which might have given rise to residual confounding. Additionally, there might be some residual confounding through our modelling of age categories, whereby we collapsed 5-year age groups to 10-year age groups for people older than 30 years. A further limitation

was that we can only derive socioeconomic deprivation information from the area around an individual's postcode at diagnosis, which, for people diagnosed in prison, is necessarily the prison and not their previous area of residence; thus, we could not assess the impact of socioeconomic deprivation on treatment or survival. The typically lower socioeconomic background of people in prison could partly explain their lower overall survival, but we cannot ascertain that without access to their previous postcodes of residence. Although we initially considered comorbidity in our analyses, we did not find any difference in the levels of comorbidity between patients diagnosed in prison and the general population, nor did this contribute to the analysis of receipt of curative treatment or survival. The finding of no difference might be because of under-reporting of comorbidity in people diagnosed in prison, for example, if they have had less interaction with the NHS. In support of this suggestion, we found that linkage to the HES data via NHS number was lower among the prison population than the general population. Comorbidity might also explain the lower curative treatment rate as these treatments might not be suitable for patients with comorbidities, in turn leading to the survival deficit observed.

This study revealed which cancers most commonly affect people in prison particularly among men and on which prevention and screening should therefore focus. Prisons have been smoking-free since 2018, but lung and bladder cancer caused by previous smoking continue to remain a substantial issue for this population. In England (and the wider UK), free cancer screening is offered for cervical cancer from ages 25 to 64 years, breast cancer from ages 50 to 70 years, and colorectal cancer from ages 60 to 74 years, and lung cancer screening for high-risk groups has recently been announced. Effective implementation of screening within prisons should be a priority and monitored carefully with data reported in a similar robust way as for the general population. For some women, access to prison health care might be an opportunity to catch up on their cervical screening, but more research is needed with women to establish how information and support can be best provided. Similarly, ensuring that all people who are incarcerated are offered vaccinations against human papillomavirus will be an important aspect of cancer prevention measures in this high-risk population. A high prevalence of liver cancer was also identified among women in prison in a Canadian study,[13] which could relate to both infection with hepatitis B virus and high alcohol consumption and should be considered in the context of prevention in the general prison population.

In this study, we were only able to identify cancers diagnosed in prison by postcode of residence. The total burden of cancers in prison will be higher, but it is difficult to establish cancer prevalence in prisons due to the current inability to access reliable data on past medical history from medical records held within prison.

To estimate cancer prevalence in prison, future work is required to match clinical data from the SystmOne primary care record system, used within prisons in England and Wales, to the cancer registry data to determine additional people diagnosed with cancer before arriving in prison, who might be living with active or recurrent cancer requiring treatment or palliative care. This matching and analysis would reveal the full burden of cancer in people in prisons and the need for services in a similar way as calculated for the general population. Our companion papers also report on care issues in prisons revealed by interviews with patients, prison officers, and prison health-care and oncology professionals.[29,30] Additionally, we note that the prison service covers both England and Wales, and so future studies should include Welsh data.

Data on people with cancer in prison should be routinely reported each year by NHS England in collaboration with Public Health Wales, the Ministry of Justice, and the Office for Health Improvement and Disparities. Explicit reporting of the number of people diagnosed with and treated for cancer is accepted as an integral part of cancer surveillance for any population. This reporting should therefore be the basis for the development, review, and audit of cancer policies within prisons. At present, there is a sense both in the literature and in practice that the prison population is missing from mainstream cancer research. For example, major delays in cancer diagnosis during the COVID-19 pandemic, with backlogs of referral and investigation, were reported for the general populations across Europe.[31] Future research should investigate whether these delays also occurred for prison populations.[32] Future efforts should also foster international collaborations to understand and compare potential inequalities and develop policies and interventions to improve cancer prevention, early diagnosis, treatment, and care in these populations globally.

For more on **cancer screening in England** see https://www.england.nhs.uk/cancer/early-diagnosis/screening-and-earlier-diagnosis/

Health Service (NHS) England (https://digital.nhs.uk/services/data-access-request-service-dars).

References
1   Aebi MF, Cocco E, Molnar L, Tiago MM. SPACE I - 2021 – Council of Europe Annual Penal Statistics: prison populations. Strasbourg: Council of Europe, 2021.
2   Allen G, Dempsey N. Prison population statistics. Briefing paper number SN/SG/04334. London: House of Commons Library, 2016.
3   Sturge G. UK Prison population statistics. Briefing paper number CBP-04334. London: House of Commons Library, 2020.
4   Ministry of Justice. Prison population figures: 2023. Jan 6, 2023. https://www.gov.uk/government/publications/prison-population-figures-2023 (accessed Jan 9, 2024).
5   Public Health England. Public health & justice report 2014. London: Public Health England, 2015.
6   Herbert K, Plugge E, Foster C, Doll H. Prevalence of risk factors for non-communicable diseases in prison populations worldwide: a systematic review. *Lancet* 2012; **379:** 1975–82.
7   Alves da Costa F, Ferreira-Borges C, Berdzuli N, et al. Non-communicable diseases are being left behind in prisons. Sept 10, 2021. https://blogs.bmj.com/bmj/2021/09/10/non-communicable-diseases-are-being-left-behind-in-prisons/ (accessed March 4, 2024).
8   Prisons and Probation Ombudsman. Prisons and Probation Ombudsman Independent Investigations: annual report 2018–19. London: Prisons and Probation Ombudsman, 2019.
9   WHO European Region. Cancer and cardiovascular health inequities in prison settings. A rapid literature review. Copenhagen: World Health Organization Regional Office for Europe, 2022.
10 Manz CR, Odayar VS, Schrag D. Disparities in cancer prevalence, incidence, and mortality for incarcerated and formerly incarcerated patients: a scoping review. *Cancer Med* 2021; **10:** 7277–88.
11 Davies EA, Sehgal A, Linklater KM, et al. Cancer in the London prison population, 1986–2005. *J Public Health (Oxf)* 2010; **32:** 526–31.
12 Davies M, Rolewicz L, Schlepper L, Fagunwa F. Locked out? Prisoners' use of hospital care. London: Nuffield Trust, 2020.
13 Kouyoumdjian FG, Pivnick L, McIsaac KE, Wilton AS, Lofters A, Hwang SW. Cancer prevalence, incidence and mortality in people who experience incarceration in Ontario, Canada: a population-based retrospective cohort study. *PLoS One* 2017; **12:** e0171131.
14 HM Prison and Probation Service. Healthcare for offenders. 2023. https://www.gov.uk/guidance/healthcare-for-offenders (accessed Aug 3, 2023).
15 Henson KE, Elliss-Brookes L, Coupland VH, et al. Data resource profile: National Cancer Registration Dataset in England. *Int J Epidemiol* 2020; **49:** 16–16h.
16 Sandhu S, Sharpe M, Findlay Ú, et al. Cohort profile: Radiotherapy Dataset (RTDS) in England. *BMJ Open* 2023; **13:** e070699.
17 Bright CJ, Lawton S, Benson S, et al. Data resource profile: the Systemic Anti-Cancer Therapy (SACT) dataset. *Int J Epidemiol* 2020; **49:** 15–15l.
18 Herbert A, Wijlaars L, Zylbersztejn A, Cromwell D, Hardelid P. Data resource profile: Hospital Episode Statistics Admitted Patient Care (HES APC). *Int J Epidemiol* 2017; **46:** 1093–93i.
19 Office for National Statistics. Mortality statistics in England and Wales QMI. 2023. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/methodologies/mortalitystatisticsinenglandandwalesqmi (accessed Nov 15, 2023).
20 NHS England. National Disease Registries Directions 2021. 2021. https://digital.nhs.uk/about-nhs-digital/corporate-information-and-documents/directions-and-data-provision-notices/secretary-of-state-directions/national-disease-register-service-directions (accessed March 28, 2024)
21 UK Parliament. Health and Social Care Act 2012. 2012. https://www.legislation.gov.uk/ukpga/2012/7/contents/enacted (accessed April 1, 2024).
22 Shryock HS, Siegel JS, Larmon EA. The methods and materials of demography, vol 2. Washington, DC: US Bureau of the Census, 1973.
23 NHS Data Model and Dictionary. Person stated gender code. 2023. https://www.datadictionary.nhs.uk/attributes/person_stated_gender_code.html (accessed Nov 28, 2023).
24 Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *Am J Epidemiol* 2011; **173:** 676–82.
25 Elliss-Brookes L, McPhail S, Ives A, et al. Routes to diagnosis for cancer—determining the patient journey using multiple routine data sets. *Br J Cancer* 2012; **107:** 1220–26.
26 NHS Data Model and Dictionary. OPCS classification of interventions and procedures. 2023. https://www.datadictionary.nhs.uk/supporting_information/opcs_classification_of_interventions_and_procedures.html (accessed Aug 3, 2023).
27 Public Health England. Technical guide—confidence intervals. 2018. https://fingertips.phe.org.uk/profile/guidance/supporting-information/ph-methods (accessed Aug 3, 2023).
28 Escobar N, Plugge E. Prevalence of human papillomavirus infection, cervical intraepithelial neoplasia and cervical cancer in imprisoned women worldwide: a systematic review and meta-analysis. *J Epidemiol Community Health* 2020; **74:** 95–102.
29 Armes J, Visser R, Lüchtenborg M, et al. Cancer in prison: barriers and enablers to diagnosis and treatment. *eClinicalMedicine* 2024; published online April 29. https://doi.org/10.1016/j.eclinm.2024.102540.
30 Hunter RM, Huynh J, Lüchtenborg M, et al. Does the cost of cancer care for people in prison differ from those in the general population? Analysis of matched English cancer registry and hospital records. *eClinicalMedicine* 2024; published online April 29. https://doi.org/10.1016/j.eclinm.2024.102575.
31 Lai AG, Pasea L, Banerjee A, et al. Estimated impact of the COVID-19 pandemic on cancer services and excess 1-year mortality in people with cancer and multimorbidity: near real-time data on cancer care, cancer deaths and a population-based cohort study. *BMJ Open* 2020; **10:** e043828.
32 The Lancet Oncology. COVID-19 and cancer: 1 year on. *Lancet Oncol* 2021; **22:** 411.