ISSN 1948-5204 (online)

World Journal of *Gastrointestinal Oncology*

World J Gastrointest Oncol 2023 December 15; 15(12): 2049-2241

Published by Baishideng Publishing Group Inc

World Journal of Gastrointestinal Oncology

Contents

Monthly Volume 15 Number 12 December 15, 2023

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Contents

NAME OF JOURNAL
World Journal of Gastrointestinal Oncology

ISSN
ISSN 1948-5204 (online)

LAUNCH DATE
February 15, 2009

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Monjur Ahmed, Florin Burada

EDITORIAL BOARD MEMBERS
https://www.wjgnet.com/1948-5204/editorialboard.htm

PUBLICATION DATE
December 15, 2023

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World J Gastrointest Oncol 2023 December 15; 15(12): 2077-2092

DOI: 10.4251/wjgo.v15.i12.2077

ISSN 1948-5204 (online)

ORIGINAL ARTICLE

Retrospective Cohort Study

Cohort study to assess geographical variation in cholangiocarcinoma treatment in England

Sophie Jose, Amy Zalin-Miller, Craig Knott, Lizz Paley, Daniela Tataru, Helen Morement, Mireille B Toledano, Shahid A Khan

Specialty type: Oncology

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's scientific quality classification

Grade A (Excellent): 0
Grade B (Very good): B
Grade C (Good): C
Grade D (Fair): 0
Grade E (Poor): 0

P-Reviewer: Lim YC, Brunei Darussalam; Wang L, China

Received: August 7, 2023
Peer-review started: August 7, 2023
First decision: September 1, 2023
Revised: September 22, 2023
Accepted: October 30, 2023
Article in press: October 30, 2023
Published online: December 15, 2023

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Abstract

BACKGROUND

Outcomes for cholangiocarcinoma (CCA) are extremely poor owing to the complexities in diagnosing and managing a rare disease with heterogenous sub-types. Beyond curative surgery, which is only an option for a minority of patients diagnosed at an early stage, few systemic therapy options are currently recommended to relieve symptoms and prolong life. Stent insertion to manage disease complications requires highly specialised expertise. Evidence is lacking as to how CCA patients are managed in a real-world setting and whether there is any variation in treatments received by CCA patients.

AIM

To assess geographic variation in treatments received amongst CCA patients in England.

METHODS

Data used in this cohort study were drawn from the National Cancer Registration Dataset (NCRD), Hospital Episode Statistics and the Systemic Anti-Cancer Therapy Dataset. A cohort of 8853 CCA patients diagnosed between 2014-2017 in the National Health Service in England was identified from the NCRD. Potentially curative surgery for all patients and systemic therapy and stent insertion for 7751 individuals who did not receive surgery were identified as three end-points of interest. Linear probability models assessed variation in each of the three treatment modalities according to Cancer Alliance of residence at diagnosis, and for socio-demographic and clinical characteristics at diagnosis.

RESULTS

Of 8853 CCA patients, 1102 (12.4%) received potentially curative surgery. The mean [95% confidence interval (CI)] percentage-point difference from the population average ranged from -3.96 (-6.34 to -1.59)% to 3.77 (0.54 to 6.99)% across Cancer Alliances in England after adjustment for patient sociodemographic and clinical characteristics, showing statistically significant variation. Amongst 7751 who did not receive surgery, 1542 (19.9%) received systemic therapy, with mean [95%CI] percentage-point difference from the population average between -3.84 (-8.04 to 0.35)% to 9.28 (1.76 to 16.80)% across Cancer Alliances after adjustment, again showing the presence of statistically significant variation for some regions. Stent insertion was received by 2156 (27.8%), with mean [95%CI] percentage-point difference from the population average between -10.54 (-12.88 to -8.20)% to 13.64 (9.22 to 18.06)% across Cancer Alliances after adjustment, showing wide and statistically significant variation from the population average. Half of 8853 patients (n = 4468) received no treatment with either surgery, systemic therapy or stent insertion.

CONCLUSION

Substantial regional variation in treatments received by CCA patients was observed in England. Such variation could be due to differences in case-mix, clinical practice or access to specialist expertise.

Key Words: Cholangiocarcinoma; Biliary tract cancer; Liver cancer; Treatment; Surgery; Systemic therapy; Chemotherapy; Stent; England

Core Tip: Outcomes for cholangiocarcinoma (CCA) are extremely poor, with late presentation meaning curative surgery is not an option for many. Systemic therapies to prolong life are limited and stent insertion for disease management is complex. In a national cohort, treatments received (surgery, systemic therapy, stent insertion) by CCA patients across geographic areas were investigated. Half of patients did not receive any of the treatments considered. The proportion that received treatments significantly varied across England. These data provide novel evidence of low and varied treatment rates for CCA patients, warranting further investigation by healthcare providers to try to improve outcomes and reduce inequality.

Citation: Jose S, Zalin-Miller A, Knott C, Paley L, Tataru D, Morement H, Toledano MB, Khan SA. Cohort study to assess geographical variation in cholangiocarcinoma treatment in England. *World J Gastrointest Oncol* 2023; 15(12): 2077-2092
URL: https://www.wjgnet.com/1948-5204/full/v15/i12/2077.htm
DOI: https://dx.doi.org/10.4251/wjgo.v15.i12.2077

INTRODUCTION

Cholangiocarcinoma (CCA) is a malignancy arising from epithelial cells along the biliary tree within or external to the liver[1,2]. CCA are sub-classified into three main sub-types according to their anatomical site of origin: Intrahepatic CCA (iCCA), within the liver parenchyma, proximal to the second order bile ducts, perihilar, and distal CCA, often collectively referred to as extrahepatic CCA (eCCA)[3-5]. iCCA comprise the second most common form of primary liver cancer worldwide, after hepatocellular carcinoma[6]. The CCA sub-types exhibit some differences in their respective clinical presentations, risk factors, routes to diagnosis and clinical management, as well as exhibiting distinct epidemiological, clinical, molecular and genetic characteristics[3,7]. Of note, multiple epidemiological studies have reported rising incidence and mortality rates for CCA over the past few decades[8-10].

All CCA carries a high mortality as it typically presents at an advanced stage, usually too late for surgical resection or transplantation, the only potentially curative treatment options. Most cases are sporadic *i.e.*, they do not occur on the background of known risk factors and no screening strategy has been proven effective at reducing mortality[3]. Most CCA patients require systemic chemotherapy, with the current standard of care first line treatment being combination gemcitabine and cisplatin, or capecitabine in an adjuvant setting[3,4]. The other main treatment required by most patients is stenting to relieve biliary obstruction. In patients with high levels of jaundice, endoscopic or percutaneous stent placement is commonly used to reduce hyperbilirubinaemia prior to surgery in patients with resectable disease, or before

systemic therapy, or for palliation[3,4]. Although the overall prognosis of CCA is poor, with only a minority of patients surviving more than 3 years after diagnosis, these treatments have been shown to improve overall survival[3,6].

The management of CCA is complex, requiring a highly specialised multi-disciplinary approach and should be carried out at centres of expertise to achieve the best clinical outcomes[3]. Data on CCA patients' access to cancer-specific treatment is lacking. One recent United Kingdom study assessed variation in the surgical management of iCCA patients only, in selected hepatobiliary centres, finding variation in surgery volumes and in the proportions of patients treated with adjuvant chemotherapy[11]. A recent observational study from the European Reference Network for the Study of CCA investigated the clinical course of 2234 CCA patients from 26 referral Healthcare Centres from 11 European countries over a 10-year period (from 2010)[12]. The study found that CCA was frequently diagnosed at an advanced stage with almost 60% of patients presenting with locally advanced or metastatic disease. Furthermore, around 20% did not receive any specific cancer therapy, but best supportive care only. Although this was an important and large multi-centre study, data was collected from self-selected expert centres and the findings may not be representative of the whole population of individual participating countries.

Variation in access to cancer-specific treatment for CCA across England has not previously been reported. The aim of this study was to investigate if there is geographical variation across England of access to surgery, systemic therapy and stenting. Results are reported at the Cancer Alliance level, representing distinct geographic areas within which key health and social care stakeholders collaborate to plan and coordinate local cancer pathways.

MATERIALS AND METHODS

CCA patients were selected from the National Cancer Registration Dataset[13]. The following ICD-10 diagnosis codes were used to define CCA: C221, C240, C248, C249 of any morphology or C220, C222, C223, C224, C227, C229 with ICD-O2 histology code 8160. Patients were considered if resident in England at the time of diagnosis and were diagnosed between 2014 and 2017. This was the most recent diagnostic period at the time of the analysis with sufficient follow-up available to assess treatment initiation. Patients were followed to the earliest of death or 15 mo following recorded date of diagnosis. The first registered tumour per individual in this time period was used for the analysis and patient and tumour characteristics associated with this diagnosis are reported. Further inclusion criteria were recorded male or female gender, and age at diagnosis between 0 and 200 years. Individuals diagnosed with cancer on their death certificate only were excluded as such patients would not have been offered treatment.

Linked patient records from the Hospital Episode Statistics (HES) Admitted Patient Care (APC) dataset, Systemic Anti-Cancer Therapy dataset and National Radiotherapy Dataset[14-16] were used to determine the treatment received by each patient. Potentially curative surgery was defined based on a list of OPCS-4 procedure codes (Supplementary Table 1) dated between one month prior and 12 mo following the date of CCA diagnosis, irrespective of any other treatments received, as per the National Disease Registration Services' standard operating procedure[17]. Amongst individuals with no evidence of surgery as defined above, the presence of systemic therapy and/or stent insertion was assessed. Systemic therapy was defined as the delivery of any systemic anti-cancer therapy regimen initiated between the one month prior and 15 mo following diagnosis. A second list of OPCS-4 codes was used to define stent insertion (Supplementary Table 1), and these were similarly searched for in the interval two months prior to and up to 15 mo following diagnosis.

Geographic variation in treatment was analysed at the Cancer Alliance level according to boundaries defined in 2020. The Cancer Alliance for each tumour was assigned according to the main residence of the patient on the date of diagnosis. Other patient characteristics of interest, identified a priori as possible confounding variables of the relationship between geography and receipt of treatment were: Person-stated gender (male/female); age at diagnosis (0-44/45-54/55-64/65-74/75-84/85+ years); area income deprivation component of the index of multiple deprivation, 2019 (quintiles); year of diagnosis; tumour sub-type (iCCA/eCCA/other); tumour morphology (adenocarcinoma/other); Charlson comorbidity index (score 0/1/2/3+)[18]; underlying liver disease (yes/no) and route to diagnosis (urgent two-week wait general practitioner referral (TWW)/emergency presentation/other/unknown)[19]. To identify underlying liver disease, HES APC episodes from 5 years prior to 1 year after diagnosis were searched for diagnostic codes indicative of chronic hepatitis C or B, primary biliary cholangitis, autoimmune hepatitis, haemochromatosis, alcoholic liver disease, or non-alcoholic liver disease (NAFLD). NAFLD was defined as fatty (change of) liver, not elsewhere classified, or by the presence of cirrhosis combined with obesity or diabetes without the presence of any other underlying liver disease[20].

Linear probability models were performed for each of the following three binary outcomes: Potentially curative surgery regardless of other treatments received (yes/no); systemic therapy where no surgery was received (yes/no); stent insertion where no surgery was received (yes/no). For each outcome, bivariate models were conducted to assess the association with each covariate of interest without adjustment for other patient and tumour factors (referred to as 'unadjusted'). An adjusted model was then fit for each outcome that included all covariates, defined a priori as being of interest, concurrently. No interactions between covariates were assessed. Covariates were Cancer Alliance, age at diagnosis, gender, area income deprivation quintile, Charlson comorbidity score, prior liver disease, tumour sub-type, tumour morphology, route to diagnosis.

Weighted effect coding was applied such that estimates generated by each linear probability model are interpretable as percentage-point deviations from the sample mean[21]. Results from the linear probability models are presented as funnel plots with significance thresholds denoting two and three SD from the sample mean, being approximately equivalent to 95.0% and 99.7% confidence intervals, respectively. A statistical significance threshold of 5% was used.

A sensitivity analysis was undertaken that additionally adjusted for stage at diagnosis in a subgroup of the cohort who had a known stage at diagnosis. This was due to the high level of missing data for this variable (45.5%). The adjusted

models for each outcome were repeated in this subgroup to determine how reducing the cohort to patients with known stage impacted model estimates, before stage was additionally adjusted for in this group.

RESULTS

There were 8872 people diagnosed with CCA between 2014 and 2017. No exclusions were made due to age or gender data quality checks. After excluding 19 (0.2%) individuals diagnosed on death certificate only, a final cohort of 8853 individuals was available for analysis. Of these, 20.9% were under 65 years old and 50.9% were women (Table 1). The majority were diagnosed with an iCCA (77.6%). Comorbidities as measured by the Charlson comorbidity index were present in 29.7% of individuals and 9.1% were classified as having underlying liver disease. The largest proportion of diagnoses were situated in the West Midlands Cancer Alliance (11.4%), with the smallest in North Central London Cancer Alliance (1.6%).

Of the 8853 patients, 12.4% (n = 1102) received potentially curative surgery. In the 7751 patients with no evidence of surgery, 19.9% (n = 1542) received systemic therapy, 27.8% (n = 2156) received a stent insertion, and 42.4% (n = 3283) received either modality alone or in combination. Of note, half (50.5%) of the initial cohort received none of the three treatments considered (Table 1).

Geographic variation in potentially curative surgery

Variation in the unadjusted percentage of patients who received potentially curative surgery was observed across the Cancer Alliances, ranging from 8.8% to 16.2% (P < 0.001). In a linear probability model that included only Cancer Alliance, the percentage treated with surgery was more than two SD higher than the sample mean in one Cancer Alliance (P < 0.05), but more than two SD lower than average for two Cancer Alliances [Table 2A (unadjusted) and Figure 1A]. This finding remained present after adjustment for all patient and tumour characteristics being considered [Table 2A (adjusted) and Figure 1B].

Geographic variation in systemic therapy

Amongst those not treated with surgery, variation in the crude percentage of patients treated with systemic therapy was observed. Across Cancer Alliances the percentage in receipt of systemic therapy ranged from 12.4% to 29.4%. In a linear probability model that included Cancer Alliance as the only independent variable, the percentage treated with systemic therapy was more than two SD above the sample mean for two Cancer Alliances, and below the mean for two Cancer Alliances [Table 2B (unadjusted) and Figure 2A, P < 0.001)]. Adjustment for patient and tumour characteristics attenuated this difference for two Cancer Alliances such that only one was observed to have a significantly lower percentage of patients receiving systemic therapy than the sample mean [Table 2B (adjusted) and Figure 2B].

Geographic variation in stent insertion

There was wide variation in the percentage of individuals who received a stent insertion amongst those not treated with potentially curative surgery. The unadjusted percentage across all Cancer Alliances ranged from 29.7% to 55.0% and was significantly higher than the sample mean for six Cancer Alliances, and significantly lower than the sample mean for five Cancer Alliances [Table 2C (unadjusted) and Figure 3A]. Adjustment for patient demographics, comorbidities and tumour characteristics did not alter this finding [Table 2C (adjusted) and Figure 3B].

Treatment associations with patient and tumour characteristics

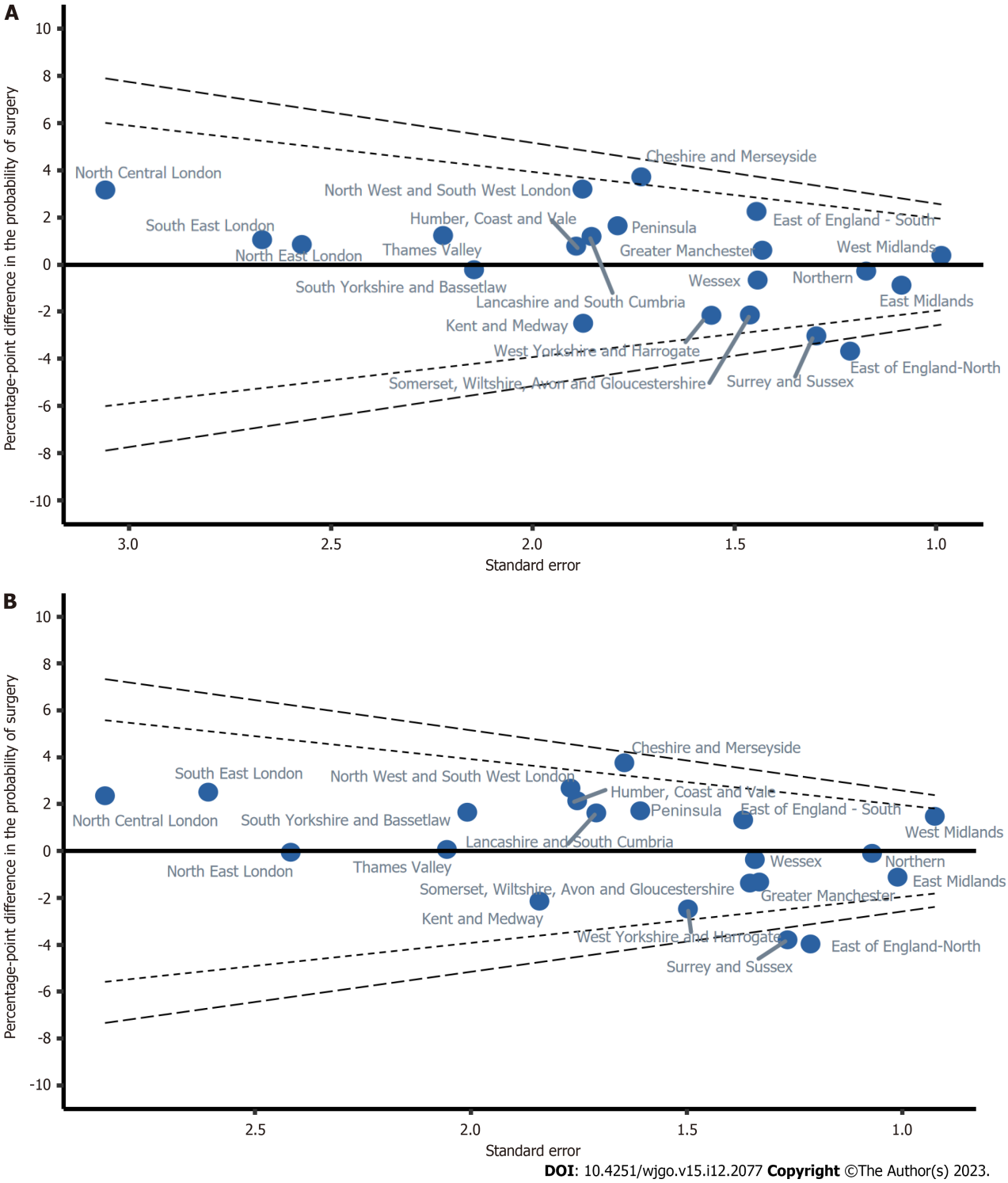
The lowest percentage treated with potentially curative surgery was observed in the 85+ age group (Table 2A unadjusted). Age remained associated with the likelihood of surgery in a model that included all other cofactors of interest, with the highest proportion amongst those aged 0-44 [adjusted percentage point difference (pp): 20.69, 95% confidence interval (CI): 13.91 to 27.47]. Likewise, in those who did not receive surgery, older age at diagnosis was associated with a lower likelihood of systemic therapy in both unadjusted and adjusted analyses (adjusted pp: -17.16, 95%CI: -18.08 to -16.23 for age 85+ years). However, the relationship between age and likelihood of stent insertion was not similarly linear (Table 2C adjusted).

Although there was a difference between male and female gender in the crude percentage that received surgery (Table 2A unadjusted), this was attenuated after adjustment (adjusted pp: -0.49, 95%CI: -1.13 to 0.16 for women). Amongst those who did not receive surgery, women were less likely than men to receive a stent insertion (adjusted pp: -1.18, 95%CI: -2.13 to -0.24), but more likely to receive systemic therapy (adjusted pp: 1.21, 95%CI: 0.43 to 2.00).

High area income deprivation was associated with a lower probability of both surgery (adjusted pp: -2.77, 95%CI: -4.10 to -1.43 for most deprived areas) and systemic therapy in the absence of surgery (adjusted pp: -2.91, 95%CI: -4.59 to -1.22) but was not strongly associated with the probability of stent insertion in those who did not receive surgery (adjusted pp; -0.34, 95%CI: -2.33 to 1.65).

Compared to the population average, iCCA patients had a lower probability of treatment with surgery (adjusted pp: -2.65, 95%CI: -3.09 to -2.22), systemic therapy amongst those without surgery (adjusted pp: -0.47, 95%CI: -0.92 to -0.02) and stent insertion amongst those without surgery (adjusted pp: -3.89, 95%CI: -4.47 to -3.31) in adjusted models.

Those diagnosed *via* an emergency route had a lower-than-average probability of surgery (adjusted pp: -3.75, 95%CI: -4.42 to -3.08) and systemic therapy in those without surgery (adjusted pp: -5.31, 95%CI: -6.11 to -4.51), but a higher probability of stent insertion without surgery (adjusted pp: =2.10, 95%CI: 1.14 to 3.07) than the population average. Whilst a TWW referral route was not strongly associated with the probability of surgery (adjusted pp: -0.58, 95%CI: -2.08

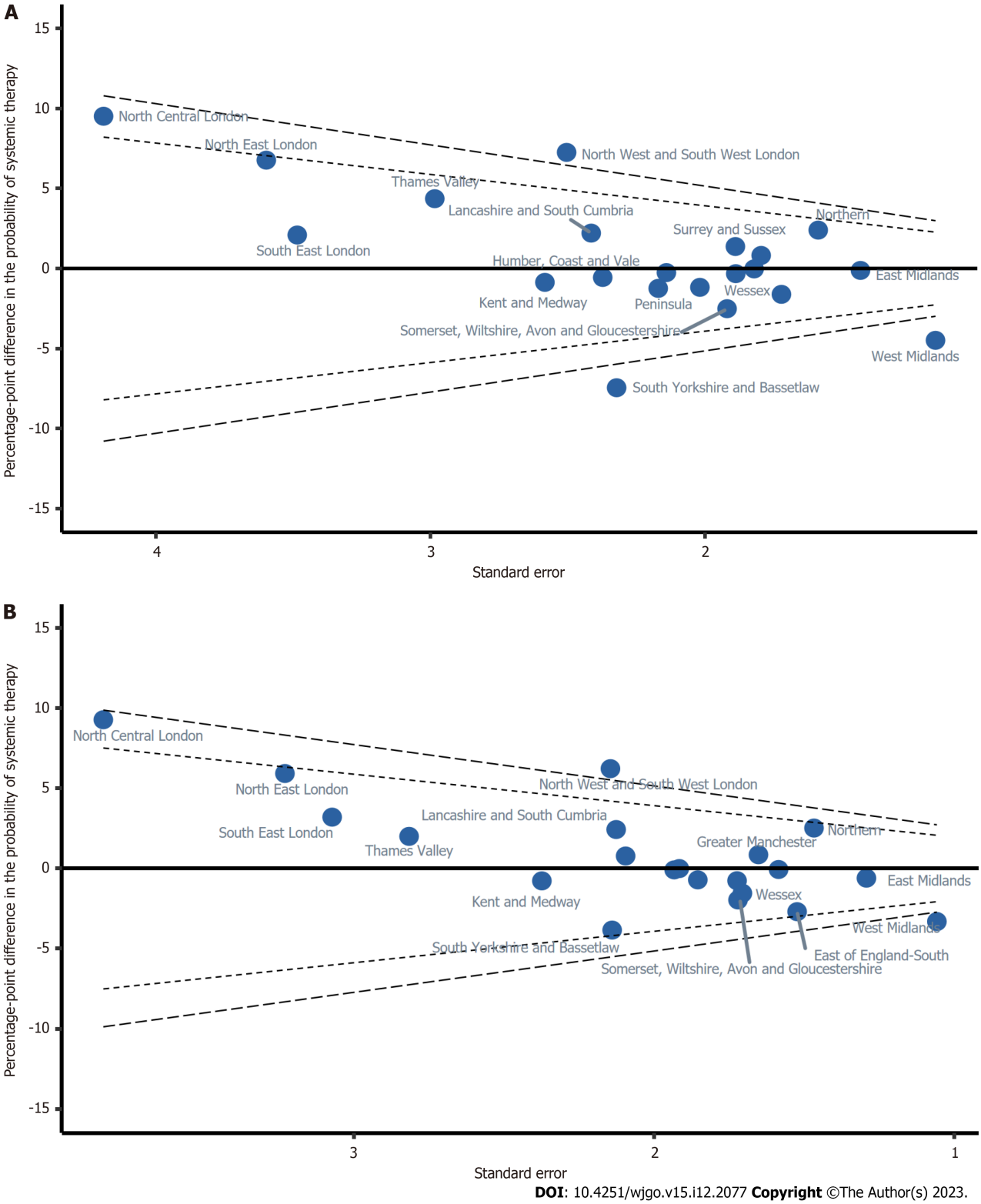


DOI: 10.4251/wjgo.v15.i12.2077

Figure 1 Percentage of cholangiocarcinoma patients treated with potentially curative surgery in each Cancer Alliance in England, 2014-2017. A: Unadjusted; B: Adjusted. Adjustment for: age, gender, income deprivation quintile, Charlson comorbidity index, underlying liver disease at diagnosis, diagnosis year, tumour morphology, tumour sub-type, and routes to diagnosis. Inner dashed line = two standard deviations difference from average. Outer dashed line = three standard deviations difference from average.

to 0.91), a TWW referral route was associated with a higher probability of systemic therapy (adjusted pp: 8.57, 95%CI: 6.55 to 10.59) and stent insertion (adjusted pp: 2.29, 95%CI: 0.06 to 4.51) among patients that did not receive surgery.

Patients with the highest categorised burden of comorbidities (3+) had a lower-than-average probability of surgery (adjusted pp: -3.19, 95%CI: -4.79 to -1.60), systemic therapy (adjusted pp: -7.06, 95%CI: -8.93 to -5.20) and stent insertion (adjusted pp: -5.53, 95%CI: -8.33 to -2.74). Conversely, of patients with evidence of liver disease specifically, there was no association with systemic therapy (adjusted pp: -0.43, 95%CI: -3.55 to 2.69), a higher-than-average probability of treatment with surgery (adjusted pp: 3.47, 95%CI: 0.96 to 5.97) and lower than average probability of stent insertion without surgery (adjusted pp: -4.19, 95%CI: -7.29 to -1.08).



DOI: 10.4251/wjgo.v15.i12.2077

Figure 2 Percentage of cholangiocarcinoma patients treated with systemic therapy amongst those who did not receive surgery in each Cancer Alliance in England, 2014-2017. A: Unadjusted; B: Adjusted. Adjustment for: age, gender, income deprivation quintile, Charlson comorbidity index, underlying liver disease at diagnosis, diagnosis year, tumour morphology, tumour sub-type, and routes to diagnosis. Inner dashed line = two standard deviations difference from average. Outer dashed line = three standard deviations difference from average.

Sensitivity analysis

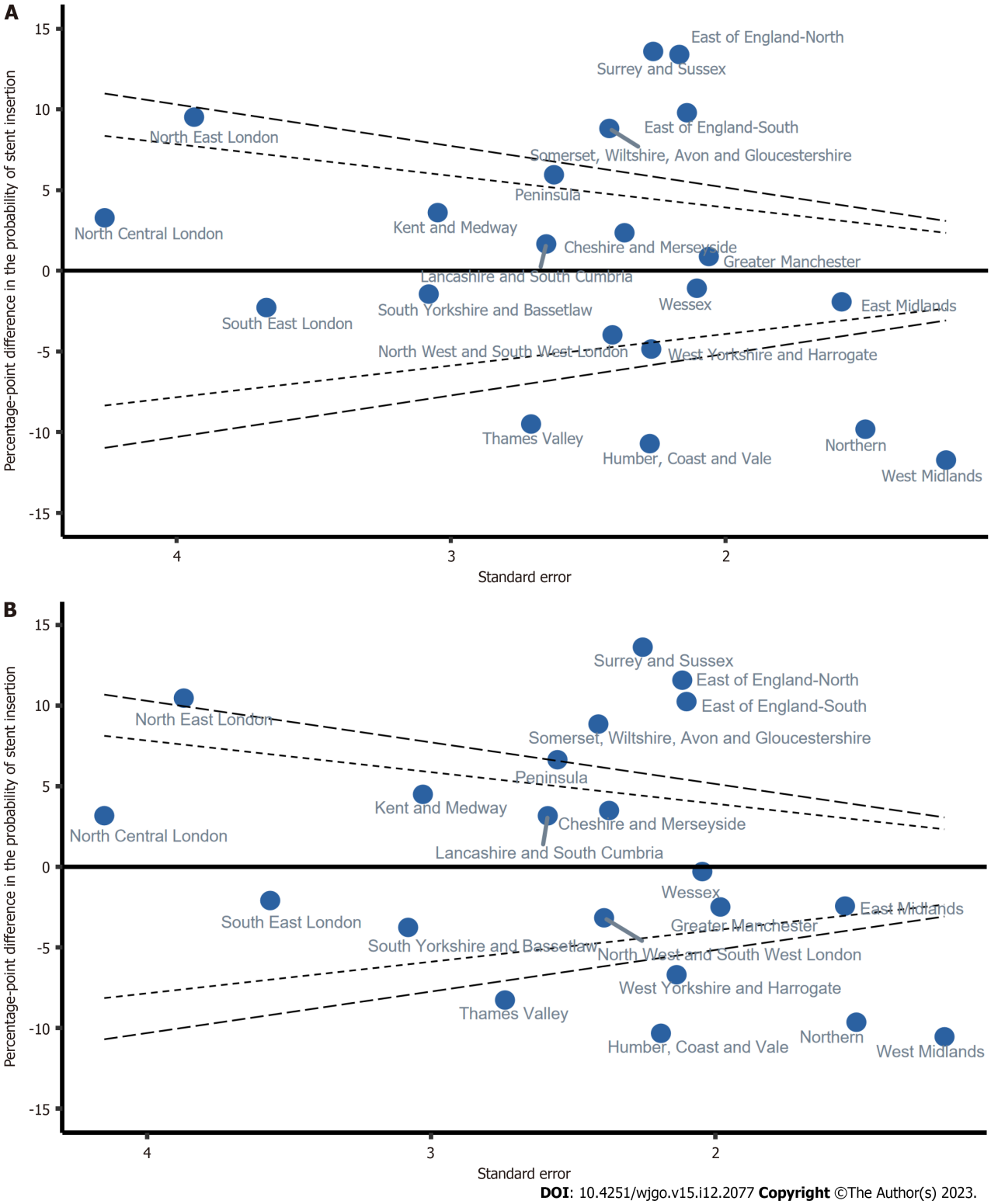
Of the 8853 CCA patients in the study cohort, 4832 (54.5%) had a known stage at diagnosis and were included in the sensitivity analysis for potentially curative surgery. Of these, 3925 (81.2%) did not receive curative surgery and were analysed for the probability of treatment with systemic therapy or stent insertion.

Table 1 Description of cholangiocarcinoma patients diagnosed between 2014 and 2017 in England, and subgroup who did not receive surgery up to 12 mo after diagnosis

Characteristics	Total	Did not receive surgery
Total patients (*n*, %)	8853 (100.0)	7751 (100.0)
Age at diagnosis (yr)		
0-44	180 (2.0)	117 (1.5)
45-54	442 (5.0)	320 (4.1)
55-64	1231 (13.9)	962 (12.4)
65-74	2407 (27.2)	1963 (25.3)
75-84	2814 (31.8)	2615 (33.7)
> 84	1779 (20.1)	1774 (22.9)
Gender		
Male	4343 (49.1)	3721 (48.0)
Female	4510 (50.9)	4030 (52.0)
Year of diagnosis		
2014	2055 (23.2)	1802 (23.2)
2015	2213 (25.0)	1951 (25.2)
2016	2259 (25.5)	1983 (25.6)
2017	2326 (26.3)	2015 (26.0)
Route to diagnosis		
Emergency presentation	4276 (48.3)	3975 (51.3)
TWW referral	1490 (16.8)	1306 (16.8)
Other GP referral	1844 (20.8)	1500 (19.4)
Other	979 (11.1)	729 (9.4)
Unknown	264 (3.0)	241 (3.1)
Stage at diagnosis		
1	310 (3.5)	203 (2.6)
2	686 (7.7)	283 (3.7)
3	330 (3.7)	26 (2.9)
4	3506 (39.6)	3213 (41.5)
Missing	4021 (45.4)	3826 (49.4)
Tumour sub-type		
CCA Other	391 (4.4)	378 (4.9)
eCCA	1595 (18.0)	1200 (15.5)
iCCA	6867 (77.6)	6173 (79.6)
Tumour morphology		
Adenomas and adenocarcinomas	8570 (96.8)	7484 (96.6)
Other	283 (3.2)	267 (3.4)
English Index of Multiple Deprivation, income component		
Quintile 1 (least deprived)	1715 (19.4)	1466 (18.9)
Quintile 2	1863 (21.0)	1609 (20.8)
Quintile 3	1797 (20.3)	1589 (20.5)
Quintile 4	1806 (20.4)	1590 (20.5)

Quintile 5 (most deprived)	1672 (18.9)	1497 (19.3)
Charlson comorbidity index		
0	6220 (70.3)	5340 (68.9)
1	1140 (12.9)	1025 (13.2)
2	678 (7.7)	623 (8.0)
3+	815 (9.2)	763 (9.8)
Underlying liver disease		
No	8044 (90.9)	7101 (91.6)
Yes	809 (9.1)	650 (8.4)
Cancer Alliance at diagnosis		
Cheshire and Merseyside	427 (4.8)	358 (4.6)
East Midlands	795 (9.0)	703 (9.1)
East of England-North	524 (5.9)	478 (6.2)
East of England-South	558 (6.3)	476 (6.1)
Greater Manchester	521 (5.9)	453 (5.8)
Humber, Coast and Vale	310 (3.5)	269 (3.5)
Kent and Medway	251 (2.8)	226 (2.9)
Lancashire and South Cumbria	330 (3.7)	285 (3.7)
North Central London	141 (1.6)	119 (1.5)
North East London	173 (2.0)	150 (1.9)
North West and South West London	358 (4.0)	302 (3.9)
Northern	715 (8.1)	628 (8.1)
Peninsula	362 (4.1)	311 (4.0)
Somerset, Wiltshire, Avon and Gloucestershire	417 (4.7)	374 (4.8)
South East London	163 (1.8)	141 (1.8)
South Yorkshire and Bassetlaw	229 (2.6)	201 (2.6)
Surrey and Sussex	488 (5.5)	442 (5.7)
Thames Valley	234 (2.6)	202 (2.6)
Wessex	475 (5.4)	419 (5.4)
West Midlands	1013 (11.4)	883 (11.4)
West Yorkshire and Harrogate	369 (4.2)	331 (4.3)
Treatment received		
Surgery only	507 (5.7)	0 (0.0)
Surgery + systemic therapy	367 (4.1)	0 (0.0)
Surgery + stent insertion	118 (1.3)	0 (0.0)
Surgery + systemic therapy + stent insertion	110 (1.2)	0 (0.0)
Systemic therapy only	1127 (12.7)	1127 (14.5)
Stent insertion only	1741 (19.7)	1741 (22.5)
Systemic therapy + stent insertion	415 (4.7)	415 (5.4)
None of surgery, systemic therapy or stent insertion	4468 (50.5)	4468 (57.6)

iCCA: Intrahepatic cholangiocarcinoma; eCCA: Extrahepatic cholangiocarcinoma; GP: General practitioner; TWW: Two week wait.



DOI: 10.4251/wjgo.v15.i12.2077

Figure 3 Percentage of cholangiocarcinoma patients treated with stent insertion amongst those who did not receive surgery in each Cancer Alliance in England, 2014-2017. A: Unadjusted; B: Adjusted. Adjustment for: age, gender, income deprivation quintile, Charlson comorbidity index, underlying liver disease at diagnosis, diagnosis year, tumour morphology, tumour sub-type, and routes to diagnosis. Inner dashed line = two standard deviations difference from average. Outer dashed line = three standard deviations difference from average.

The proportion of people staged varied by Cancer Alliance, from 36.7% to 74.7% ($P < 0.001$). Those with unknown stage at diagnosis were more likely to be older, diagnosed in an earlier year, have a high comorbidity score and an 'other' tumour sub-type or morphology (all $P < 0.001$, results not shown). Repeating the adjusted model of the main analysis in these subgroups identified different Cancer Alliances as having treatment probabilities that varied significantly (>2 SD) from the population average (Supplementary Table 2). This suggests that the subgroup of individuals with known stage at diagnosis was not generalisable to the whole cohort of individuals with CCA.

Table 2 Estimated percentage of cholangiocarcinoma patients in England 2014-2017 that received

	A: Potentially curative surgery				B: Systemic therapy in those who did not receive surgery				C: Stent insertion in those who did not receive surgery			
	Unadjusted		Adjusted		Unadjusted		Adjusted		Unadjusted		Adjusted	
	Estimate (95%CI)		Estimate 95%CI		Estimate (95%CI)		Estimate 95%CI		Estimate (95%CI)		Estimate 95%CI	
Population average (intercept)	12.45	(11.76, 13.14)	12.45	(11.81, 13.09)	19.89	(19.01, 20.78)	19.89	(19.1, 20.69)	27.82	(26.85, 28.78)	27.82	(26.85, 28.78)
Cheshire and Merseyside	3.71	(0.32, 7.10)	3.77	(0.54, 6.99)	-1.18	(-5.13, 2.78)	-0.09	(-3.88, 3.70)	2.35	(-2.29, 6.99)	3.50	(-1.15, 8.16)
East Midlands	-0.88	(-3.00, 1.25)	-1.11	(-3.10, 0.87)	-0.12	(-2.93, 2.69)	-0.60	(-3.14, 1.93)	-1.93	(-5.02, 1.16)	-2.43	(-5.45, 0.60)
East of England - North	-3.67	(-6.05, -1.29)	-3.96	(-6.34, -1.59)	0.82	(-2.70, 4.34)	-0.06	(-3.17, 3.04)	13.40	(9.15, 17.65)	11.59	(7.44, 15.74)
East of England - South	2.25	(-0.59, 5.08)	1.33	(-1.36, 4.01)	-1.62	(-4.99, 1.76)	-2.70	(-5.68, 0.29)	9.79	(5.59, 13.98)	10.26	(6.14, 14.38)
Greater Manchester	0.60	(-2.20, 3.41)	-1.32	(-3.93, 1.29)	-0.03	(-3.59, 3.54)	0.86	(-2.38, 4.09)	0.88	(-3.16, 4.92)	-2.48	(-6.37, 1.40)
Humber, Coast and Vale	0.78	(-2.93, 4.49)	2.14	(-1.29, 5.58)	-0.56	(-5.21, 4.09)	0.78	(-3.33, 4.88)	-10.72	(-15.18, -6.25)	-10.32	(-14.62, -6.03)
Kent and Medway	-2.49	(-6.16, 1.19)	-2.14	(-5.75, 1.47)	-0.87	(-5.93, 4.19)	-0.77	(-5.43, 3.88)	3.60	(-2.38, 9.58)	4.51	(-1.43, 10.44)
Lancashire and South Cumbria	1.19	(-2.45, 4.82)	1.63	(-1.72, 4.98)	2.21	(-2.52, 6.94)	2.43	(-1.74, 6.60)	1.66	(-3.54, 6.86)	3.18	(-1.90, 8.25)
North Central London	3.16	(-2.84, 9.15)	2.36	(-3.22, 7.94)	9.52	(1.30, 17.73)	9.28	(1.76, 16.80)	3.28	(-5.08, 11.63)	3.18	(-4.95, 11.32)
North East London	0.85	(-4.19, 5.89)	-0.05	(-4.79, 4.69)	6.77	(-0.28, 13.82)	5.93	(-0.41, 12.26)	9.52	(1.80, 17.23)	10.48	(2.89, 18.06)
North West and South West London	3.19	(-0.48, 6.87)	2.68	(-0.79, 6.15)	7.26	(2.35, 12.17)	6.23	(2.02, 10.43)	-3.97	(-8.70, 0.75)	-3.16	(-7.84, 1.53)
Northern	-0.28	(-2.58, 2.02)	-0.10	(-2.20, 2.00)	2.40	(-0.71, 5.51)	2.52	(-0.35, 5.40)	-9.82	(-12.74, -6.90)	-9.63	(-12.58, -6.69)
Peninsula	1.64	(-1.87, 5.15)	1.72	(-1.43, 4.87)	-1.24	(-5.50, 3.01)	-0.01	(-3.76, 3.75)	5.95	(0.80, 11.09)	6.65	(1.64, 11.66)
Somerset, Wiltshire, Avon and Gloucestershire	-2.14	(-5.00, 0.73)	-1.37	(-4.02, 1.29)	-2.51	(-6.28, 1.25)	-1.97	(-5.34, 1.41)	8.82	(4.07, 13.57)	8.87	(4.14, 13.59)
South East London	1.05	(-4.19, 6.28)	2.51	(-2.6, 7.62)	2.09	(-4.74, 8.92)	3.20	(-2.82, 9.23)	-2.28	(-9.48, 4.91)	-2.08	(-9.08, 4.91)
South Yorkshire and Bassetlaw	-0.22	(-4.43, 3.98)	1.66	(-2.28, 5.59)	-7.46	(-12.01, -2.91)	-3.84	(-8.04, 0.35)	-1.45	(-7.49, 4.59)	-3.75	(-9.79, 2.29)
Surrey and Sussex	-3.02	(-5.56, -0.48)	-3.79	(-6.27, -1.30)	1.37	(-2.33, 5.07)	-0.76	(-4.14, 2.61)	13.59	(9.15, 18.02)	13.64	(9.22, 18.06)
Thames Valley	A1.23	(-3.13, 5.58)	0.07	(-3.96, 4.10)	4.36	(-1.49, 10.21)	2.00	(-3.52, 7.52)	-9.50	(-14.81, -4.19)	-8.26	(-13.63, -2.89)
Wessex	-0.66	(-3.49, 2.17)	-0.36	(-2.99, 2.27)	-0.32	(-4.02, 3.38)	-1.55	(-4.89, 1.80)	-1.09	(-5.21, 3.04)	-0.29	(-4.30, 3.72)
West Midlands	0.39	(-1.55, 2.32)	1.48	(-0.33, 3.29)	-4.49	(-6.77, -2.22)	-3.31	(-5.39, -1.24)	-11.73	(-14.08, -9.39)	-10.54	(-12.88, -8.20)
West Yorkshire and Harrogate	-2.15	(-5.20, 0.90)	-2.47	(-5.40, 0.46)	-0.26	(-4.45, 3.94)	-0.71	(-4.35, 2.92)	-4.86	(-9.31, -0.40)	-6.69	(-10.88, -2.50)
Age 0-44	22.14	(15.21, 29.08)	20.69	(13.91, 27.47)	37.29	(28.28, 46.31)	36.41	(27.47, 45.35)	-1.37	(-9.44, 6.70)	-1.59	(-9.41, 6.24)

Age 45-54	15.07	(11.03, 19.11)	13.24	(9.38, 17.11)	30.34	(24.98, 35.70)	28.96	(23.77, 34.15)	-4.91	(-9.47, -0.34)	-5.80	(-10.26, -1.34)
Age 55-64	9.38	(7.31, 11.46)	7.59	(5.58, 9.61)	23.18	(20.34, 26.03)	21.61	(18.82, 24.40)	-0.07	(-2.73, 2.59)	-0.39	(-3.00, 2.21)
Age 65-74	6.11	(4.86, 7.36)	4.84	(3.64, 6.04)	10.60	(8.94, 12.26)	9.59	(7.97, 11.21)	1.47	(-0.27, 3.21)	1.75	(0.06, 3.44)
Age 75-84	-5.41	(-6.29, -4.53)	-4.83	(-5.69, -3.96)	-8.88	(-9.95, -7.81)	-8.68	(-9.73, -7.63)	1.49	(0.07, 2.90)	1.53	(0.16, 2.90)
Age 85+	-12.21	(-12.9, -11.52)	-9.55	(-10.28, -8.83)	-19.18	(-20.05, -18.30)	-17.16	(-18.08, -16.23)	-2.81	(-4.6, -1.01)	-2.83	(-4.64, -1.02)
Female	-1.81	(-2.49, -1.13)	-0.49	(-1.13, 0.16)	-0.30	(-1.16, 0.56)	1.21	(0.43, 2.00)	-1.09	(-2.05, -0.12)	-1.18	(-2.13, -0.24)
Male	1.88	(1.17, 2.58)	0.51	(-0.16, 1.18)	0.33	(-0.60, 1.26)	-1.32	(-2.16, -0.47)	1.18	(0.13, 2.22)	1.28	(0.25, 2.31)
Income deprivation quintile 1 (least deprived)	2.12	(0.63, 3.61)	2.04	(0.64, 3.43)	3.15	(1.22, 5.08)	3.17	(1.41, 4.92)	0.98	(-1.11, 3.08)	0.47	(-1.59, 2.52)
Income deprivation quintile 2	1.23	(-0.15, 2.61)	1.17	(-0.11, 2.45)	1.44	(-0.34, 3.22)	1.88	(0.29, 3.47)	1.07	(-0.91, 3.04)	0.30	(-1.60, 2.20)
Income deprivation quintile 3	-0.90	(-2.24, 0.43)	-0.21	(-1.47, 1.05)	-0.21	(-1.96, 1.54)	0.24	(-1.32, 1.79)	1.14	(-0.85, 3.13)	0.66	(-1.26, 2.59)
Income deprivation quintile 4	-0.50	(-1.84, 0.85)	-0.38	(-1.63, 0.88)	-2.53	(-4.23, -0.84)	-2.32	(-3.85, -0.79)	-0.98	(-2.93, 0.98)	-1.08	(-2.98, 0.82)
Income deprivation quintile 5 (most deprived)	-2.03	(-3.38, -0.68)	-2.77	(-4.10, -1.43)	-1.70	(-3.48, 0.07)	-2.91	(-4.59, -1.22)	-2.28	(-4.28, -0.27)	-0.34	(-2.33, 1.65)
Diagnosis year 2014	-0.16	(-1.41, 1.08)	0.49	(-0.67, 1.65)	-1.46	(-3.05, 0.12)	0.08	(-1.35, 1.50)	-1.85	(-3.64, -0.06)	-1.81	(-3.53, -0.09)
Diagnosis year 2015	-0.64	(-1.81, 0.54)	-0.48	(-1.57, 0.61)	-0.77	(-2.29, 0.75)	-0.56	(-1.93, 0.81)	-0.55	(-2.27, 1.16)	-0.29	(-1.95, 1.36)
Diagnosis year 2016	-0.24	(-1.42, 0.93)	-0.30	(-1.41, 0.80)	0.69	(-0.85, 2.22)	0.08	(-1.29, 1.46)	0.82	(-0.90, 2.53)	1.04	(-0.62, 2.69)
Diagnosis year 2017	1.00	(-0.19, 2.20)	0.32	(-0.79, 1.43)	1.41	(-0.14, 2.95)	0.39	(-0.99, 1.77)	1.42	(-0.31, 3.14)	0.88	(-0.77, 2.53)
Adenomas and adenocarcinomas	0.23	(0.14, 0.32)	0.24	(0.14, 0.35)	0.49	(0.38, 0.59)	0.23	(0.10, 0.36)	-0.04	(-0.23, 0.15)	0.40	(0.18, 0.61)
Other morphology	-6.82	(-9.54, -4.10)	-7.35	(-10.55, -4.16)	-13.58	(-16.57, -10.59)	-6.38	(-10.05, -2.72)	1.08	(-4.31, 6.48)	-11.15	(-17.12, -5.18)
eCCA sub-type	12.40	(10.56, 14.23)	12.34	(10.58, 14.10)	1.64	(-0.50, 3.78)	2.89	(0.92, 4.87)	19.07	(16.51, 21.62)	19.28	(16.7, 21.86)
iCCA sub-type	-2.35	(-2.78, -1.93)	-2.65	(-3.09, -2.22)	0.10	(-0.35, 0.55)	-0.47	(-0.92, -0.02)	-3.66	(-4.20, -3.13)	-3.89	(-4.47, -3.31)
Other sub-type	-9.17	(-11.00, -7.33)	-3.70	(-6.01, -1.38)	-6.74	(-10.12, -3.36)	-1.52	(-4.98, 1.94)	-0.62	(-5.01, 3.78)	2.37	(-2.50, 7.24)
Emergency presentation diagnosis route	-5.45	(-6.14, -4.76)	-3.75	(-4.42, -3.08)	-7.95	(-8.80, -7.09)	-5.31	(-6.11, -4.51)	1.52	(0.55, 2.49)	2.10	(1.14, 3.07)
GP referral diagnosis route	6.16	(4.65, 7.68)	4.61	(3.17, 6.05)	6.10	(4.15, 8.04)	4.18	(2.39, 5.97)	-4.60	(-6.54, -2.65)	-5.28	(-7.16, -3.40)
IP and OP diagnosis route	13.04	(10.54, 15.55)	9.44	(7.09, 11.79)	12.54	(9.35, 15.73)	7.65	(4.69, 10.61)	-2.76	(-5.77, 0.25)	-2.75	(-5.69, 0.18)
TWW referral diagnosis route	-0.14	(-1.66, 1.37)	-0.58	(-2.08, 0.91)	10.96	(8.75, 13.18)	8.57	(6.55, 10.59)	2.92	(0.65, 5.19)	2.29	(0.06, 4.51)
Unknown diagnosis route	-2.99	(-7.06, 1.07)	-3.21	(-6.51, 0.08)	-5.61	(-10.73, -0.49)	-8.05	(-11.96, -4.15)	-5.21	(-11.31, 0.89)	-5.94	(-11.07, -0.81)

Charlson score - 0	1.69	(1.28, 2.10)	0.69	(0.30, 1.09)	3.19	(2.65, 3.73)	1.02	(0.51, 1.53)	1.52	(0.86, 2.18)	1.38	(0.73, 2.04)
Charlson score - 1	-2.31	(-3.98, -0.64)	-0.28	(-1.85, 1.29)	-3.40	(-5.56, -1.25)	0.42	(-1.52, 2.37)	-1.73	(-4.26, 0.80)	-2.00	(-4.45, 0.45)
Charlson score - 2	-4.32	(-6.35, -2.29)	-2.06	(-3.96, -0.17)	-6.06	(-8.71, -3.40)	-0.81	(-3.25, 1.63)	-1.97	(-5.30, 1.35)	-1.77	(-4.94, 1.40)
Charlson score - 3+	-6.07	(-7.74, -4.39)	-3.19	(-4.79, -1.60)	-12.84	(-14.71, -10.97)	-7.06	(-8.93, -5.20)	-6.73	(-9.52, -3.93)	-5.53	(-8.33, -2.74)
Liver disease-no	-0.73	(-0.99, -0.47)	-0.35	(-0.60, -0.10)	-0.51	(-0.80, -0.21)	0.04	(-0.25, 0.32)	0.46	(0.17, 0.75)	0.38	(0.10, 0.67)
Liver disease-yes	7.23	(4.65, 9.82)	3.47	(0.96, 5.97)	5.53	(2.33, 8.73)	-0.43	(-3.55, 2.69)	-4.99	(-8.11, -1.86)	-4.19	(-7.29, -1.08)

Apart from the intercept, estimates represent the percentage-point difference from the weighted cohort average probability of each route. CI: Confidence interval; iCCA: Intrahepatic cholangiocarcinoma; eCCA: Extrahepatic cholangiocarcinoma; GP: General Practitioner; IP: Inpatient; OP: Outpatient; TWW: Two week wait.

Adding adjustment for stage at diagnosis did not appear to explain much of the variation in the probability of surgery observed between Cancer Alliances. (Supplementary Table 2, model A). One Cancer Alliance no longer had a probability of potentially curative surgery that was >2 SD higher than average, but two additional Cancer Alliances were identified as having higher probabilities of surgery. Amongst patients who were not treated with surgery but had a known stage at diagnosis, adjustment for stage identified one additional Cancer Alliance that had a lower-than-average probability of systemic therapy, again indicating that adjustment for stage did not explain variation observed in the main analysis (Supplementary Table 2, model B). One less Cancer Alliance was observed to have a lower-than-average probability of stent insertion after adjusting for stage at diagnosis, leaving three Cancer Alliances with a significantly lower probability of stent insertion than average (Supplementary Table 2, model C).

DISCUSSION

After adjustment for patient and tumour factors, there was significant variation amongst English Cancer Alliances in CCA patients receiving cancer-specific treatments, including potentially curative surgery, systemic therapy without curative surgery or stent insertion without curative surgery. To our knowledge, this is the first study to look at potential variation in CCA treatment at a national level. There was evidence of significant variation amongst Cancer Alliances in the percentage receiving surgery, or systemic therapy in the absence of surgery. Most variation however was observed in the percentage receiving stent insertion in the absence of surgery, suggesting there may be gaps in expertise, access and/or clinical expertise for this treatment modality. In so far as we were able to adjust for differences in patient populations between Cancer Alliances, this adjustment did not reduce the level of variation observed. However, not every CCA patient will be clinically eligible or in need of stent insertion and our inability to account for clinical status with the available data means the observed variation might still be explainable by differences in clinical case-mix and not necessarily evidence of varied or poor practice.

Whilst we have analysed treatment modalities separately, there is a possibility that the propensity toward each treatment within an area is linked, due to local expertise, protocols or capacity. An area with lower rates of surgery may have correspondingly higher rates of systemic therapy, for example. This did not often appear to be borne out in the data, with no such correspondence between Cancer Alliances that significantly varied from average in the proportion who received systemic therapy compared to either stent insertion or surgery. Two Cancer Alliances that showed lower than

average proportions receiving surgery showed higher than average proportions receiving stent insertion in the absence of surgery.

In terms of patient factors that we were able to adjust for, higher income deprivation was associated with a lower likelihood of receiving surgery or systemic therapy, independently of geography. There is already evidence that socioeconomic factors play a powerful role in determining the health of individuals[22,23]. As regards cancer, the importance of socioeconomic factors has been demonstrated in association with screening, incidence, stage at diagnosis, and survival, especially in private health care settings[24,25]. However, relatively little has been reported on how socioeconomic factors affect access to cancer system therapies, especially in publicly funded health systems such as the United Kingdom National Health Service (NHS), where cancer care at the point of service is free of charge[26,27]. A study conducted in Canada's Public payer Universal healthcare system examined the association between material deprivation and receipt of cancer care among patients with advanced gastrointestinal cancer. It found that patients from the most deprived communities were significantly less likely to see an oncology specialist after a diagnosis and significantly less likely to receive radiation and/or chemotherapy compared to those living in the least materially deprived communities [28]. To our knowledge, this is the first study to report a similar theme in patients with CCA.

Increasing co-morbidities and emergency presentation were both associated with a lower probability of surgery, in keeping with the fact that higher surgical risk may preclude treatment for the former group and likely advanced CCA stage at presentation may preclude treatment for the latter.

That half of CCA patients in England received none of the main treatments for CCA is of interest. To our knowledge, regarding CCA, no previous study of national data has studied or reported this before. The Surveillance, Epidemiology and End Results (SEER) cancer registry, representing around 28% of the population of the United States, recently showed that approximately 50% of eCCA patients and 40% of iCCA patients did not receive surgery or adjuvant therapy over a comparable calendar period[29]. This indicates a higher proportion of CCA patients receive surgical treatment in the United States than our data showed for England. However, differences in the treatment end-points defined, differences between the healthcare systems and CCA populations of the United States and England, and the select coverage of the SEER study make these findings difficult to directly compare and interpret. In the European Reference Network for the Study of CCA study, 20% of patients did not receive any specific cancer therapy, but best supportive care only[12]. Data for their study was collected from self-selected expert centres in those hospitals who chose to send in their data. These centres are large expert referral centres and the study data is not therefore reflective of "real world" overall public healthcare. Our study involved the entire NHS (all public, government-funded hospitals), so all patients from all NHS hospitals were included. The high rates of short-term mortality observed in this group may well explain the observed lack of treatment, as their case may have been too advanced for any active treatment to be considered beneficial. Further studies are warranted to explore if this high proportion of patients had adequate clinical reasons to not receive any of the main treatments for CCA. Nonetheless, this highlights the importance of increasing the therapeutic options available to those diagnosed with CCA to prolong survival, either through earlier diagnosis to preserve current treatment options or through increased research into more effective systemic therapy options.

With the available data we were unable to account for certain relevant features of clinical status, such as degree of liver disease and performance status at the time of diagnosis, which could be key prognostic factors for treatment options. Performance status data were missing for 75.1% of the cohort at diagnosis, whereas degree of liver disease is not possible to abstract from the data sources available. Our intention to account for differences in the stage at diagnosis was hindered due to missing data for 45.5% of the cohort. Although a sensitivity analysis in those with reported stage was performed, the subgroup of individuals with known stage could have been highly selected and therefore their findings may not be generalisable to the entire CCA population. This highlights the importance of documenting and collecting information on stage of CCA at diagnosis in the future. It is unclear why completeness is relatively poor for this tumour site compared to other cancers. That said, in the group where CCA stage was known, the stage at diagnosis did not appear to explain much, if any, of the variation observed.

Based on a national cohort of CCA patients, these data are highly representative of CCA patients and treatment in England, where treatment is free at point of access *via* the NHS. However, these findings will be less generalisable to other countries that have different healthcare systems and guidelines as to the management of CCA.

CONCLUSION

Certainly, some Cancer Alliances appear to have lower than average rates of treatment for CCA patients. The reasons for this require further investigation that would be aided by more detail on patient clinical status and clinical case-mix than was available *via* this national registration database. It is important to understand whether observed differences are due to differences in clinical practice, case mix or geographical differences in access to expert facilities, in order to successfully implement evidence-based solutions to reduce variation and inequality in treatments received.

ARTICLE HIGHLIGHTS

Research background

Cholangiocarcinoma (CCA) is a cancer with poor survival outcomes that is increasing in incidence worldwide. In clinical practice there can be barriers to providing treatments that can improve outcomes for those with CCA. Potentially curative

surgery is not an option for those diagnosed with advanced disease, which represents the majority of patients. Stent insertion to manage disease complications is a complex procedure requiring access to specialist expertise that is not routinely available in all areas. There are currently relatively few recommended systemic treatment options available that can prolong survival.

Research motivation

Due to the complexity of treating CCA, we hypothesise that there could be variation in the treatments received by CCA patients. Such variation could contribute to the poor outcomes experienced by CCA patients. There is very little data to evidence variation in the care and management of CCA in England, so research into this area is needed. Identifying variation that could point to inequality is the first step toward improving patient outcomes, leading to further research into understanding why this variation exists and ultimately improvement strategies to reduce these variations in care.

Research objectives

We aimed to investigate whether there was evidence of geographic variation in the proportion of CCA patients that received each of three main cancer-specific treatments: potentially curative surgery; systemic therapy amongst those that did not receive surgery; stent insertion amongst those that did not receive surgery.

Research methods

We conducted a retrospective cohort study including patients diagnosed with CCA from 2014-2017 in England. We used linear probability models to investigate geographic variation in the proportions of that received either potentially curative surgery, systemic therapy (in the absence of surgery) or stent insertion (in the absence of surgery) across Cancer Alliance areas in England, adjusting for potential confounders.

Research results

Half of CCA patients in England received none of the cancer treatments we investigated in this study. Only 12.4% received potentially curative surgery. Across all Cancer Alliance areas, the mean percentage-point difference from the population average [95% confidence interval (CI)] ranged from -3.96 (-6.34 to -1.59)% to 3.77 (0.54 o 6.99)% after adjustment for patient sociodemographic and clinical characteristics, showing statistically significant variation.

Amongst those who did not receive surgery, 19.9% received systemic therapy, with mean percentage-point difference from the population average [95%CI] ranging from -3.84 (-8.04 to 0.35)% to 9.28 (1.76 to 16.80)% across Cancer Alliances after adjustment. Stent insertion was received by 27.8%. Across Cancer Alliances, after adjustment for confounders, the mean percentage-point difference from population average [95%CI] ranged between -10.54 (-12.88 to -8.20)% and 13.64 (9.22 to 18.06)%, showing wide and statistically significant variation from the population average.

It is unknown whether the observed variation is evidence of inequality in access to treatment and differing clinical practice or can be explained by factors we were unable to account for in our analysis, such as patient choice and differences in the clinical case-mix of patients in these areas.

Research conclusions

We found statistically significant geographic variation in the proportions of CCA patients receiving surgery, systemic therapy and stent insertion across Cancer Alliance areas in England.

Research perspectives

Local detailed review of treatment pathways should be undertaken to understand in more detail why rates of treatment were low and whether the observed variation indicates disparities in access to care or differences in clinical practice. Greater understanding of why variation in care is present can support the development of future strategies to reduce unwarranted variation and improve outcomes.

ACKNOWLEDGEMENTS

This work uses data that has been provided by patients and collected by the NHS as part of their care and support. The data are collated, maintained and quality assured by the National Disease Registration Service, which is part of NHS England.

FOOTNOTES

Author contributions: Jose S, Knott C, Khan SA, Morement H and Zalin-Miller A designed the study; Paley L and Toledano MB advised on the study design; Jose S, Zalin-Miller A and Knott C had full access to the underlying data in the study; all authors contributed to the interpretation of results; Jose S and Khan SA drafted the manuscript; Knott C, Morement H, Paley L, Tataru D, Toledano MB and Zalin-Miller A reviewed and revised the manuscript; all authors approved the final version of the manuscript had access to the study data and accept responsibility to submit for publication.

Supported by AMMF; National Disease Registration Service, National Health Service England.

Institutional review board statement: The study was reviewed and approved for publication by our Institutional Reviewer.

Informed consent statement: NHS England and has a special legal instruction to collect patient data without needing informed consent. This instruction is granted under section 254 of the Health and Social Care Act 2012.

Conflict-of-interest statement: Dr Jose reports grants from AMMF-The Cholangiocarcinoma Charity, during the conduct of the study.

Data sharing statement: The data that support the findings of this study are available from NHS England. Restrictions apply to the access and use of the data used to undertake this study. A data dictionary is available at https://digital.nhs.uk/ndrs/data/access-to-data.

STROBE statement: The authors have read the STROBE Statement-checklist of items, and the manuscript was prepared and revised according to the STROBE Statement-checklist of items.

Country/Territory of origin: United Kingdom

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S-Editor: Qu XL
L-Editor: A
P-Editor: Xu ZH

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