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Travel time to hospital and treatment for breast, colon, rectum, lung, ovary and prostate cancer

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ABSTRACT

The aim was to examine the effect of geographical access to treatment services on cancer treatment patterns. Records for patients in northern England with breast, colon, rectal, lung, ovary and prostate tumours were augmented with estimates of travel time to the nearest hospital providing surgery, chemotherapy or radiotherapy. Using logistic regression to adjust for age, sex, tumour stage, selected tumour pathology characteristics and deprivation of place of residence, the likelihood of receiving radiotherapy was reduced for all sites studied with increasing travel time to the nearest radiotherapy hospital. Lung cancer patients living further from a thoracic surgery hospital were less likely to receive surgery, and both lung cancer and rectal cancer patients were less likely to receive chemotherapy if they lived distant from these services. Services provided in only a few specialised centres, involving longer than average patient journeys, all showed an inverse association between travel time and treatment take-up.

1. Introduction

Since the Hospital Plan of 1962, services in the UK have become increasingly concentrated in district general hospitals, located near the population centres they serve. Services such as radiotherapy and thoracic surgery were recognised as needing larger catchments and were provided only in certain district hospitals.[1] The Calman–Hine Report later reviewed services, recommending that outcomes would be improved by further consolidation in fewer, larger units with more specialist knowledge, better facilities and sufficient patient throughput to promote expertise.[2] The advantages of centralising services were expected to outweigh any disadvantage of longer travel for some patients, but little was known about the effects of patient travel to hospital on treatment uptake. Recently, some concern has been expressed that the centralisation of services in large city hospitals might lead to problems in gaining access for more distant, rural, populations. In particular, the demands of treatment at a distant location, especially where the intention is palliation and treatment is administered regularly, might deter some patients from undergoing therapy if the apparent cost and effort involved outweighed the perceived health benefits.[3,4] For example, in a US study, nearly 50% of cancer patients stated that long travel distance, not having access to a vehicle and having no-one to accompany them would be barriers to receiving treatment.[5]

A number of factors have been widely reported to influence the particular treatment any patient receives. These include co-morbidities and marital status,[6,7] expected lifespan, deprivation,[6,8,9] extent of the tumour and its pathology,[11] type of hospital visited[4,12] and specialist consulted,[13,14] and surgical referral practice.[15]

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Relatively few studies have examined the effect of geographical accessibility on treatment. Some have used a simple urban-rural classification. Rural colorectal patients in Scotland were found to be more likely to receive chemotherapy than were urban patients, but the difference was not statistically significant and the effect of differences in stage of disease at diagnosis could not be assessed.[16] In France, no significant difference in uptake of surgery for colorectal cancer was reported between urban and rural residents after adjusting for age, sex, tumour pathology, stage and type of hospital.[8] However, Madelaine et al. reported significantly lower treatment rates for rural lung cancer patients in France, after taking occupational class into consideration.[17]

Some studies have used straight line distance or estimated travel times as a proxy for travel effort. Punglia et al. found that increasing distance to the nearest radiotherapy centre was associated with a decreasing likelihood of receiving post-mastectomy radiation therapy, with an Odds Ratio of 0.996 with each additional mile.[18] In rural USA, non small-cell lung cancer patients living at greater straight line distance from a specialist cancer centre were significantly more likely to undergo surgery but were less likely to receive radiotherapy or chemotherapy than closer patients.[6] That work concluded those living at greater distance from hospital favoured surgery over other options because of travel implications: surgery required one hospitalisation whereas chemotherapy and radiotherapy may have required repeated visits for treatment. Faced with two treatment options offering equivalent survival, patients might weigh the costs in terms of time, expense and inconvenience of travel to therapy against the perceived benefits. Molenaar et al. came to similar conclusions for breast cancer patients in the Netherlands[19] as did Nattinger et al. in the USA.[20] Older women, those in work or with childcare commitments in that study were more likely to opt for mastectomy and avoid the outpatient radiotherapy visits advised after breast conserving surgery. Using a more sophisticated methodology based on road travel times, Athas et al. found that breast cancer patients living further than 75 miles from a radiotherapy hospital were significantly less likely to receive adjuvant post-operative radiotherapy than those living closer.[21]

In the UK, Cosford et al. found no significant relationship between area-based measures of average drive time to a radiotherapy facility and the proportion of patients receiving radiotherapy.[3] This was a small study in which travel times were not calculated for individual patients and no correction was made for case-mix, sex, stage or pathology. Furthermore, the setting was central England, where maximum travel times were short (up to 1 hour). A more recent study by Campbell et al. in north-east Scotland,[10] where rural remoteness is much more of an issue, used straight-line distance to the closest cancer centre as a proxy for rurality and adjusted for the effects of age, tumour pathology, stage and deprivation. They found no significant relationship between this measure and uptake of chemotherapy, radiotherapy or surgery for lung cancer patients, but colorectal cancer patients living further from a cancer centre were significantly less likely to receive radiotherapy.

This study examines the effect of geographical access on the uptake of surgery, chemotherapy and radiotherapy for cancer in a region of England containing urban populations living close to health facilities and remote rural populations much more distant from hospitals. We test the hypothesis that increasing travel effort may decrease access to important treatment services. The research aims to improve on the methodology of previous work by including a large number of patient records involving several cancer sites, by allowing for other influences on treatment likelihood in a systematic way and by using more appropriate measures of access to treatment.

2. Patients and methods

2.1. Setting

The study area was northern England, the area covered by the Northern and Yorkshire Cancer Registry (NYCRIS) stretching south from the Scottish border to beyond the River Humber. The region has a population of around 6.7 million. It is diverse both geographically and demographically. There are sparsely populated areas with remote farms and hamlets (upland North Cumbria, Northumberland and North Yorkshire) and densely populated conurbations (Leeds/Bradford, Newcastle upon Tyne, Middlesbrough) with some smaller cities such as York and Durham. There are also strong variations in socio-economic deprivation.

2.2. Subjects

NYCRIS supplied records of patients registered with breast, colon, rectum, lung, ovary or prostate cancer from 1994 to 2002 inclusive. The registry was formed from the merger of two earlier registries in 1998. For the first 4 years of the study data collected by the former Northern Registry were unavailable, so only records from the former Yorkshire Registry were used. Data for the entire NYCRIS catchment was analysed from 1998 onwards. The tumour sites were selected because previous studies indicated that access to healthcare might affect survival,[8,22] or because early intervention had been shown to affect outcome.[23] Lung cancer patients excluded those with mesothelioma, breast patients included only females with invasive carcinoma, and patients with atypical tumour pathology types and death certificate only cases were omitted from this analysis. The outcomes measured were whether the patient had received surgery, chemotherapy or radiotherapy at any stage of their disease.

2.3. Measures of access to treatment services

The residential locations of all patients meeting the inclusion criteria were mapped in a geographical information system (ArcGIS) from their postcodes. The locations of hospitals were also entered into the GIS. All hospitals which had provided surgery, chemotherapy or radiotherapy for cancer treatment were ranked in order of their number of treatments for each cancer site, and those that had treated over 99% of cases were selected. To avoid including hospitals which only rarely offered treatment, we did not consider those units that together accounted for less than 1% treatments for each type of cancer. Private healthcare providers were also excluded.

A previous pilot study determined that 87% of cancer patients in the study area travelled to hospital by motor vehicle, so road travel time was selected as the most appropriate single measure of physical accessibility.[24] The Meridian digital road network, provided by the UK Ordnance Survey was used, and average travel speeds dependent on road class, type (single or dual carriageway), and urban/rural setting, were assigned to each section of the road network. Travel times were estimated from every postcode location to the nearest hospitals where specific treatments were available. Journey time estimates derived in this way are closely related to the times of actual car journeys reported by cancer patients.[24]

Patient postcodes were assigned a deprivation measure based on the 2004 Index of Multiple Deprivation (IMD 2004) score for the lower level super output census area in which they were located. The IMD 2004 is a composite measure of area material deprivation and includes an access to services domain.[25] To avoid double counting we modified each score by removing the access component. The larger the IMD score, the greater the level of deprivation.

The anonymised dataset for analysis consisted of tumour site, tumour stage, patient age and sex, treatments received, certain site-specific characteristics, plus the access and deprivation measures. Tumour stage was categorised one (localised) to four (distant metastases), with a further category of 'stage unknown'. Some characteristics of the tumour or of the treatment were recorded because it was anticipated that these might affect the likelihood of treatment. Lung cancer patients were classified into small-cell lung cancer, non-small-cell lung cancer and those not coded as either type. Breast cancer patients were divided into those with no surgery and those with breast conserving surgery, mastectomy or both.

2.4. *Analysis*

The factors associated with treatments provided were determined using conditional logistic regression analysis models in SPSS for each tumour site. Stage was poorly recorded for lung and prostate patients, and was not considered in the analyses for these sites. The measures of travel time were modelled as a categorical variable, with the patients being divided into quartiles and odds ratios calculated relative to the first quartile (those living closest to hospital).

3. Results

Altogether 117,097 patients were included in the study, with fewer numbers of ovarian cancer patients compared with the other sites. Numbers receiving the different treatments, stratified by age, are given in Table 1. All the treatments were primary and not for tumour recurrence or metastasis. The frequency of each treatment varied considerably. As anticipated, the provision of all treatments was more common in the younger (<70 years) age group for all tumour sites. Most breast, colon, rectal and ovary cancer patients received surgery, while this was less common amongst prostate and lung cancer patients. Chemotherapy was received by just over half the ovarian cancer patients, but smaller proportions of patients in the other categories. Radiotherapy was given to just over half the breast cancer patients, but to smaller proportions of other patients. Radiotherapy was more commonly

Table 1 – Numbers of patients receiving surgery, chemotherapy and radiotherapy by cancer site

Age (years):	Breast (%)		Colon (%)		Rectum (%)		Lung (%)		Ovary (%)		Prostate (%)	
	<70	70+	<70	70+	<70	70+	<70	70+	< 70	70+	<70	70+
Surgery												
Received	17,942	5,302	5,483	8,309	4,388	4,556	2,237	1,315	2,601	934	2,752	4,657
	(95.2)	(57.9)	(87.7)	(78.4)	(85.7)	(72.5)	(15.3)	(6.5)	(80.9)	(46.4)	(38.9)	(34.2)
Did not receive	892	3,817	770	2,273	720	1,727	12,358	18,881	605	1,065	4,284	8,851
	(4.7)	(41.7)	(12.3)	(21.5)	(14.1)	(27.5)	(84.3)	(93.1)	(18.8)	(52.9)	(60.5)	(65.0)
Not known	14	35	2	13	11	4	56	76	10	13	44	100
	(0.1)	(0.4)	(0.02)	(0.1)	(0.2)	(0.1)	(0.4)	(0.4)	(0.3)	(0.6)	(0.6)	(0.7)
Chemotherapy												
Received	7,549	230	2,760	1,215	2,241	827	4,014	1,769	2,041	877	7,035	13,557
	(40.1)	(2.5)	(44.1)	(11.5)	(43.8)	(13.2)	(27.4)	(8.7)	(63.5)	(43.6)	(99.4)	(99.6)
Did not receive	11,299	8,924	3,495	9,380	2,878	5,460	10,637	18,503	1,175	1,135	40	37
	(59.9)	(97.5)	(55.9)	(88.5)	(56.2)	(86.8)	(72.6)	(91.3)	(36.5)	(56.4)	(0.6)	(0.3)
Not known	0	0	0	0	0	0	0	0	0	0	5	14
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.1)
Radiotherapy												
Received	12,359	2,689	222	180	1,651	1,253	7,002	6,855	42	11	2,103	1,126
	(65.6)	(29.4)	(3.5)	(1.7)	(32.3)	(19.9)	(47.8)	(33.8)	(1.3)	(0.5)	(29.7)	(8.3)
Did not receive	6,339	6,398	5,993	10,359	3,418	5,008	7,593	13,346	3,140	1,985	4,905	12,355
	(33.6)	(69.9)	(95.8)	(97.8)	(66.8)	(79.7)	(51.8)	(65.8)	(97.6)	(98.7)	(69.3)	(90.8)
Not known	150	67	40	56	50	26	56	71	34	16	72	127
	(0.8)	(0.7)	(0.6)	(0.5)	(0.1)	(0.4)	(0.4)	(0.4)	(1.1)	(0.8)	(1.0)	(0.9)
Total	18,848	9,154	6,255	10,595	5,119	6,287	14,651	20,272	3,216	2,012	7,080	13,608
	(67.3)	(32.7)	(37.1)	(62.9)	(44.9)	(55.1)	(42.0)	(58.0)	(61.5)	(38.5)	(34.2)	(65.8)

used for treating rectal tumours than tumours in the colon. Very few prostate cancer patients were recorded as being treated by chemotherapy and few ovarian cancers were treated by radiotherapy, so these combinations were not analysed further.

Table 2 shows that the number of hospitals providing each treatment varied considerably between treatment types, and in some cases, between cancer sites. While many hospitals provided some surgery and chemotherapy services, in keeping with the 1962 policy only six centres provided radiotherapy. Thoracic surgery for lung cancer was available in only eight centres. For chemotherapy, colon and rectal cancer patients were referred to the fewest facilities (21 and 19 respectively). Travel times to the closest facility offering treatment were consequently greater for radiotherapy than for surgery or chemotherapy. There were some variations between sites, but the boundaries between the travel time quartiles were very approximately 8 minutes, 12 minutes (the median) and 19 minutes for surgery and chemotherapy. Estimated travel times quartiles for radiotherapy, on the other hand, were divided at approximately 24 minutes, 35 minutes (the median) and 50 minutes.

The associations between receipt of surgery and patient characteristics are shown in Table 3, which gives adjusted odds ratios. The coefficients for age (representing odds ratios for increments of 1 year) had values significantly less than 1.0, indicating a reduction in the likelihood of surgery for all cancer types with increasing age of the patient. Male colon cancer patients were more likely to receive surgery than females, but the sex of the patient made no significant difference for rectal or lung cancer patients. The four cancer sites for which tumour stage information was available showed

Table 2 – Numbers of hospitals[a] providing treatment to study patients by cancer site

	Breast	Colon	Rectum	Lung	Ovary	Prostate
Surgery	43	40	42	8	40	35
Chemotherapy	45	21	19	35	29	–
Radiotherapy	6	6	6	6	–	6

a Hospitals providing treatment to less than 1% of patients excluded.

Table 3 – Surgery: Odds Ratios and 95% confidence intervals for predictors of receipt of treatment

	Breast	Colon	Rectum	Lung	Ovary	Prostate
Age	0.88** (0.87 – 0.88)	0.94** (0.94 – 0.95)	0.94** (0.94 – 0.95)	0.96** (0.95 – 0. 96)	0.93** (0.92 – 0.93)	0.99** (0.98 – 0.99)
Male	Females only	1.1* (1.0 – 1.2)	1.1 (0.95 – 1.2)	1.0 (0.93 – 1.1)	Females only	Males only
Stage						
1	1.0	1.0	1.0		1.0	
2	1.2 (0.73 – 1.9)	2.1** (1.3 – 3.4)	0.99 (0.72 – 1.4)	NA	0.44 (0.03 – 7.40)	NA
3	0.13** (0.07 – 0.25)	0.89 (0.50 – 1.6)	0.86 (0.56 – 1.3)		0.03** (0.01 – 0.25)	
4	0.01** (0.01 – 0.02)	0.02** (0.01 – 0.03)	0.03** (0.02 – 0.04)		0.02** (0.001 – 0.08)	
Unknown	0.22** (0.19 – 0.26)	0.05** (0.04 – 0.08)	0.09** (0.07 – 0.12)		0.03** (0.01 – 0.18)	
Site specific condition	NA	NA	NA	1.0	NA	NA
Site specific condition	NA	NA	NA	(A) 13.3** (11.3 – 15.7)	NA	NA
Site specific condition	NA	NA	NA	(B) 0.68** (0.51 – 0.90)	NA	NA
Deprivation	0.99** (0.98 – 0.99)	0.99** (0.99 – 1.0)	0.99** (0.98 – 0.99)	0.99** (0.99 – 1.0)	0.99** (0.99 – 1.0)	0.99** (0.99 – 1.0)
Time to hospital						
Quartile 1	1.0	1.0	1.0	1.0	1.0	1.0
Quartile 2	1.1 (0.95 – 1.2)	1.0 (0.92 – 1.2)	1.0 (0.89 – 1.2)	0.81** (0.73 – 0.90)	1.0 (0.86 – 1.2)	1.0 (0.93 – 1.1)
Quartile 3	0.99 (0.88 – 1.1)	1.1 (0.95 – 1.2)	0.98 (0.85 – 1.1)	0.77** (0.70 – 0.86)	0.93 (0.77 – 1.1)	0.89** (0.82 – 0.96)
Quartile 4 (furthest)	0.95 (0.84 – 1.1)	0.95 (0.83 – 1.1)	1.1 (0.91 – 1.2)	0.76** (0.68 – 0.85)	1.1 (0.92 –1.4)	0.93 (0.85 – 1.0)

(A) Non Small-cell Lung Cancer, (B) Small-cell Lung Cancer.
*$p < 0.05$, **$p < 0.01$, NA = not assessed.

Table 4 – Chemotherapy: Odds Ratios and 95% confidence intervals for predictors of receipt of treatment

	Breast	Colon	Rectum	Lung	Ovary
Age	0.89**	0.90**	0.91**	0.92**	0.98**
	(0.88 – 0.89)	(0.90 – 0.91)	(0.91 – 0.92)	(0.91 – 0.92)	(0.98 – 0.99)
Male	Females only	1.3**	1.2**	0.98	Females only
		(1.2 – 1.4)	(1.1 – 1.3)	(0.91 – 1.1)	
Stage					
1	1.0	1.0	1.0		1.0
2	4.9**	17.9**	5.9**		10.7**
	(3.9 – 6.2)	(10.3 – 31.2)	(4.4–7.8)	NA	(4.1 – 28.5)
3	13.3**	140.6**	40.7**		10.2**
	(7.6 – 23.3)	(79.8 – 247.6)	(30.1 – 55.0)		(6.0 – 17.4)
4	12.2**	110.6**	33.7**		7.6**
	(9.9 – 15.2)	(63.5 – 192.6)	(25.5 – 44.6)		(4.7 – 12.3)
Unknown	5.7**	84.6**	22.4**		2.0**
	(5.1 – 6.3)	(48.6 – 147.1)	(17.1 – 29.3)		(1.2 – 3.0)
Site specific condition	(C) 1.0	NA	NA	1.0	NA
Site specific condition	(D) 0.84*		NA	(A) 2.4**	NA
	(0.72 – 0.98)	NA		(2.1 – 2.7)	
Site specific condition	(E) 1.7**	NA		(B) 54.9**	NA
	(1.4 – 1.9)		NA	(48.3 – 62.5)	
Site specific condition	(F) 1.0	NA	NA	NA	NA
	(0.87 – 1.2)				
Deprivation	0.99	0.99**	0.99**	0.99**	0.99**
	(0.98 – 1.0)	(0.98 – 0.99)	(0.99 – 1.0)	(0.99 – 0.99)	(0.99 – 1.0)
Time to hospital					
Quartile 1	1.0	1.0	1.0	1.0	1.0
Quartile 2	1.1	1.1	1.1	0.98	1.0
	(0.95 – 1.2)	(0.95 – 1.2)	(0.97 – 1.3)	(0.88 – 1.1)	(0.86 – 1.2)
Quartile 3	1.1*	0.89	1.1	0.97	0.99
	(1.0 – 1.2)	(0.79 – 1.0)	(0.94 – 1.3)	(0.88 – 1.1)	(0.84 – 1.2)
Quartile 4 (furthest)	0.977	0.882	0.828*	0.703**	1.0
	(0.89 – 1.1)	(0.78 – 1.0)	(0.72 – 0.96)	(0.63 – 0.79)	(0.88 – 1.2)

(A) Non Small-cell Lung Cancer, (B) Small-cell Lung Cancer,*(C)* No surgery, *(D)* BCS, *(E)* Mastectomy, *(F)* BCS followed by mastectomy.
* $p < 0.05$, ** $p < 0.01$, NA = not assessed.

that the likelihood of surgery was reduced considerably for tumours recorded at stages 3 and 4 compared with stage 1. For lung cancer, non small-cell tumours were more likely and small-cell tumours were less likely to receive surgery than other pathology types. For all cancer sites, surgery was less likely for patients who lived in deprived areas compared with patients living in more affluent areas. The coefficients give the odds ratios for one increment in the deprivation score, which ranged from 0 to 80.

As with all the models, the associations with travel time presented in the table hold constant the effects of the other variables included in the table. Adjusting for the effects of age, sex, tumour stage, site-specific conditions and deprivation, the coefficients for the likelihood of surgery with travel time to the nearest treatment hospital showed no association for most sites. The exception was lung cancer, where the odds for surgery were progressively and significantly reduced in quartiles 2 to 4 compared with the closest.

Table 4 gives the results for chemotherapy. Older patients were less likely to receive chemotherapy than younger ones, and males were more likely than females with colon and rectal cancer. The tumour stage was very influential, as were the condition-specific factors, especially whether a lung cancer was small-cell lung cancer. Patients were significantly less likely to receive chemotherapy if they lived in a deprived area for all cancer sites except breast cancer. Holding these associations constant, colon, rectal, and lung cancer patients living in the longest hospital travel time quartile had reduced chances of chemotherapy compared with those in the shortest, although the finding for colon cancer was just short of reaching statistical significance.

The radiotherapy results appear in Table 5. Again, the treatment became less likely with age, more likely in men with cancer of the rectum, and was extremely dependent on tumour stage and site-specific factors. Radiotherapy was especially likely to be received by women who had breast conserving surgery following breast cancer. Treatment was negatively associated with the deprivation level of the place of residence for breast, lung and prostate cancers. Allowing for these associations, receipt of radiotherapy was adversely associated with travel time to the nearest treatment facility for all cancer sites. The reduction in treatment likelihood for colon cancer was similar in magnitude to the other sites but was not statistically significant because of smaller numbers.

Although the models presented in Tables 3–5 control for age, we investigated whether there was a differential effect of accessibility amongst younger and older patients by stratifying them according to age (<70 years versus 70+ years). There was no evidence of strong or consistent differences in

Table 5 – Radiotherapy: Odds Ratios and 95% confidence intervals for predictors of receipt of treatment

	Breast	Colon	Rectum	Lung	Prostate
Age	0.96**	0.96**	0.97**	0.97**	0.91**
	(0.95 – 0.96)	(0.96 – 0.97)	(0.96 – 0.97)	(0.96 -0.97)	(0.90 – 0.91)
Male	Females only	1.2	1.4**	1.0	Males only
		(0.95 – 1.4)	(1.3 – 1.5)	(0.98 – 1.1)	
Stage					
1	1.0	1.0	1.0		
2	2.9**	9.9**	1.8**		
	(2.4 – 3.6)	(3.1 – 31.3)	(1.6 – 2.1)	NA	NA
3	5.1**	14.2**	2.3**		
	(2.9 – 8.7)	(4.3 – 46.3)	(1.9 – 2.8)		
4	2.8**	17.5**	1.4**		
	(2.3 – 3.3)	(5.6 – 55.1)	(1.2 – 1.6)		
Unknown	1.1**	11.6**	1.9**		
	(1.0 – 1.2)	(3.7 – 36.6)	(1.7 – 2.2)		
Site specific condition	(C) 1.0	NA	NA	1.0	NA
Site specific condition	(D) 24.1**		NA	(A) 2.2**	NA
	(21.4 – 27.1)	NA		(2.1 – 2.3)	
Site specific condition	(E) 3.0**	NA	NA	(B) 1.4**	NA
				(1.3 – 1.5)	
	(2.7 – 3.4)				
Site specific condition	(F) 1.5**	NA	NA	NA	NA
	(1.3 – 1.7)				
Deprivation	0.99**	0.99	0.99	0.99**	0.99**
	(0.98 – 0.99)	(0.99 – 1.0)	(0.99 – 1.0)	(0.99 – 1.0)	(0.98 – 0.99)
Time to hospital					
Quartile 1	1.0	1.0	1.0	1.0	1.0
Quartile 2	0.91*	0.72*	0.71**	0.86**	1.0
	(0.83 – 0.98)	(0.55 – 0.96)	(0.63 – 0.80)	(0.81 – 0.92)	(0.91 – 1.1)
Quartile 3	0.94	0.77	0.58**	0.85**	1.1
	(0.87 – 1.0)	(0.58 – 1.0)	(0.52 – 0.66)	(0.79 – 0.90)	(0.97 – 1.2)
Quartile 4 (furthest)	0.80**	0.80	0.64**	0.86**	0.88*
	(0.73 – 0.87)	(0.60 – 1.1)	(0.57 – 0.73)	(0.80 – 0.91)	(0.79 – 0.99)

(A) Non Small-cell Lung Cancer, (B) Small-cell Lung Cancer, (C) No surgery, (D) BCS, (E) Mastectomy, (F) BCS followed by mastectomy.
*$p < 0.05$, **$p < 0.01$, NA = not assessed.

the effects of travel time for these two groups. Compared to the unstratified results presented, ovarian cancer patients in the under 70 age group were significantly more likely to have surgery if they lived in the furthest travel quartile (OR 1.4, $p < 0.05$) whilst surgery was less likely amongst prostate cancer patients aged 70 or over in the same quartile (OR 0.869, $p < 0.01$). For chemotherapy, colon cancer patients aged over 70 living in the furthest quartile were less likely to receive treatment (OR 0.803, $p < 0.05$). The other odds ratios were similar to the unstratified ones presented.

4. Discussion

No clear picture of the effect of physical accessibility on the likelihood of treatment has emerged from previous studies, but they have varied in their geographical setting, measurement of physical accessibility, and ability to control for other influences. The likelihood of receiving surgery or chemotherapy was not related to the proximity of the service for most patients. The exceptions were surgery and chemotherapy for lung cancer patients and chemotherapy for rectal cancer patients, which showed evidence of being less likely for those with a longer journey to receive the treatment. Two of these three exceptions were for services provided at only a few sites, involving longer journeys than other treatments. Travel to radiotherapy involved the longest journeys because only six centres provided it. Patients with breast, rectal, lung and prostate cancers were all less likely to receive radiotherapy if they lived further from the radiotherapy centres.

The residential locations of patients studied here represented as wide a range of physical accessibility as can be found in England, from densely populated urban areas close to large hospitals to remote rural locations over 1 hour's drive from the closest hospital and up to 3 hours from the nearest cancer centre. Ideally, information on car ownership and means of transport used to visit hospital should have been included, but this is not available. Nevertheless, by developing a detailed GIS database, we were able to calculate more appropriate and precise measures of access than have been attempted previously. Most cancer patients travel to hospital by car, so car travel time is arguably the best single measure of variations in ease of access, even for the minority of people without a household car or too ill to drive. These people rely mostly on being taken in a friend or relative's car, in a taxi or by hospital transport, journeys all of which increase in difficulty with drive time.

For the majority of people in northern England, where car ownership rates are high and journeys to hospital generally take less than 1 hour, getting to hospital for treatment is not likely to be a serious issue. The high proportions of

patients who attended hospitals that were not the closest to their home (36% of surgery patients and 43% of patients receiving chemotherapy, compared with only 6% for radiotherapy) demonstrated the perceived advantages of attending a more specialist (or otherwise preferred) facility outweighed the inconvenience of extra travel for many, although it cannot be assumed that the clinical needs of these were the same as those who first attended a local hospital. Actual travel times to treatment were likely to be affected by a tendency for the most mobile patients to be referred to hospitals at longer distances in exchange for greater choice, which would complicate the interpretation of results. To avoid this source of bias, the estimated car journey time to the nearest hospital offering treatment was selected as the most appropriate measure of accessibility.

In contrast to some previous studies, this investigation was able to control for several factors that had a substantial effect on the likelihood of treatment. The age and sex of the patient, stage of the disease, pathology of the tumour, nature of the surgery performed in the case of breast cancer, and level of deprivation in the place of residence were all found to influence the treatment received, and it was possible to hold these effects constant while examining the association between treatment and travel time. It was not possible to include all the known influences on treatment uptake. Comorbidity information was not available, and we were not able to distinguish curative and palliative treatments or include factors such as variations between specialists or particular hospital characteristics. Failing to control for such factors might have confounded the results, but only if the uncontrolled factors were themselves associated with travel times.

The information available about material deprivation referred to populations in small areas rather than the actual cancer patients. Although people who lived in poorer areas consistently had less chance of treatment, we were unable to ascertain whether the patients themselves were deprived. Hence the results can only strongly suggest that materially deprived individuals were also disadvantaged in terms of access to cancer treatment, a finding which is consistent with that of others.

This investigation was prompted by the current UK policy of concentrating cancer services into fewer centres. Where benefits of service centralisation are perceived, it is important that the process does not create new barriers to access. There may be particular considerations in situations where internal markets are present and there might be, for example, pressures for those in primary care to commission services from local hospitals which have been assigned as their care providers. In such cases, unequal provision of local services as a consequence of centralisation could create tensions. Our results suggest that geographical inaccessibility did not appear to have any detrimental influence on the likelihood of a patient receiving the treatments commonly offered in large general hospitals, but all the treatments provided at only a few specialised centres showed evidence of diminishing likelihood with increasing travel time.

The finding raises the possibility that the prognosis of patients requiring treatment at specialist centres may be poorer. In a recent work using the same sample of patients we examined the relationship between travel times to health care and stage and survival for cancers in Northern England.[26] We found that stage at diagnosis was associated with increasing travel time to general practitioners for breast and colorectal cancers and risk of death was associated with travel time to general practitioners for prostate cancer, although no consistent associations were observed with travel time to hospital. The associations between hospital travel times and treatment observed here may therefore have had no significant impact on mortality. However, we did not have information on recurrences. In a meta-analysis of randomised trials for the treatment of breast cancer, the European Breast Cancer Trialists Collaborative Group (EBCTCG) found that both radiotherapy[27] and chemotherapy[28] substantially reduced 5 year recurrence rates, as well as 15 year morality. Hence the impacts on outcomes of the effects we observed here require further investigation, particularly to consider survival over a longer period.

Service centralisation brings clear benefits, and indeed may be the only option for radiotherapy. Nevertheless, the policy of locating certain services in a small number of institutions with the intention of assuring uniform high quality is being undertaken on the assumption that the centralised service will be equally accessible to all residents of its catchment population. The National Health Service sought to achieve this in the provision of radiotherapy by arranging for a Consultant in that discipline to undertake clinics in all the affiliated District General Hospitals, this being extended over the past decade to include attendance at multidisciplinary team meetings.[29] Our results suggest provision may still be suboptimal as we illustrate that there is reduced uptake for these services amongst patients resident in socioeconomically deprived localities and by those where the facility is more remote from their residence. To meet these hidden needs will require extra capacity, and our findings raise the possibility that further concentration of cancer services into a small number of specialised centres could introduce further geographical inequalities in treatment uptake unless measures are taken to ensure that travel effort does not constitute a barrier to appropriate care.

Conflict of interest statement

None declared.

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