The impact of the COVID-19 pandemic on radiotherapy services in England, UK: a population-based study

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Summary

Background **The indirect impact of the COVID-19 pandemic on cancer outcomes is of increasing concern. However, the extent to which key treatment modalities have been affected is unclear. We aimed to assess the impact of the pandemic on radiotherapy activity in England.**

Methods **In this population-based study, data relating to all radiotherapy delivered for cancer in the English NHS, between Feb 4, 2019, and June 28, 2020, were extracted from the National Radiotherapy Dataset. Changes in mean weekly radiotherapy courses, attendances (reflecting fractions), and fractionation patterns following the start of the UK lockdown were compared with corresponding months in 2019 overall, for specific diagnoses, and across age groups. The significance of changes in radiotherapy activity during lockdown was examined using interrupted time-series (ITS) analysis.**

Findings **In 2020, mean weekly radiotherapy courses fell by 19·9% in April, 6·2% in May, and 11·6% in June compared with corresponding months in 2019. A relatively greater fall was observed for attendances (29·1% in April, 31·4% in May, and 31·5% in June). These changes were significant on ITS analysis (p<0·0001). A greater reduction in treatment courses between 2019 and 2020 was seen for patients aged 70 years or older compared with those aged younger than 70 years (34·4% *vs* 7·3% in April). By diagnosis, the largest reduction from 2019 to 2020 in treatment courses was for prostate cancer (77·0% in April) and non-melanoma skin cancer (72·4% in April). Conversely, radiotherapy courses in April, 2020, compared with April, 2019, increased by 41·2% in oesophageal cancer, 64·2% in bladder cancer, and 36·3% in rectal cancer. Increased use of ultra-hypofractionated (26 Gy in five fractions) breast radiotherapy as a percentage of all courses (0·2% in April, 2019, to 60·6% in April, 2020; ITS p<0·0001) contributed to the substantial reduction in attendances.**

Interpretation **Radiotherapy activity fell significantly, but use of hypofractionated regimens rapidly increased in the English NHS during the first peak of the COVID-19 pandemic. An increase in treatments for some cancers suggests that radiotherapy compensated for reduced surgical activity. These data will assist health-care providers in understanding the indirect consequences of the pandemic and the role of radiotherapy services in minimising these consequences.**

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Introduction

The indirect consequences of the COVID-19 pandemic are of increasing concern. The UK was one of the most severely affected countries in Europe during the first wave of the pandemic. As cases escalated in March, 2020, the National Health Service (NHS) restructured in anticipation of large numbers of inpatients requiring respiratory support.[1] Similar steps were taken by health-care providers globally.[2]

The impact of this pivot towards COVID-19, which is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), for patients with cancer is of particular concern given their need for timely diagnosis, treatment, and symptom palliation. Alongside surgery and systemic anticancer therapy, radiotherapy plays a major part both as a curative treatment and in the palliation of localised symptoms from advanced disease. It is estimated that a third of all patients with cancer in the UK will receive radiotherapy during their disease course.[3] At the outset of the pandemic, all three treatment modalities were affected by constraints on COVID-19 testing and staff shortages. Surgical services faced additional pressure as a consequence of the adaptation of theatre space for the care of acutely unwell patients requiring ventilation.

In response to these pressures, service providers, commissioners, and professional bodies within the UK and internationally issued revised guidance for cancer care. Drawing on evidence and expert consensus, these guidelines also addressed concerns about in-hospital transmission of SARS-CoV-2 and the potentially heightened risks of infection during cancer treatment.[4,5] Within these site-specific guidelines, suggestions included treatment omission or delay, the use of radiotherapy to replace or to bridge to surgery, and the wider use of short, high daily dose (hypofractionated) radiotherapy.[5]

Research in context

Evidence before this study

The indirect consequences of the COVID-19 pandemic on the care of patients with cancer are of concern. However, the extent to which radiotherapy services were affected is unclear. To identify studies reporting on changes in radiotherapy activity during the COVID-19 pandemic, we searched PubMed for articles published in English between Jan 1 and Oct 1, 2020, using the search terms ("cancer" or "malignancy") AND ("radiation therapy" OR "radiotherapy") AND ("COVID-19" OR "coronavirus" OR "SARS-CoV-2"). So far, only analyses of radiotherapy activity across single or small numbers of centres, or larger survey-based studies assessing changes to radiotherapy practice have been undertaken. These studies are at risk of responder bias and are not sufficiently comprehensive to detail changes in radiotherapy activity or prescriptions for individual cancers, or to quantify how these have varied as the pandemic has progressed.

Added value of this study

To our knowledge, this is the first comprehensive, nationwide analysis of radiotherapy activity during the first wave of the COVID-19 pandemic, from national lockdown on March 23 to June 28, 2020. We show an overall decrease in radiotherapy activity in the English National Health Service over this period. This decline is predominantly attributable to a reduction in treatments for prostate and non-melanoma skin cancer—malignancies for which there is evidence for the safety of treatment delay. By contrast, treatments for oesophageal, bladder, and rectal cancers markedly increased. We also demonstrate an increase in the use of hypofractionated regimens. Radiotherapy activity remained suppressed up to June, 2020, which might reflect delays in cancer diagnostic pathways.

Implications of all the available evidence

Although radiotherapy activity decreased during the first wave of the pandemic, our data suggest that the overall impact of this decline is likely to be modest. In addition, radiotherapy appears to have mitigated against some of the indirect harms of the pandemic by maintaining curative treatment options despite the challenges facing surgical services. As COVID-19 cases again rise, these data are crucial for modelling indirect harms of the pandemic and establish a new baseline for radiotherapy treatments from which to plan for the ongoing delivery of care throughout subsequent pandemic waves and into the recovery beyond. They also reinforce the need to address any persisting delays in cancer diagnostic pathways.

As cases of COVID-19 have risen again, it is important to understand the indirect consequences of the first pandemic peak. However, currently, our understanding of changes to radiotherapy practice is limited to a small number of surveys of radiation oncology centres in Europe, the USA, and Latin America.[6–8] These studies are at risk of responder bias, have limited information about individual cancers and regimen use, and are not able to quantify longitudinal changes during the pandemic. In the absence of this information, the indirect harms of the pandemic cannot be accurately modelled. Such data are also required by service providers, commissioners, and clinicians to mitigate against these indirect consequences. Mitigation measures include identifying cohorts of patients for whom treatment has been modified and who as a consequence might require tailored clinical follow-up, and establishing a new baseline for radiotherapy treatment patterns from which planning for future waves and for the longer-term recovery of cancer services can be developed.

In England, all NHS radiotherapy providers submit data directly from their treatment delivery systems to Public Health England (PHE) on a monthly basis to form the National Radiotherapy Dataset (RTDS).[9] This dataset contains information on more than 135 000 courses of radiotherapy delivered across the English NHS each year. In this study, we used the RTDS to explore changes in radiotherapy activity during the first peak in COVID-19 cases.

See Online for appendix

Methods

Study design

In this population-based study, we analysed radiotherapy activity across all 52 English NHS radiotherapy providers during the year before the pandemic and during the first wave of COVID-19 cases, from the date of the beginning of the UK lockdown on March 23 to June 28, 2020. PHE routinely collects data on the diagnosis and treatment of patients with cancer within the NHS under section 251 of the Health and Social Care act (2006). There is limited radiotherapy capacity in England outside these NHS centres. Study-specific ethical approval was not sought for this work, which was considered to be operational research within PHE's core remit.

Data sources

We extracted data for all external beam radiotherapy courses and attendances (which closely align to fractions) delivered to patients with cancer between Feb 4, 2019, and June 28, 2020. All ages and tumour sites were included.

Data items from RTDS used within this analysis were the diagnosis for which the treatment was delivered (defined using the 10th revision of the International Classification of Diseases [ICD-10][10]) allocated to clinically appropriate groupings (eg, head and neck cancer), as detailed in the appendix (p 1); patient age and sex; treatment intent, defined by the treating clinician as curative (including both primary or radical and adjuvant), palliative, or other (including treatments for which intent was not submitted); planned dose in Gy; planned fractionation; date of course start; attendance dates; and provider organisation.

Data analysis

Radiotherapy courses were allocated to the week in which they started and attendances (fractions) to the week in which they occurred. We defined weeks using the International Organization for Standardization calendar and allocated them to the month in which they began. We defined radiotherapy activity by the mean weekly number of treatment courses and attendances per month. We calculated percentage change in activity for each month between February and June, 2020, compared with the equivalent month in 2019 (ordinarily, limited year-on-year variation in activity is anticipated). This approach ensured minor weekly fluctuations were smoothed across each month and that comparisons recognised seasonality and bank holiday periods. During the study period, between one and four providers per month had not submitted data at the time of data extraction (appendix p 1). To adjust for this missing data, we incorporated additional activity on the basis of the proportion of activity delivered by the missing centres in months for which complete data were available.

We examined the differences in courses and attendances compared with 2019 by provider, treatment intent, age, sex, diagnosis, and region. Given the known increase in risk of adverse COVID-19 outcomes with age,[11] data were dichotomised at 70 years, in line with UK shielding advice.[12]

We assessed the significance of the change in activity following lockdown using interrupted time-series (ITS) analysis with multivariable generalised linear regression models.[13] Lockdown and easing of lockdown were specified as binary variables, applied to all timepoints beyond March 23, 2020 (the date of the start of the lockdown) and June 1, 2020 (when some English schools partly reopened), respectively. These terms were interacted with time to parameterise the slope beyond the initial lockdown and lockdown easing. Adjustment was made for weeks that included a bank holiday, Christmas in 2019 (parameterised separately because this week includes two bank holidays), and seasonal variation (incorporated using Fourier terms; appendix p 2).[13] We used Newey-West errors to recognise autoregressive errors and heteroscedasticity. Model predictions are presented graphically alongside the observed weekly course and attendance numbers. Separate models were fitted to both the adjusted (recognising missing data) and observed data (sensitivity analysis). Significance was defined as a p value of less than 0·05. The ITS model was used to predict the reduction in courses delivered between March 23 and June 28, 2020, following adjustment for missing data, with 95% CIs defined based on the linear model predictions.

We assessed change in treatment fractionation for patients aged 18 years or older for specified diagnoses (appendix p 1). Radical treatments were grouped into categories based on the prescribed dose per fraction (<2 Gy per fraction, standard fractionation [2·00–2·49 Gy per fraction], mild-to-moderate hypofractionation [2·5–4·9 Gy per fraction], and ultra-hypofractionation [≥5 Gy per fraction]). The proportion of activity delivered using each categorisation was assessed by diagnosis. Palliative treatments delivered to patients with these diagnoses were separately grouped as single fraction, two to five fractions, six to ten fractions, and greater than ten fractions, and then analysed similarly.

Based on the extensive changes observed in fractionation patterns delivered for breast cancer, we investigated these patterns further using ITS analysis. This analysis was done as detailed previously using a Poisson distribution to allow recognition of the small number of courses per week for some regimens.

All statistical analyses were carried out using StataIC 64, version 16. Data are presented graphically using Stata1C 64, Tableau, and Excel.

Role of the funding source

There was no funding source for this study.

Results

The mean weekly number of radiotherapy courses delivered across the English NHS in 2019 was 2570 (SD 246). This number fell by 502 (–19·9%) in April, 2020, from 2526 (SD 178) in April, 2019 (table 1; appendix p 2). A fall of 151 (–6·2%) from 2425 (SD 172) was observed in May and 307 (–11·6%) from 2633 (60) in June, 2020. By comparison, greater reductions were observed for treatment attendances when compared with equivalent months in 2019: a fall of 10 290 (–29·1%) from 35 332 (SD 2544) in April, 10 573 (–31·4%) from 33 665 (2776) in May, and 11 380 (–31·5%) from 36 130 (233) in June, 2020.

Substantial variation was seen across radiotherapy providers in both the direction and magnitude of change in mean weekly courses compared with the corresponding months in 2019, ranging from –53·5% to 13·3% in April, 2020, –45·7% to 15·4% in May, 2020, and –28·7% to 31·9% in June, 2020 (appendix p 8). All regions of the country saw a fall in courses in April with subsequent recovery, although the extent of this recovery varied (appendix p 9).

On ITS analyses, after adjustment for missing data, lockdown was associated with a significant reduction in courses and attendances (p<0·0001) for pandemic terms relating to both the change in activity at the point of lockdown and slope immediately afterwards. Model outputs are presented in figure 1 and the appendix (pp 4–5). Between March 23 and June 28, 2020, a predicted 3263 (95% CI 2936–3590) fewer treatment courses and 119 050 (112 632–125 470) fewer attendances

	Courses					Attendances				
	February, 2020	March, 2020	April, 2020	May, 2020	June, 2020	February, 2020	March, 2020	April, 2020	May, 2020	June, 2020
Total										
Observed	2631	2449	2024	2274	2130	36 121	34 716	25 042	23 092	22 631
Adjusted	2659	2449	2024	2274	2326	36 489	34 716	25 042	23 092	24 750
SD	107	239	226	246	59	514	2460	1017	1665	594
Percentage change	–2·9%	–7·8%	–19·9%	–6·2%	–11·6%	–2·4%	–8·5%	–29·1%	–31·4%	–31·5%
Palliative										
Observed	847	827	653	789	788	3593	3380	2270	2623	2771
Adjusted	855	827	653	789	861	3629	3380	2270	2623	3030
SD	33	60	75	113	65	162	415	228	355	241
Percentage change	1·0%	–1·8%	–20·1%	–1·5%	–5·3%	0·7%	–7·0%	–35·7%	–20·9%	–20·4%
Radical										
Observed	1774	1614	1362	1474	1332	32 426	31 227	22 684	20 376	19 792
Adjusted	1793	1614	1362	1474	1454	32 756	31 227	22 684	20 376	21 645
SD	83	206	152	137	16	570	2054	950	1355	364
Percentage change	–3·1%	–9·3%	–19·4%	–8·7%	–15·2%	–2·2%	–8·2%	–28·3%	–32·6%	–32·9%
Other*										
Observed	11	9	9	10	10	103	108	88	93	68
Adjusted	11	9	9	10	11	104	108	88	93	75
SD	5	3	4	1	2	14	8	11	15	14
Percentage change	–74·3%	–74·5%	–54·4%	2·5%	36·5%	–62·9%	–61·6%	–50·2%	–26·2%	–16·4%
Females aged younger than 70 years										
Observed	848	829	797	839	718	12 196	11 691	8974	8382	7459
Adjusted	857	829	797	839	784	12 320	11 691	8974	8382	8157
SD	47	50	99	101	19	143	516	400	743	229
Percentage change	–2·6%	–2·8%	–2·2%	5·3%	–8·2%	3·0%	–7·3%	–23·4%	–25·7%	–33·6%
Females aged 70 years or older										
Observed	487	471	339	419	349	5464	5241	3526	3347	3100
Adjusted	492	471	339	419	381	5520	5241	3526	3347	3390
SD	31	48	21	67	5	107	443	233	362	136
Percentage change	–2·3%	–1·8%	–25·8%	–2·1%	–18·9%	–2·9%	–6·9%	–31·9%	–32·6%	–36·1%
Males aged younger than 70 years										
Observed	584	518	459	508	488	9159	8905	6885	6560	6590
Adjusted	590	518	459	508	533	9252	8905	6885	6560	7207
SD	20	49	73	39	27	284	723	227	346	362
Percentage change	0·3%	–10·0%	–15·1%	–2·7%	–6·7%	–2·8%	–6·8%	–22·8%	–23·0%	–19·2%
Males aged 70 years or older										
Observed	713	631	429	508	575	9302	8878	5657	4803	5483
Adjusted	720	631	429	508	628	9397	8878	5657	4803	5996
SD	45	127	42	56	62	125	820	365	285	585
Percentage change	–6·1%	–15·6%	–39·9%	–25·1%	–14·8%	–8·0%	–12·5%	–40·6%	–46·1%	–37·7%

Observed weekly mean, weekly mean adjusted for missing data with SD, and percentage change compared with corresponding month of 2019. *Cancers for which treatment intent was not specified by the clinician; numbers in this group dropped steeply in 2019 with improvements to data collection, although, given their low frequency, this change is unlikely to have had a significant effect on the results more widely.

Table 1: **Mean weekly courses and attendances in the months before and after the start of the first UK lockdown on March 23, 2020**

were delivered in England than would have been expected had the pandemic not occurred.

Changes in mean weekly curative treatment courses and attendances by diagnosis, are provided in table 2 and the appendix (pp 3, 10–11). The largest reduction in courses in 2020 was observed in prostate cancer (with a decrease of 266 [–77·0%] in April, 2020, from 346 [SD 43] in April, 2019) and non-melanoma skin cancer (a decrease of 58 [–72·4%] from 80 [SD 16], for the same period). Conversely, marked increases in the number of courses in 2020, compared with the equivalent months in 2019, were seen in other diagnoses: bladder cancer courses increased by 18 (64·2%) from 27 (SD 5) in April; oesophageal cancer courses increased by 14 (41·2%) from 32 (10) in April; and rectal cancer courses increased by 25 (36·3%) from 69 (11) in April. Attendances were similarly affected, although compared with courses relatively greater reductions were observed in breast cancer, rectal cancer, lymphoma, and palliative treatments (table 2; appendix pp 10–11).

The mean weekly number of treatment courses delivered to patients aged 70 years or older in April, 2020, fell by 403 (–34·4%) to 768 (SD 63) from 1171 (94) in April, 2019. A smaller reduction was seen in patients younger than 70 years (a fall of 99 [–7·3%] to 1256 [SD 166] in April, 2020, from 1355 [92] in April, 2019). Of these patients, a weekly mean of less than 12 courses were delivered to patients aged younger than 18 years throughout the study period. Given these small numbers of courses, temporal changes over time were not assessed in patients younger than 18 years. The differential effect of age was most notable in patients with breast cancer (mean weekly courses falling by 59 [–32·5%] to a mean of 123 [SD 8] in April, 2020, from 182 [SD 25] in April, 2019, in those aged 70 years or older *vs* increasing by one [0·3%] from a mean of 513 [SD 42] in April, 2019, to 515 [86] in April, 2020, in those younger than 70 years), and non-melanoma skin cancer (falling by 57 [–71·0%] from a mean of 80 [14] in April, 2019, to 23 [4] in April, 2020, in those aged 70 years or older and six [–52·9%] from a mean of 12 [4] in April, 2019, to six [1] in April, 2020, in those younger than 70 years; appendix pp 12–14).

In April, 2019, a mean 949 (SD 78; 60·9%) of 1558 (121) weekly curative courses delivered to patients aged 18 years or older used a mild-to-moderately hypofractionated regimen (2·5–4·9 Gy per fraction). In 2020, these numbers fell to 486 (SD 32; 38·9%) of 1250 (140) mean weekly courses in April and remained low in May (543 [65; 39·9%] of 1360 [128]) and June (528 [17; 43·4%] of 1215 [19]). By contrast, ultra-hypofractionation (≥5 Gy per fraction) increased from 146 (SD 25; 9·4%) of 1558 (121) mean weekly courses in April, 2019, to 498 (113; 39·9%) of 1250 (140) mean weekly courses in April, 2020, 545 (62; 40·0%) of 1360 (128) mean weekly courses in May, 2020, and 414 (27; 34·0%) of 1215 (19) mean weekly courses in June, 2020. Figure 2 and the appendix (p 6) show these results for individual diagnoses.

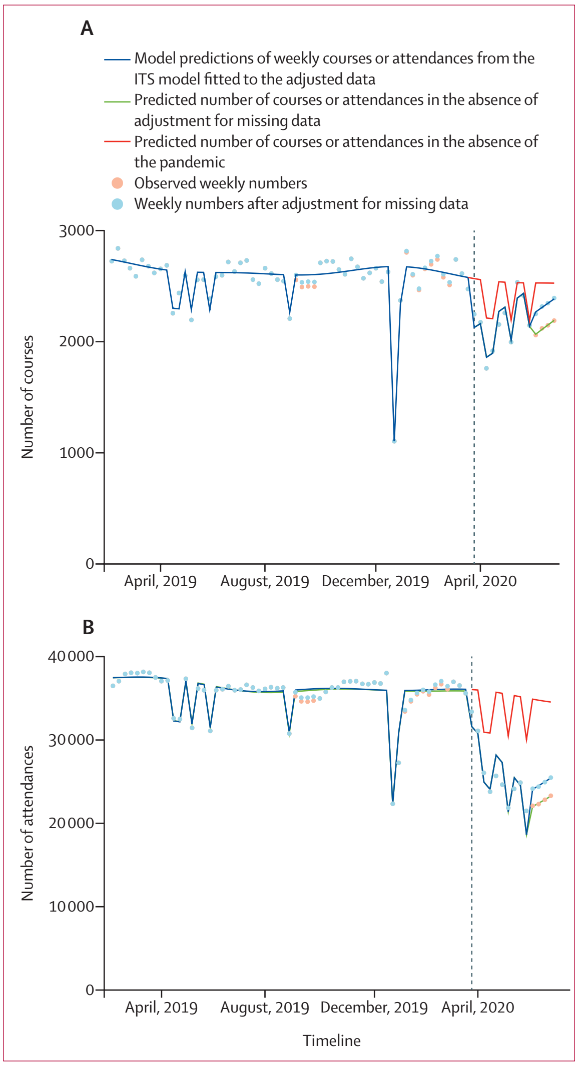


Figure 1: **Courses (A) and attendances (B) of radiotherapy delivered within the English NHS over the year preceding and period following the first UK lockdown for the COVID-19 pandemic**
The dashed line indicates the beginning of the lockdown on March 23, 2020. ITS=interrupted time series. NHS=National Health Service.

A major contributor to the increase in ultra-hypofractionation was the increased use of 26 Gy in five fractions for adjuvant breast cancer treatment. Whereas in April, 2019, one (SD 1; 0·2%) of 597 (54) mean weekly courses were delivered using this regimen, this number increased to 345 (79; 60·6%) of 570 (92) mean weekly courses in April, 2020. Conversely, the use of 40 Gy in 15 fractions fell from 546 (SD 49; 91·5%) of 597 (54) mean weekly courses to 188 (11; 33·0%) of 570 (92) mean weekly courses on the same comparison. ITS regression confirmed the significance of these changes (p<0·0001 for the change in use of 26 Gy in five fractions during lockdown; figure 3; appendix p 7). A marked increase in the use of ultra-hypofractionation in the neoadjuvant treatment of rectal cancer was also

	Courses					Attendances				
	February, 2020	March, 2020	April, 2020	May, 2020	June, 2020	February, 2020	March, 2020	April, 2020	May, 2020	June, 2020
Anal cancer										
Observed	22	25	23	20	11	615	614	635	598	382
Adjusted	22	25	23	20	12	622	614	635	598	418
SD	6	5	7	4	1	45	25	27	49	63
Percentage change	–4·4%	21·5%	9·7%	2·6%	–48·9%	11·2%	8·7%	16·7%	12·5%	–27·2%
Bladder cancer										
Observed	20	28	45	55	26	370	521	730	992	674
Adjusted	20	28	45	55	28	373	521	730	992	737
SD	5	3	5	11	6	29	61	125	85	133
Percentage change	–7·3%	–1·4%	64·2%	143·3%	17·1%	–27·9%	3·7%	37·4%	87·0%	48·8%
Brain cancer										
Observed	58	51	43	42	41	1325	1145	948	845	817
Adjusted	58	51	43	42	45	1338	1145	948	845	893
SD	9	7	7	4	7	76	67	55	80	66
Percentage change	–10·6%	–24·7%	–19·9%	–28·4%	–22·6%	10·6%	–20·0%	–26·7%	–25·1%	–33·0%
Breast cancer										
Observed	634	597	570	618	493	9617	9289	6036	5400	4828
Adjusted	640	597	570	618	539	9715	9289	6036	5400	5279
SD	41	43	92	90	35	362	556	347	640	326
Percentage change	1·3%	–4·5%	–4·5%	6·6%	–12·5%	2·8%	–5·7%	–34·8%	–39·9%	–45·4%
Cervical cancer										
Observed	21	21	22	17	13	520	471	563	464	360
Adjusted	21	21	22	17	14	525	471	563	464	394
SD	4	7	5	5	4	48	30	15	49	18
Percentage change	–10·9%	6·3%	0·7%	–37·7%	–32·7%	–9·9%	–16·6%	12·2%	–19·3%	–37·6%
Head and neck cancer										
Observed	122	120	132	116	80	3249	3337	3415	3319	2467
Adjusted	124	120	132	116	87	3282	3337	3415	3319	2698
SD	14	16	23	23	3	98	62	147	205	249
Percentage change	–0·2%	4·2%	9·7%	4·0%	–25·6%	–6·6%	–2·9%	5·1%	3·4%	–18·8%
Lung cancer										
Observed	135	140	139	147	102	1955	2089	1893	1884	1350
Adjusted	136	140	139	147	111	1974	2089	1893	1884	1476
SD	7	13	13	22	19	77	72	80	155	158
Percentage change	6·8%	8·5%	–1·9%	10·8%	–11·5%	8·2%	9·0%	–5·8%	–0·1%	–21·5%
Lymphoma										
Observed	55	52	40	49	45	760	706	523	497	556
Adjusted	56	52	40	49	49	768	706	523	497	608
SD	5	9	7	9	4	31	56	48	84	5
Percentage change	5·9%	–5·5%	–19·2%	23·1%	–1·7%	12·2%	–10·8%	–25·1%	–14·2%	–7·9%
Oesophageal cancer										
Observed	24	30	46	43	25	519	621	735	1110	658
Adjusted	25	30	46	43	28	524	621	735	1110	720
SD	2	8	17	11	2	19	18	142	81	109
Percentage change	–14·8%	1·9%	41·2%	71·3%	–3·2%	–9·1%	–7·3%	9·5%	79·8%	18·8%
Other cancer diagnosis										
Observed	148	124	107	113	115	2642	2284	1858	1837	1886
Adjusted	149	124	107	113	125	2668	2284	1858	1837	2062
SD	14	8	19	12	10	93	221	96	92	117
Percentage change	2·4%	–8·0%	–17·8%	2·3%	–3·6%	9·5%	–11·0%	–19·2%	–15·9%	–10·2%

(Table 2 continues on next page)

	Courses					Attendances				
	February, 2020	March, 2020	April, 2020	May, 2020	June, 2020	February, 2020	March, 2020	April, 2020	May, 2020	June, 2020
(Continued from previous page)										
Prostate cancer										
Observed	372	285	80	144	285	8471	7958	3706	2174	4595
Adjusted	375	285	80	144	311	8557	7958	3706	2174	5025
SD	30	115	11	54	44	249	976	852	224	1125
Percentage change	–10·9%	–25·3%	–77·0%	–58·0%	–13·7%	–12·4%	–14·3%	–55·7%	–72·5%	–39·7%
Rectal cancer										
Observed	72	76	94	80	37	1435	1445	1252	907	602
Adjusted	73	76	94	80	41	1449	1445	1252	907	658
SD	7	9	24	14	9	30	68	82	171	41
Percentage change	–5·2%	–5·7%	36·3%	22·3%	–43·7%	9·5%	0·2%	–8·6%	–29·3%	–55·8%
Non-melanoma skin cancer										
Observed	94	65	22	34	59	949	747	389	352	618
Adjusted	94	65	22	34	64	959	747	389	352	676
SD	18	24	3	8	6	84	133	56	59	104
Percentage change	–12·7%	–29·2%	–72·4%	–57·8%	–28·4%	–8·5%	–24·7%	–52·5%	–56·7%	–28·8%

Observed weekly mean, weekly mean adjusted for missing data with SD, and percentage change compared with the corresponding month in 2019 based on adjusted data are presented. Where diagnoses including small numbers of courses are considered, the adjustment for missing data must be interpreted with caution.

Table 2: **Mean weekly number of radical episodes and attendances by month by diagnosis**

observed, with a reduction in the use of less than 2 Gy per fraction regimens.

The proportion of palliative treatment courses delivered using a single fraction rose from a weekly mean of 223 (39·3%) of 568 (SD 37) in April, 2019, to 233 (50%) of 463 (62) in April, 2020, with a corresponding fall in treatments delivered using more than five fractions over the same period (125 [22·0%] of 568 [37] to 74 [16·0%] of 463 [62]).

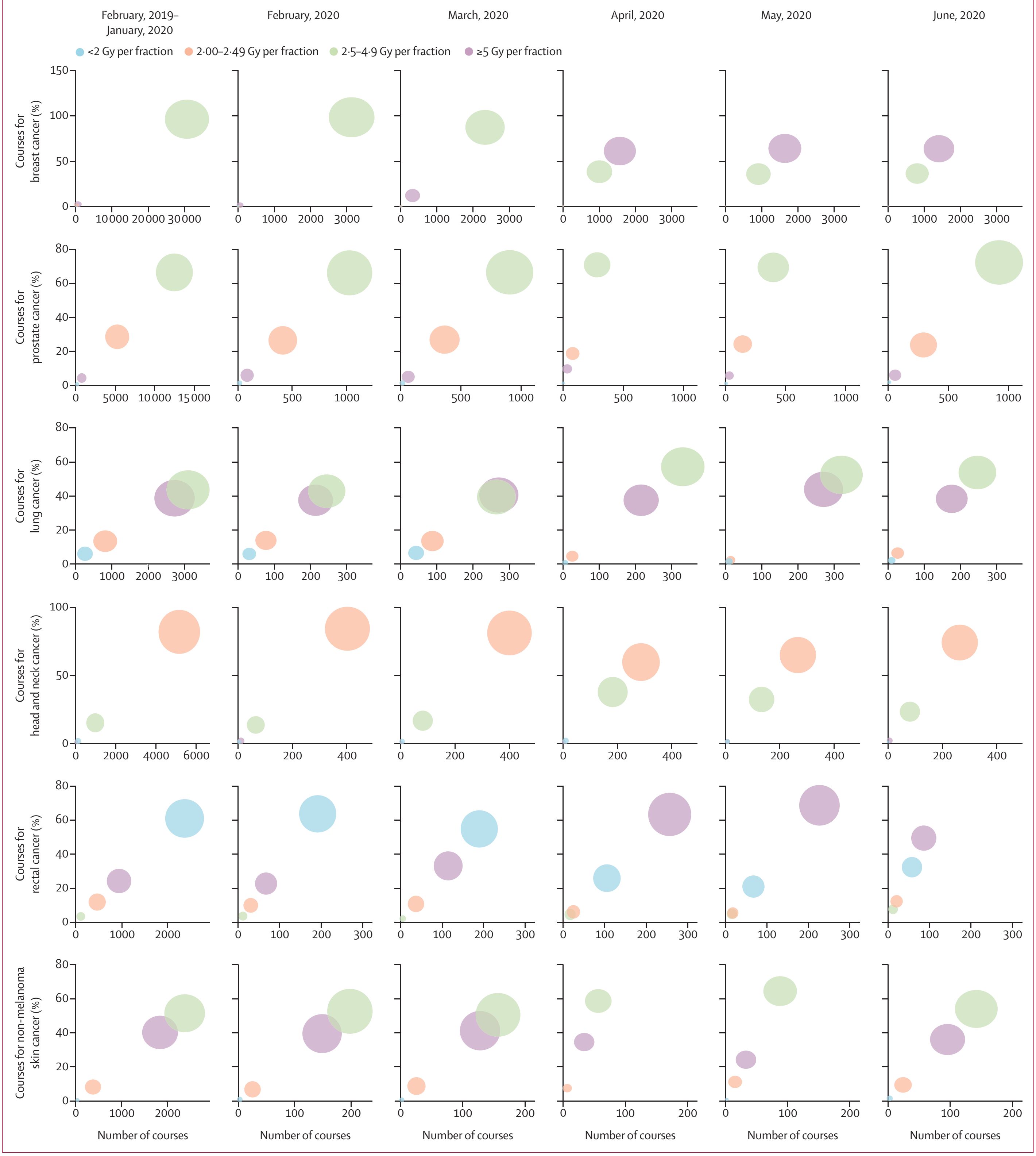
Discussion

We have shown that the number of patients receiving radiotherapy in the English NHS fell significantly during the first wave of the COVID-19 pandemic. When compared with a year previously, a 20% reduction in radiotherapy courses was seen in April, 2020, immediately after the beginning of the UK national lockdown. Recovery was not complete by June, 2020 (12% reduction), despite the easing of lockdown and decrease in number of NHS inpatients with COVID-19. We project that compared with the same period a year previously (March 23 to June 28, 2019), 3263 fewer treatment courses were delivered with 119 050 fewer treatment attendances across the English NHS. The disproportionately greater fall in treatment attendances largely reflects a rapid increase in the use of ultra- hypofractionated treatment regimens across several tumour sites.

These analyses are based on a comprehensive national dataset. However, the reduction in activity that we report compares favourably with the more limited surveys of radiation oncology departments undertaken following the first pandemic peak in both the USA and Europe.[7,8] An approximate 25% reduction in patient volume was, for example, reported for centres in Europe, including the UK, with patient volume in the USA predicted to be a third lower. By contrast, at 8%, the reported median reduction in patient volume in Latin America is far more modest than observed in the UK.[6]

Beyond overall changes in radiotherapy activity, we also highlight how these changes varied by age group and diagnosis. At the onset of the pandemic, several professional bodies issued guidance for safely maintaining radiotherapy services.[4,5] A key concern at the time related to the potential for hospitals to act as a reservoir for SARS-CoV-2,[14] and for a potentially heightened risk from COVID-19 for patients with cancer, particularly in those aged 70 years or older.[11] Reflecting this concern, many guidelines advocated the deferral of treatment if it was safe to do so, or if the potential risks of treatment outweighed the benefits.

We demonstrate that treatment courses fell by a much a greater degree in patients aged 70 years or older than in patients younger than 70 years. This might partly be a consequence of decisions made by clinicians and patients to defer treatment in this higher-risk group. It might also in part reflect the age profile of patients with prostate cancer and non-melanoma skin cancer, for whom falls greater than anticipated from European surveys were observed. In prostate cancer, randomised evidence supports a delay in delivery of radiotherapy of up to 6 months between diagnosis and treatment if patients are commenced on androgen deprivation therapy, or even active surveillance in patients with low-risk disease.[15,16] The extent to which evidence supports treatment delays



(Figure 2 continues on next page)

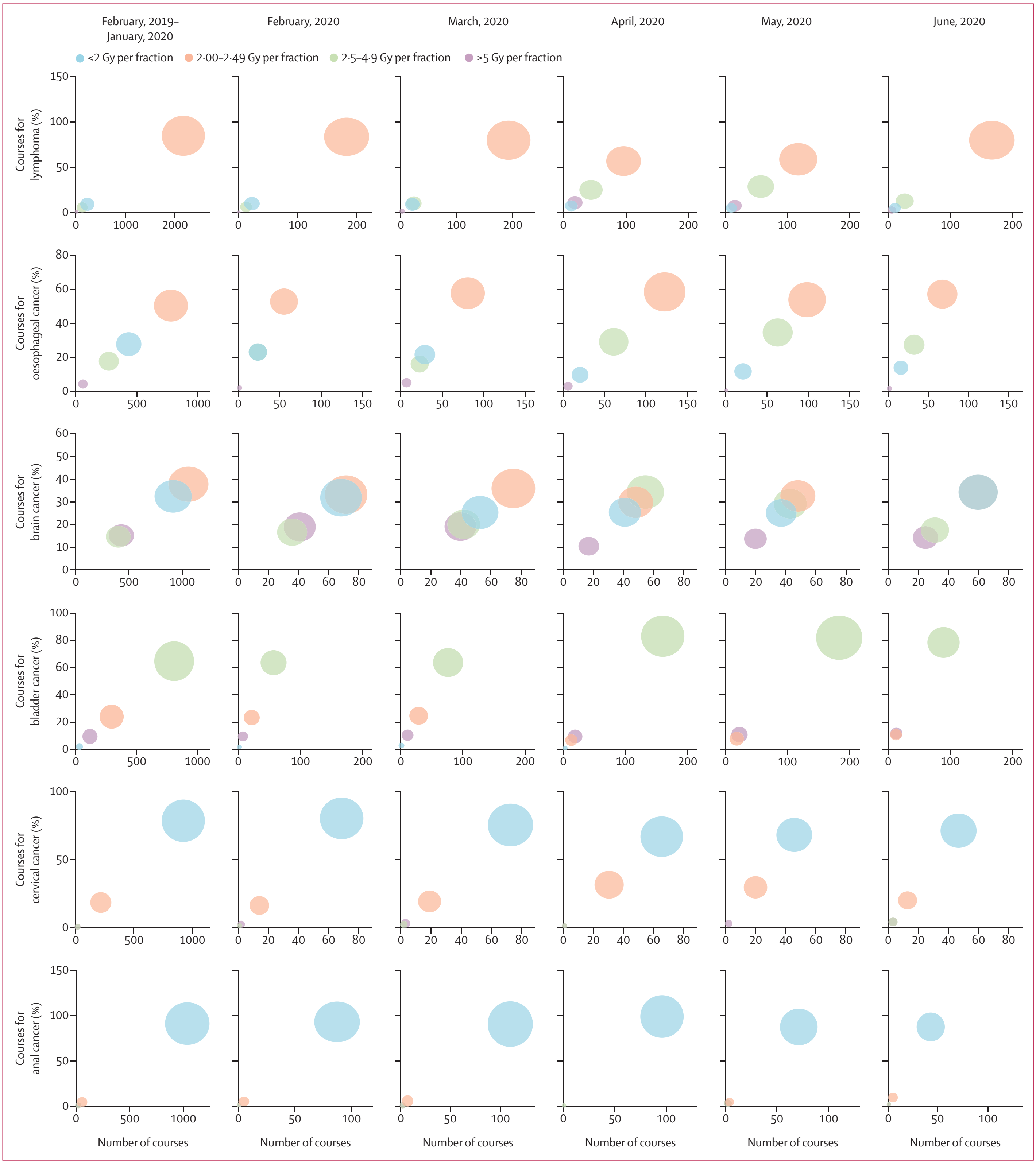


Figure 2: **Bubble plot showing the change in fractionation patterns over time for courses delivered with curative intent for a range of diagnoses**
Diagnoses are presented in descending order of total number of courses. The size of the bubble reflects the number of treatments delivered using the specified fractionation category.

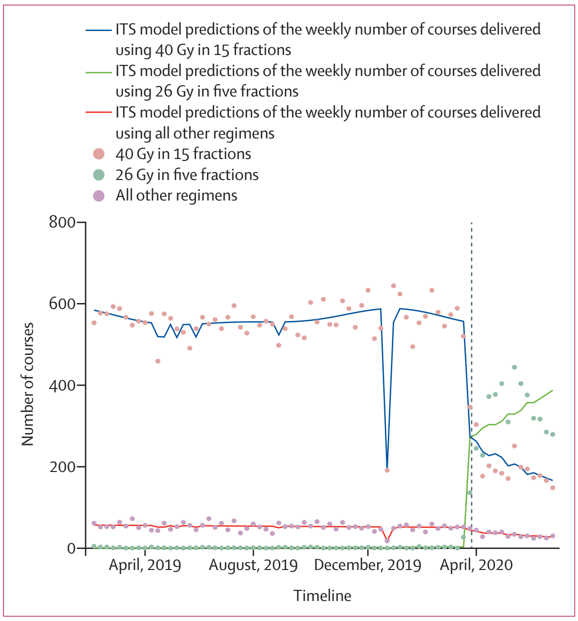


***Figure 3:* Change in fractionation patterns delivered for breast cancer across the English NHS before and after the first UK lockdown**
Model predictions (lines) of the use of differing regimens for the adjuvant treatment of breast cancer with observed weekly courses (dots).The dashed line indicates the beginning of the lockdown on March 23, 2020. ITS=interrupted time series. NHS=National Health Service.

in non-melanoma skin cancer is less well defined, although for small basal cell carcinomas delay is unlikely to change the likelihood of cure.[17] Additionally, a differential effect of age on treatment delivery was seen in breast cancer, potentially reflecting altered clinical decision making based on an assessment of risk and informed by the results of the PRIME-II trial.[18] Similarly, specific concerns for adverse COVID-19 outcomes in patients with lung cancer might have contributed to the reduction in 2 Gy per fraction treatments (often delivered with concurrent chemotherapy) in favour of mild-to-moderate hypofractionation.

By contrast, a rise in curative courses was observed for rectal, bladder, and oesophageal cancer during April and May, 2020; cancers in which disease biology precludes substantial treatment delays. The increase in courses observed in this study might reflect the use of radiotherapy as an alternative definitive treatment approach to surgery. Several modelling studies have estimated large numbers of excess deaths due to limitations to surgical services.[19,20] However, these studies have not taken into account the use of radiotherapy in place of surgery, as shown here. Equally, although equipoise exists between radiotherapy and surgery for the treatment of bladder cancer and oesophageal squamous cell carcinoma, surgery is superior in oesophageal adenocarcinoma.[21,22] For rectal cancer, radiotherapy offers a mechanism to support delayed surgery with the potential for a substantial minority to avoid resection entirely. One immediate consequence of this shift in treatment patterns should be an urgent review of post-treatment surveillance protocols to ensure that patients who received an alternative treatment approach, and for whom cancer recurs can, where appropriate, be swiftly identified and referred for salvage resection. In the long-term, analysis of the outcomes of patients who have undergone radiotherapy in place of surgery, for reasons unrelated to their individual baseline condition, could provide valuable comparative data in settings in which randomisation between surgery and radiotherapy has historically been challenging.[21]

In line with guidance advocating reductions in hospital visits, treatment attendances fell significantly post-lockdown as a consequence of the wider use of hypofractionated radiotherapy. Most strikingly, the results of the FAST-Forward trial were incorporated into national guidelines supporting rapid and widespread adoption of a 26 Gy in five fractions regimen in place of the previous 40 Gy in 15 fractions standard for adjuvant breast cancer radiotherapy.[23,24] In this context, the decision in March, 2020, to move away from a per-attendance tariff for national radiotherapy commissioning is likely to have supported providers in rapidly adopting this new evidence base.[1] In addition, as a UK-wide study, the experience of delivering these quality-assured hypofractionated regimens within a trial setting will likely have aided its rapid implementation.[23] These changes show that, at least for some indications, the pandemic has beneficially catalysed the adoption of a new evidence base.

An increase in hypofractionation was also seen for palliative treatments, with half of these delivered as a single fraction in April, 2020. This change is appropriate and in keeping with evidence for most palliative indications. However, the concomitant reduction in the number of palliative treatment courses is concerning given the role of these treatments in improving quality of life for patients with localised symptoms due to advanced incurable cancer.[25]

Finally, in keeping with centres catching up on deferred treatments, prostate and non-melanoma skin cancer treatments were returning to baseline in June, 2020. Across a range of other diagnoses, despite smaller declines during lockdown, a reduction in activity was observed in June, 2020, compared with June, 2019. For some diagnoses (eg, cervical cancer), the temporary reduction or cessation of screening programmes might have played a part. However, NHS waiting time data demonstrate that in June, 2020, referrals for possible symptomatic cancer remained 21% below those in June, 2019. New diagnoses were suppressed by 26%, which is probably a key contributor to the ongoing suppression in radiotherapy activity up to June, 2020.[26] Consistent with this finding, there was limited change in compliance with the 31-day treatment targets in radiotherapy, which remained above 95% throughout the study period.[27] The time between diagnosis and commencing treatment might have limited the effect of the pandemic in May (compared with April and June), as previously diagnosed patients began their treatment. These results reinforce concerns about the effect of the COVID-19 pandemic on cancer diagnostic pathways and, in turn, outcomes.[28,29] This will require examination in the future, once complete cancer registration data are available.

To our knowledge, this is the first comprehensive national analysis of changes in radiotherapy provision during the first wave of the COVID-19 pandemic. Nevertheless, this study does have limitations. Data were only available for England and a lag in data collection and availability (of approximately 2–3 months) means more contemporaneous data are not available, so that longer-term changes in radiotherapy activity beyond the first wave of the pandemic cannot yet be seen. In addition, data were missing from four centres, which had not completed their activity submission in June, 2020. However, having adjusted for these missing data within our analyses, it is unlikely to substantially affect the conclusions reached. A small number of private providers deliver radiotherapy in England. Data from these providers are not routinely collected, so we cannot comment on the role of the private sector. Due to the limitations of and longitudinal changes in COVID-19 testing in England, it is extremely challenging to interpret the association between regional COVID-19 prevalence and radiotherapy delivery, and as such this was not attempted. Finally, although the RTDS provides robust data on the changes in courses and attendances for radiotherapy, it does not provide data on why these changes were made. Although assumptions can be made for the population as a whole, the data cannot provide definitive information on an individual patient level. Data relating to individual patient treatment decisions made during the COVID-19 pandemic will be collated by the UK National Cancer Research Institute Clinical and Translational Radiotherapy Research Working Group COVID radiotherapy initiative, and will be linked with other national datasets to determine the effect on patient outcomes.[30]

Radiotherapy activity in the English NHS fell significantly during the first wave of the COVID-19 pandemic. This decrease occurred predominantly in cancers for which treatment can be safely delayed and through the use of hypofractionation. By contrast, increased activity in specific diagnoses suggests that radiotherapy was used to compensate for reduced surgical activity. Overall, the effect on cancer outcomes of changes in radiotherapy activity during the first pandemic peak is likely to be modest, and an increase in radiotherapy use might have helped to mitigate against the loss of surgical capacity. However, the continued suppression in radiotherapy activity up to June, 2020, supports an urgent need to restore diagnostic pathways.

Contributors

KS led study design, analysed data, developed figures, interpreted data, and developed the initial manuscript draft. CMJ contributed to study design and figure development, interpreted data, and contributed to the writing of the manuscript. RG, CR, MS, and SL contributed to study design; data extraction, verification, and interpretation; and writing of the manuscript. RS contributed to study design and data analysis, interpreted the data, and reviewed the manuscript. LM contributed to the study design, data extraction, and figure development, and reviewed the final manuscript. PL, ME, DS-M, and TR contributed to the interpretation of the results and development of the manuscript. EM contributed to the study design, data analysis and interpretation, and development of the manuscript. All authors had full access to all of the data extracted from PHE, and the corresponding author had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

The aggregate data and meta-data used in this analysis along with further information is available online at http://www.ncin.org.uk/cancer_type_and_topic_specific_work/topic_specific_work/covid19. Access to patient-level data can be arranged via https://www.gov.uk/government/publications/accessing-public-health-england-data/about-the-phe-odr-and-accessing-data. The data presented here are available to NHS clinicians and service managers via PHE's Cancerstats2 dashboard, which will be updated regularly. We look forward to working with clinicians to use these data in order to inform the process of recovery, restoration, and, where necessary, reconfiguration over the coming months.

For **PHE's Cancerstats2 dashboard** see https://cancerstats.ndrs.nhs.uk/

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