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Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed.
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The impact of the COVID-19 pandemic on radiotherapy services in England, UK: A population-based study from the National Radiotherapy Dataset

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Web appendix

Table 1s. Diagnostic groupings by ICD-10 code:

Diagnosis	ICD-10 code
Anal	C21
Bladder	C67
Brain/CNS	C70-C71,D32-D33
Breast	C50,D05
Cervix	C53
Head and neck	C00-C14,C30-C32
Lung	C33-C34
Lymphoma	C81-C85
Oesophageal	C15
Prostate	C61
Rectal	C20
Non-melanomatous skin cancer	C44

All morphological subtypes are included in each group.

Table 2s. Details of missing data:

During the study period a small number of centres failed to complete the monthly data submission to Public Health England. These were more frequent in recent months and were as follows:

Month	Data completeness
Feb 2019	Complete
March 2019	Complete
April 2019	Complete
May 2019	Complete
June 2019	Complete
July 2019	Complete
August 2019	Complete
September 2019	1 centre missing
October 2019	Complete
November 2019	Complete
December 2019	Complete
January 2020	1 centre missing
February 2020	1 centre missing
March 2020	Complete
April 2020	Complete
May 2020	Complete
June 2020	4 centres missing

Regression equation:

$$\text{Courses at time}(t) = \beta_0 + \beta_1 * \text{Time} + \beta_2 * \text{Bank holiday} + \beta_3 * \text{Christmas} + \beta_4 * \text{Pandemic} + \beta_5 * \text{Recovery} + \beta_6 * \text{Seasonality vector} + \beta_7 * \text{Pandemic} * \text{Time} + \beta_8 * \text{Recovery} * \text{Time} + \text{error}$$

Table 3s

Average weekly courses and attendances in February-June 2019 in the overall treated population. These numbers provide the baseline data on which the % change in table 1 is calculated.

	Courses					Attendances				
	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19
Total	2738	2656	2526	2425	2633	37384	37938	35332	33665	36130
Std dev.	74.3	65.5	178.2	172.1	59.6	745.4	307.8	2543.8	2776.1	232.7
Other	42	35	19	10	8	280	282	176	126	89
Std dev.	6.1	9.5	13.4	2.0	0.8	13.8	32.5	57.6	18.6	13.1
Palliative	847	842	817	801	909	3606	3634	3531	3317	3806
Std dev.	56.4	45.4	55.8	96.3	32.0	116.3	162.1	263.4	359.3	99.0
Curative	1849	1779	1689	1614	1716	33498	34022	31625	30223	32234
Std dev.	21.9	32.3	133.8	90.4	44.0	707.6	345.8	2268.3	2434.5	269.0
Female<70	880	853	814	796	854	11965	12609	11713	11278	12282
Std dev.	19.5	10.4	54.9	31.2	18.1	408.9	194.0	770.5	976.1	63.0
Female≥70	503	480	457	428	470	5687	5628	5177	4966	5308
Std dev.	23.5	20.5	35.9	31.3	22.8	119.7	105.8	426.3	435.3	96.8
Male <70	588	576	541	523	571	9522	9555	8918	8518	8922
Std dev.	24.2	22.6	38.8	46.0	15.7	83.0	25.9	592.1	676.4	66.7
Male ≥70	768	748	714	678	738	10210	10146	9524	8904	9618
Std dev.	29.6	35.7	62.0	76.4	46.1	204.3	15.8	767.8	691.7	69.6

Table 4s

Average weekly courses and attendances in February-June 2019 by individual diagnoses. These numbers provide the baseline data on which the % change in table 2 is calculated.

	Courses					Attendances				
	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19
Anal	23	20	21	20	23	559	564	544	532	574
Std dev	5.7	6.3	7.3	4.2	2.8	26.7	17.6	36.4	42.7	17.5
Bladder	21	28	27	23	24	518	503	532	531	496
Std dev	4.1	5.1	5.1	4.5	2.1	39.4	20.7	30.4	53.7	25.9
Brain	65	68	53	58	58	1211	1430	1293	1128	1333
Std dev	12.4	5.6	7.3	7.0	1.0	38.2	91.8	141.5	84.6	18.3
Breast	632	626	597	580	616	9452	9854	9261	8986	9662
Std dev	11.0	19.8	53.5	21.3	11.7	358.3	212.5	703.9	898.9	132.2
Cervix	23	20	22	27	22	583	566	502	575	632
Std dev	7.2	4.4	4.6	3.0	3.7	11.9	39.8	23.9	46.4	38.5
Head and Neck	124	115	121	112	118	3513	3437	3250	3211	3324
Std dev	9.5	6.5	13.8	19.8	4.4	73.7	100.9	130.4	133.7	34.6
Lung	128	129	141	132	125	1825	1917	2010	1886	1879
Std dev	8.8	11.0	11.6	13.6	5.4	49.9	39.5	136.4	70.7	93.7
Lymphoma	53	55	50	40	50	684	792	699	579	660
Std dev	6.0	3.5	4.8	3.4	4.1	51.7	13.1	59.9	69.4	26.5
Oesophageal	29	29	32	25	29	577	670	671	617	606
Std dev	11.5	3.9	9.6	3.2	3.0	30.4	24.1	43.4	44.9	31.9
Other dx	146	135	130	111	130	2438	2568	2300	2183	2298
Std dev	10.6	7.9	15.7	23.4	11.6	39.4	26.3	174.3	198.9	44.4
Prostate	421	382	346	342	360	9768	9290	8374	7901	8333
Std dev	38.0	18.0	43.3	24.9	17.0	207.7	204.1	711.6	745.4	81.6
Rectal	77	81	69	65	72	1323	1442	1371	1283	1490
Std dev	5.0	9.3	10.9	9.2	10.4	28.6	91.0	123.9	98.7	36.1
Skin	108	92	80	81	90	1048	992	820	813	949
Std dev	15.0	2.6	16.2	19.7	16.5	48.9	84.1	128.5	80.8	46.1

Table 5s.

Interrupted time series analyses of the impact of the COVID-19 pandemic on radiotherapy courses and attendances in the English NHS. These results include adjustment for missing data by adding treatment courses and attendances in line with the proportion of activity usually observed in those centres where data had not yet been submitted.

	Coef.	p	L 95% CI	U 95% CI
a) Adjusted courses				
Pandemic	-3001.461	<0.0001	-3325.291	-2677.632
Seasonality terms				
Cos 1	45.509	<0.0001	37.443	53.575
Cos 2	12.595	0.055	-0.256	25.446
Sin 1	-24.643	<0.0001	-34.745	-14.540
Sin 2	-16.621	0.025	-31.141	-2.100
Time (weeks)	-1.805	<0.0001	-2.124	-1.486
Bank holiday	-337.789	<0.0001	-362.871	-312.707
Christmas	-1234.414	<0.0001	-1270.627	-1198.201
Recovery	-484.356	0.016	-877.762	-90.950
Recovery-Time interaction	3.213	0.287	-2.705	9.131
Pandemic-Time interaction	42.715	<0.0001	37.721	47.709
Constant	2690.576	<0.0001	2680.285	2700.868
b) Adjusted attendances				
Pandemic	42032.410	<0.0001	33458.790	50606.040
Seasonality terms				
Cos 1	456.471	<0.0001	309.221	603.721
Cos 2	-178.053	0.193	-446.326	90.220
Sin 1	72.109	0.402	-96.454	240.671
Sin 2	188.120	0.123	-51.042	427.283
Time (weeks)	-27.844	<0.0001	-32.447	-23.241
Bank holiday	-4993.044	<0.0001	-5831.737	-4154.350
Christmas	-8617.681	<0.0001	-9541.588	-7693.775
Recovery	-92648.890	<0.0001	-104230.700	-81067.050
Recovery-Time interaction	1342.879	<0.0001	1171.034	1514.724
Pandemic-Time interaction	-774.407	<0.0001	-908.180	-640.633
Constant	37161.740	<0.0001	36966.750	37356.720

Table 6s

Interrupted time-series analysis assessing the impact of the pandemic upon radiotherapy a) courses and b) attendances in the English NHS. Sensitivity analysis based upon observed data.

	Coef.	p	L 95% CI	U 95% CI
a) Observed courses				
Pandemic	-2927.723	<0.0001	-3250.424	-2605.023
Seasonality terms				
Cos 1	48.146	<0.0001	39.348	56.944
Cos 2	9.997	0.156	-3.814	23.807
Sin 1	-23.215	<0.0001	-34.891	-11.538
Sin 2	-23.541	0.002	-38.397	-8.685
Time (weeks)	-2.051	<0.0001	-2.423	-1.678
Bank holiday	-336.823	<0.0001	-361.641	-312.005
Christmas	-1232.903	<0.0001	-1270.357	-1195.450
Recovery	-557.457	0.005	-948.614	-166.299
Recovery-Time interaction	1.568	0.600	-4.301	7.437
Pandemic-Time interaction	41.734	<0.0001	36.788	46.680
Constant	2692.751	<0.0001	2681.346	2704.155
b) Observed attendances				
Pandemic	42923.510	<0.0001	34231.080	51615.940
Seasonality terms				
Cos 1	481.321	<0.0001	318.744	643.897
Cos 2	-212.248	0.150	-501.235	76.739
Sin 1	80.303	0.362	-92.319	252.925
Sin 2	108.213	0.419	-154.243	370.669
Time (weeks)	-31.122	<0.0001	-36.593	-25.651
Bank holiday	-4981.282	<0.0001	-5809.700	-4152.864
Christmas	-8589.922	<0.0001	-9502.971	-7676.873
Recovery	-93764.430	<0.0001	-105633.500	-81895.350
Recovery-Time interaction	1329.855	<0.0001	1153.663	1506.046
Pandemic-Time interaction	-786.011	<0.0001	-921.773	-650.250
Constant	37197.880	<0.0001	36973.630	37422.130

Table 7s.

Fractionation category delivered for a) curative radiotherapy courses and b) palliative courses. Average weekly courses per month displayed with standard deviation (SD) and proportion of activity per fractionation category below. Courses included here are those relating to the diagnoses documented in table 1s for both 7s(a) and (b).

a) Dose per fraction		Feb 2019 - Jan 2020					Apr-20				
		<2Gy	2-2.49Gy	2.5-4.99Gy	≥5Gy	Other/unknown	<2Gy	2-2.49Gy	2.5-4.99Gy	≥5Gy	Other/unknown
Brain	Mean	17.3	20.2	7.7	8.1	3.7	9.0	10.3	13.0	3.0	3.3
	SD	5.2	4.5	3.0	3.5	1.7	4.1	2.4	5.0	3.6	1.7
	%	30.3	35.5	13.6	14.2	6.4	23.4	26.6	33.8	7.8	8.4
Bladder	Mean	0.4	5.7	15.1	2.2	0.3	0.5	3.0	38.0	3.5	0.0
	SD	0.6	3.0	4.5	1.5	0.5	1.0	1.8	4.5	2.4	0.0
	%	1.9	24.0	63.7	9.3	1.1	1.1	6.7	84.4	7.8	0.0
Breast	Mean	1.2	4.7	582.0	13.2	4.0	0.8	1.5	209.0	357.0	1.8
	SD	1.3	2.2	64.9	4.4	1.9	0.5	1.7	13.6	80.3	1.5
	%	0.2	0.8	96.2	2.2	0.7	0.1	0.3	36.7	62.6	0.3
Cervix	Mean	17.1	4.3	0.3	0.3	0.2	14.8	6.8	0.0	0.3	0.0
	SD	4.4	2.2	0.5	0.7	0.4	3.3	2.4	0.0	0.5	0.0
	%	77.1	19.2	1.5	1.6	0.7	67.8	31.0	0.0	1.1	0.0
Head and neck	Mean	1.9	96.7	18.3	0.9	0.5	2.3	77.5	50.3	0.8	1.5
	SD	1.5	11.8	4.8	0.9	0.7	1.0	13.8	9.9	0.5	1.3
	%	1.6	81.7	15.5	0.7	0.4	1.7	58.6	38.0	0.6	1.1
Lung	Mean	7.7	17.4	56.6	50.5	0.8	1.5	6.0	77.5	52.5	1.0
	SD	3.5	4.5	9.4	9.2	1.2	1.3	3.2	7.5	10.5	0.8
	%	5.8	13.1	42.5	38.0	0.6	1.1	4.3	56.0	37.9	0.7
Lymphoma	Mean	4.5	41.0	2.7	0.3	0.4	3.0	20.8	11.0	4.8	0.0
	SD	2.3	6.4	1.6	0.5	0.7	2.2	5.4	5.2	2.1	0.0
	%	9.1	84.0	5.4	0.7	0.7	7.6	52.5	27.8	12.0	0.0
Oesophageal	Mean	8.2	14.4	5.0	1.2	0.1	4.0	27.3	13.3	1.3	0.0
	SD	3.3	4.5	2.3	1.3	0.2	2.3	10.6	6.8	1.0	0.0
	%	28.3	49.9	17.4	4.2	0.2	8.7	59.6	29.0	2.7	0.0
Prostate	Mean	3.1	100.9	231.8	15.4	2.1	1.0	14.0	56.8	7.5	0.3
	SD	1.7	20.6	43.3	4.1	2.2	0.8	3.8	8.3	1.0	0.5
	%	0.9	28.6	65.6	4.4	0.6	1.3	17.6	71.4	9.4	0.3
Rectal	Mean	44.4	9.0	2.3	18.1	0.4	22.3	5.5	4.0	61.3	0.8
	SD	8.1	3.0	1.6	4.8	0.6	4.9	1.9	5.0	24.5	1.5
	%	59.8	12.1	3.1	24.4	0.5	23.7	5.9	4.3	65.3	0.8
Skin	Mean	0.5	7.0	45.1	34.9	1.1	0.0	1.8	13.0	6.5	0.8
	SD	0.8	2.9	10.7	11.2	1.2	0.0	1.3	4.1	2.5	1.0
	%	0.5	7.9	51.0	39.4	1.2	0.0	8.0	59.1	29.5	3.4
b) Palliative fractionation		Single #	2-5 #	6-10 #	>10 #	Other/unknown	Single #	2-5 #	6-10 #	>10 #	Other/unknown
Palliative	Mean	229.4	227.8	87.4	37.6	4.4	232.5	153.5	47.3	26.5	2.8
	SD	22.7	28.3	12.3	6.7	2.1	31.8	25.6	3.4	4.8	1.5
	%	39.1	38.8	14.9	6.4	0.8	50.3	33.2	10.2	5.7	0.6

Table 8s.

ITS regression of breast cancer fractionation patterns. IRR – Incidence Rate Ratio. Based upon course numbers adjusted for missing data.

	IRR	p	L 95% CI	U 95% CI
26 Gy in 5#				
Pandemic	77.546	<0.0001	11.065	543.449
Time (weeks)	1.026	0.137	0.992	1.062
Bank holiday	1.028	0.764	0.857	1.234
Christmas	0.000	0.993	0.000	.
Pandemic-Time interaction	1.001	0.945	0.962	1.042
Constant	0.682	0.586	0.172	2.706
40 Gy in 15#				
Pandemic	4.746	0.005	1.598	14.095
Seasonality terms				
Cos 1	1.026	0.073	0.998	1.055
Cos 2	1.010	0.495	0.982	1.038
Sin 1	0.980	0.239	0.948	1.013
Sin 2	0.991	0.504	0.964	1.018
Time (weeks)	1.000	0.809	0.998	1.001
Bank holiday	0.942	0.054	0.887	1.001
Christmas	0.345	<0.0001	0.267	0.445
Pandemic-Time interaction	0.963	<0.0001	0.947	0.979
Constant	566.792	<0.0001	541.557	593.202
Other fractionation pattern				
Pandemic	6.500	0.015	1.443	29.273
Time (weeks)	0.998	0.094	0.996	1.000
Bank holiday	0.932	0.185	0.839	1.034
Christmas	0.371	<0.0001	0.229	0.601
Pandemic-Time interaction	0.967	0.004	0.945	0.989
Constant	56.624	<0.0001	52.624	60.929

Figure 1s

Waterfall plots illustrating the percentage change in treatment courses by provider organisation in April, May and June 2020 compared to the equivalent months in 2019. Four providers are excluded in June due to missing data. One very small provider is seen to have an increase in courses of 13.3% in April 2020 compared to April 2019.

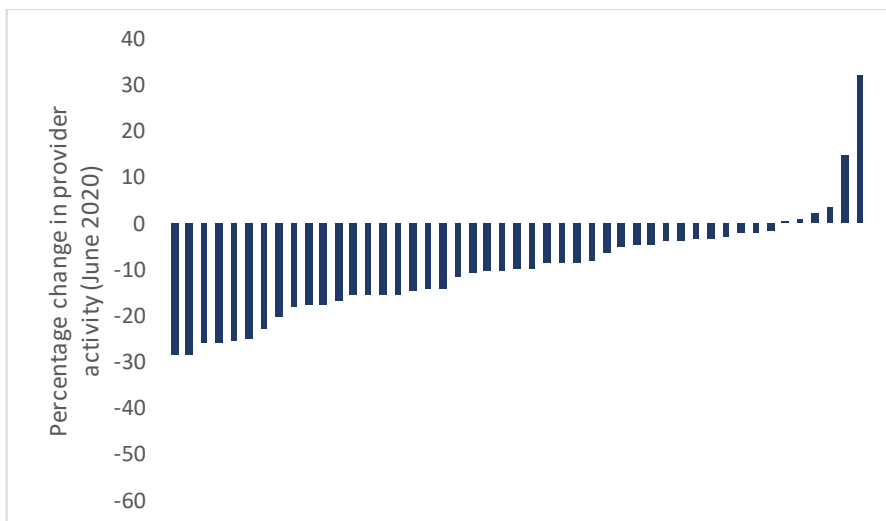
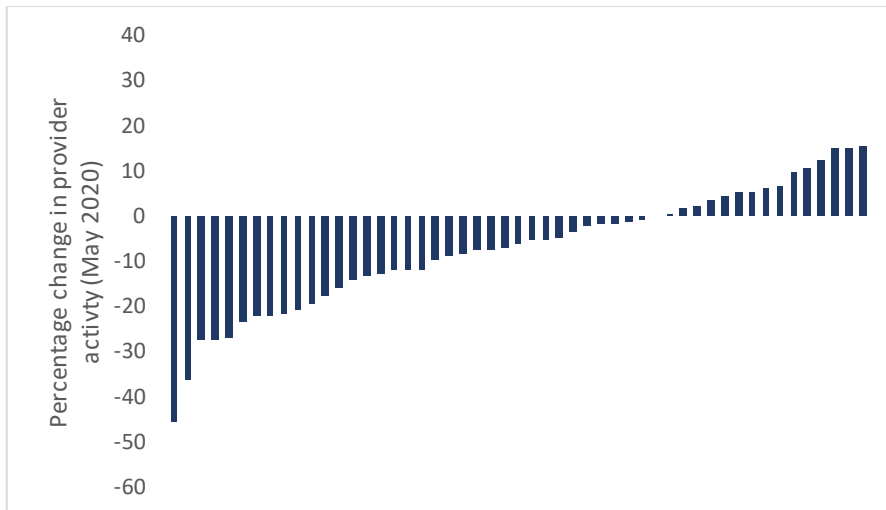
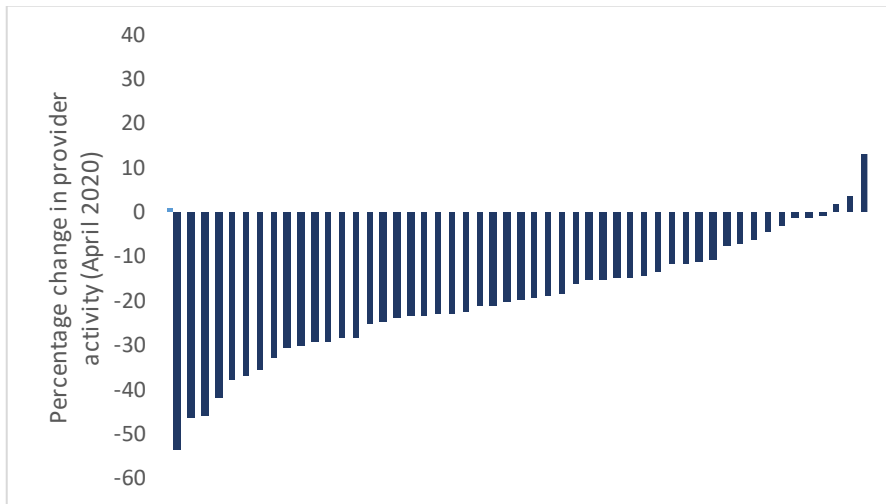


Figure 2s

Bar chart illustrating the change in weekly average courses observed between February and June 2020 by NHS England region. These data are not adjusted for missing and as such the data for June are not presented as the consequences of missing data cannot be disentangled from the ongoing effects of the pandemic.

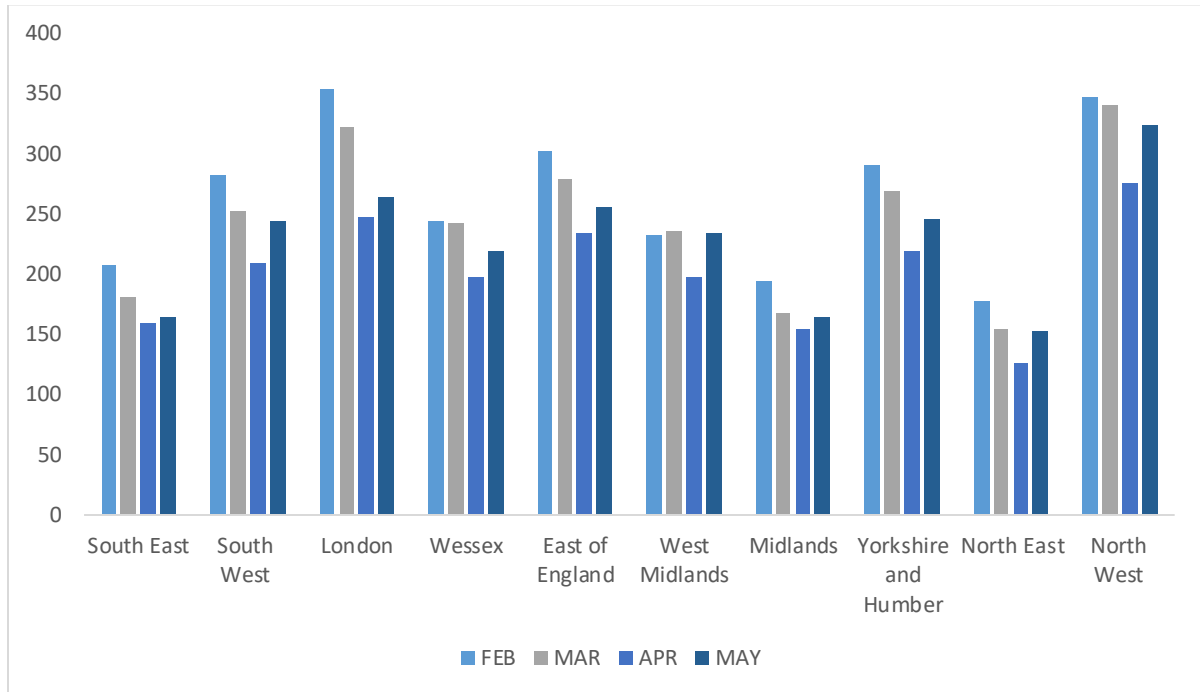
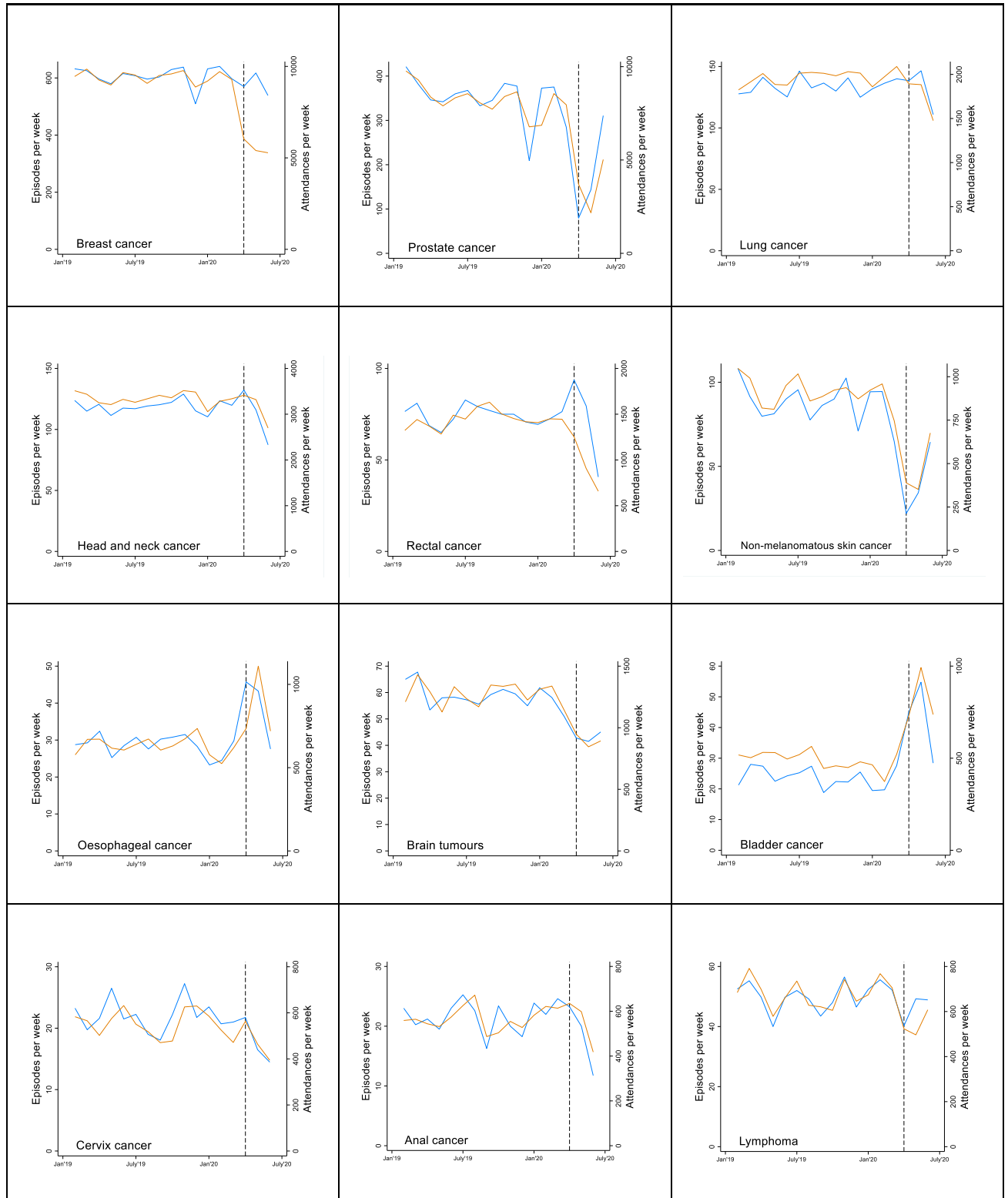


Figure 3s.

Average weekly courses (blue) and attendances (orange) following adjustment for missing data by individual cancer diagnoses and separately all palliative courses.



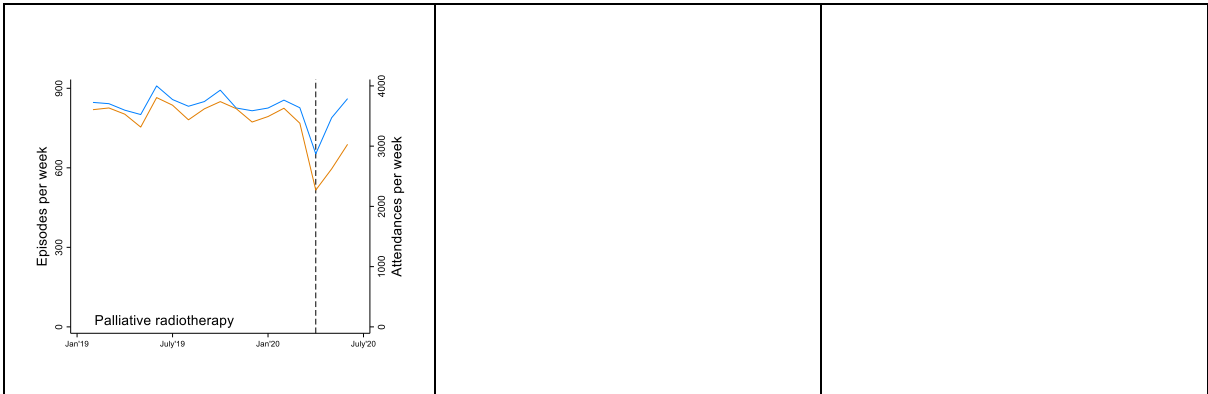


Figure 4s.

Bar chart demonstrating the average weekly number of treatment courses delivered to patients of less than 70 years old and 70 and over in 2019 and February-June 2020. Including treatment of curative, palliative and other intent and adjusted for missing data.

