How has COVID-19 impacted cancer waiting times in England?

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Authors

Arturo de la Cruz Libardi

Farzaneh Farhoush

Wing Lam Erica Fong

Alessandro Giovannone

Emily Jin

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Executive Summary

COVID-19 has been a hugely destructive force in England since its arrival in January 2020, with almost 3.5mn recorded cases and over 100,000 deaths at the time of writing. Due to the huge influx of COVID-19 patients into hospitals, the delivery of cancer services across the country have been severely impacted. Our goal was to investigate the magnitude of this impact through the lens of cancer waiting time (CWT) performance, against their target operational standards. The CWT data used for our analyses was publicly available on the NHS England website.

We investigated performance in the three main CWT measures against national operational standards set by the NHS, i.e. the proportion of patients completing the pathway within the target time period: 1) two-week-wait (2WW) from urgent GP referral with suspected cancer to first outpatient appointment (operational standard - 93%); 2) 31 day (31D) wait from decision to treat to first treatment of any kind (96%); 3) 62 day (62D) wait from urgent GP referral to first treatment of any kind (85%).

We investigated how percentage performance in these measures varied over time during the pandemic and compared to trends observed in the data before the March lockdown to establish how these trends were impacted by COVID-19, at a national level for all cancers. We also looked at how performance trends varied specifically for breast, lung, lower gastrointestinal and urological cancers, as well as performance variations between different geographical cancer alliances in England. Finally, we investigated how the absolute numbers of patients being recorded on these three pathways changed over time and how these have been impacted by the pandemic.

Key findings

The 2WW target was the worst affected measure, largely driven by a sustained decline in breast cancer performance. This is the only cancer type to see significant performance declines on the 2WW pathway during the entirety of the pandemic, falling to as low as 75% in November. LGI is by far the worst performing cancer on the 62D pathway, with performance dropping to an all-time low of 56% in April 2020. This is the only cancer type operating below the operational standard for all CWT measures. Lung cancer performance has remained remarkably resilient during the pandemic, with its performance on all three pathways seeing improvements in average performance post pandemic. Similarly, urological cancer has not registered any significant negative changes in performance trends after the start of the pandemic. However, the numbers of patients completing each pathway are yet to really recover to predicted levels based on previous trends. The predicted shortfall on the 2WW pathway is between 348,000 and 803,000 (95% prediction intervals) patients, which represents between 19 - 35% of the predicted number of patients not completing this pathway. The proportions are less severe on the 31D (8 - 17%) and 62D targets (9 - 26%), but by no means trivial. Last but not least, the West Midlands was one of the worst affected cancer alliances in England, consistently ranking in the bottom 3 of 21 alliances for all CWT measures during the pandemic, whilst Kent & Medway was a consistent top performer.

Implications and limitations

Given our findings considerations should be made, with emphasis given, to breast and LGI cancer service provision. Reduced 2WW performance for breast cancer indicates fewer patients are receiving the outpatient appointments required within 2 weeks, and similarly for LGI patients on the 62D pathway, the required treatment. As fewer patients are seen on all CWT pathways than predicted, this corroborates existing findings on the additional unmet need for cancer service provision during the pandemic. Efforts to detect such patients must not waiver. The key question for the future is how the NHS will address the ongoing decline in CWT performance, worsened by COVID-19, amid a continual rise in patient numbers. Despite the findings shown by our analyses, patient-specific data is required to understand the consequences of CWT delays faced by patients. Furthermore, given there are only nine data points and lots of variation for the months post lockdown, the trends in CWT performance are prone to change as only short-term effects are witnessed. Lastly, causal factors underpinning geographical variations during COVID-19 are likely to be multifactorial and require further quantitative analysis with additional data which was not feasible with this report.

Introduction

Cancer waiting time (CWT) standards were introduced to the national cancer strategy in order to improve the time taken for a diagnosis and treatment to be received by suspected cancer patients (Department of Health, 2000). NHS England records waiting times for suspected and diagnosed cancer patients using nine CWT targets, of which there are three main measures, that record different parts of the referral to treatment pathway. Each CWT measure has an operational standard that defines the target proportion of patients to be seen or treated with the CWT target's timeline (see Appendix 1). The waiting time for suspected and diagnosed cancer patient 2015/16 report showed that in the year 2015, 8 out of 9 CWT performances met or exceeded the set operational standard (Samuels, et al., 2016). This has since decreased, as in 2019 only 4 out of 9 CWT performances met or exceeded the operational standard (Richardson, et al., 2020). In 2015, the Independent Cancer Taskforce (ICF) recommended the introduction of a new 28-day Faster Diagnosis Standard (FDS), which has been monitored since April 2019 and was to be reported on from April 2020 (ICF, 2015). However, the reporting of this CWT measure has been delayed due to the COVID-19 pandemic and as yet there is no published data available on performance of the 28-day FDS.

Previous studies have assessed whether CWT data are representative of the cancer population and if it can be used to assess cancer survival. A study linked CWT diagnosis and treatment data to individual level national cancer registry data and found that patients who were in the youngest and oldest categories were less likely to be included in CWT data (Di Girolamo, et al., 2018a). NHS patients were also more likely to be missed in CWT data if the patient's route of diagnosis was unknown or an emergency, tumour stage presentation was unknown, the patient had comorbidities or died within 30 days of diagnosis or before treatment (Di Girolamo, et al., 2018a). For patients included in 2009-2013 CWT data, those with lung or colorectal cancer showed poorer one year net survival outcomes if they were treated within the 62-day target (Di Girolamo, et al., 2018b). This could be explained by the so-called waiting time paradox, where patients with late-stage diagnosis are treated more rapidly but experience poorer outcomes, or the possible preferred use of palliative treatments to help meet targets, as curative treatments such as major surgery, chemotherapy or radiotherapy, are more resource intensive and require longer to plan (Di Girolamo, et al., 2018b). A study ran by the Royal College of Surgeons of England (RCSE) found that 8 out of 10 surgeons were unable to operate in November 2019 due to a lack of beds and nearly 4 in 10 surgeons had said that as a result of this, more complex surgeries were performed due to patients being on the waiting list for longer and cancer patient situations becoming more advanced (Royal College of Surgeons of England, 2020a). A manifesto was set out by RCSE, which included developing a 5-year plan to tackle lengthening waiting times for operations and an addition of at least 3,000 beds in hospitals (Royal College of Surgeons of England, 2019). Although patient outcomes cannot be dictated by the time between referral and treatment alone, the CWT targets are still important indicators to adhere to, as it allows cancer patients to get treated faster than many other diseases (Di Girolamo, et al., 2018b).

However, in the week commencing the 27th January 2020, the UK recorded its first case of COVID-19 (Peter Moss, 2020). At the beginning of February 2020, thousands of planned surgeries were cancelled due to the growing COVID-19 pandemic and only after the April peak of COVID-19 cases had passed were surgeries resumed (Royal College of Surgeons of England, 2020b). During the course of the pandemic, hospitals and health care services have come under huge pressure to deal with the extremely high caseload of COVID-19 patients, leading to a lack of access to anaesthesia, diagnostics, sterile equipment, staff, COVID-19 tests, PPE, beds and a theatre for surgeons who needed to resume practice (Royal College of Surgeons of England, 2020a). Cancer patients remain to be among those prioritised for treatment through the use of 'COVID-light' and private hospitals, where many surgeons who were not redeployed for the pandemic remained to deal with the demand for urgent treatment (Royal College of Surgeons of England, 2020a). A study made predictions across three scenarios and found that the backlog of cancer diagnosis and treatment impacted by the COVID-19 pandemic will lead to a substantial increase in the number of avoidable cancer deaths and years of life lost in England if urgent interventions are not put into place (Maringe, et al., 2020). COVID-19 will undoubtedly have had an impact on cancer referrals and treatment. Understanding how and to what extent patients have been impacted will be critical in meeting their future needs and assessing the current damage.

Proposed scope and objectives of the report

Our aim is to investigate how the NHS has performed according to national cancer waiting time targets and to what extent the COVID-19 pandemic has affected current and future performance. We will assess this by first observing how CWT performance has changed over time, using data from 2009 – 2020. Secondly, we will assess the variation of CWT performance between different cancer types: breast, lung, lower gastrointestinal (LGI) and urological, where LGI and urological are used as proxies for bowel and prostate cancer respectively. Then we will assess how the performance has varied between geographical regions of England, by grouping providers to their corresponding cancer alliance. Lastly, we will use the absolute number of patients seen and treated to estimate the shortfall in patients seen and treated due to the impact of the COVID-19 pandemic. The three main cancer waiting time targets we will look at are:

1. 2-week-wait (2WW): from urgent referral with suspected cancer by a GP to first outpatient attendance, with an operational standard of 93%.
2. 31-day (31D): from decision to treat a diagnosed cancer patient to receiving first treatment of any kind, with an operational standard of 96%.
3. 62-day (62D): from urgent referral by a GP with suspected cancer to receiving first treatment of any kind, with an operational standard of 85%.

Methods

Data source and preparation

Data used for this report is publicly available cancer waiting time data, which is routinely collected, aggregated and published by NHS England (NHS England, 2021). Data extract files based on monthly provider-level data from October 2009 to November 2020 were merged into a single file before mapping each entry to a regional cancer alliance (NHS England, 2020). This was done using a provider to sustainability and transformation partnerships (STP) look-up file and a STP to cancer alliance look-up file provided by NHS Digital (2020) and the Office of National Statistics (2020a) respectively. These data contain the month and year of entries, total number of patients each month, the number of patients seen within the CWT target and the number of breaches of the CWT standard. Performance was computed by finding the percentage of patients seen within the target time from the total. The data was filtered to retain information on patients of all cancer types, as well as cancer specific data for breast cancer, lower gastrointestinal cancer, urological cancer and lung cancer. The data for urological cancer in the 2WW and 62D pathways excludes testicular cancer. All code and datasets used will be available in the GitHub repository: https://github.com/ericawlfong/Data-Challenge.

Analysis of cancer waiting time performance over time

To produce national trends, data was aggregated by all cancers and performance calculated as the aggregate performance of all providers. To produce cancer specific trends, data was aggregated by each cancer of interest before calculating the national performance within each cancer type. Lines of best fit were drawn using the LOESS method when plotting multiple curves on one plot.

Analysis of numbers of suspected and diagnosed cancer patients

Data from the merged data extract files mapped to cancer alliance were separated into pre- and post-March time periods, with March 2020 as the first month of the national lockdown. Linear regression models of the log of numbers of patients in each pre-COVID-19 month were fit against the date (month of the year) and a factor variable used to take the seasonal nature of the data into account (Appendices 7-9). This was performed using R statistical software. A normal distribution was used to fit the models, with a different model fit for each of the two week wait, 31 day and 62 day targets. Assumptions of linearity, homoscedasticity and normality were probed by plotting residuals vs fitted values and normal quantile-quantile plots (Appendices 2 and 3). The linear models were then used to predict the expected numbers of patients in each of the post-COVID-19 months (March to November 2020), including 95% prediction intervals.

Analysis of cancer waiting time performance by cancer alliance

Data from the merged data extract files mapped to cancer alliance were joined to the Cancer Alliances (April 2020) Boundaries EN BUC (Ultra Generalised 500m) shapefile available from the Office for National Statistics (2020b). Heatmaps for each cancer waiting time measure were plotted using the ggplot2 package in R statistical software to represent performance for each cancer alliance.

Interrupted time series analysis

Interrupted time series (ITS) analyses were performed to test whether CWT target performance decreased after the month of the first national lockdown (March 2020). The pre-COVID-19 period was defined as January 2018 to Feb 2020, and March 2020 was established as the interruption point. Prior to fitting a regression model, the aggregated dataset was expanded to simulate an individual-level one to weight observations by the number of patients included in the calculation of each monthly statistic. Two logistic regression models were constructed with the binary outcome of meeting or not meeting the target waiting time. The models shared three terms: 1) a variable tracking time; 2) a variable coding for the absence or presence of COVID-19; 3) a variable tracking the interaction between time and intervention (Lopez Bernal, et al., 2017). Additionally, one of the models included a term to account for seasonality in the data. To compare current with counterfactual trends, a third model was created with no seasonality and a constant intervention variable. The changes in both slope and level of performance pre- and during COVID-19 were recorded and their direction and statistical significance was visualized through plots and assessed via p-values from the regression model outputs. Selected regression outputs and a brief interpretation of coefficients can be found in appendix 5.

Forecasting of future cancer waiting time performance

The 'fpp2' analysis package was used to model future predictions (12 months on) from our current data and the final chosen model type was an Auto-Regressive Integrated Moving Average model (ARIMA). Preliminary analysis of the data had shown that our full dataset had a slight downward trend and seasonality. The model was built using all available data points, therefore also including COVID-19 data, and all models were evaluated using cross-validation and a summary of all sensitivity analysis results and the chosen model parameters can be found in the appendix (Appendix 6).

Results

National cancer waiting time performance trends

Since October 2009, the national level performance of all three CWT targets has been gradually declining, with 2WW and 62D target performances dropping below the operational standard even before the COVID-19 pandemic. Following the first lockdown, 31D and 62D performance decreased by approximately 2% and 10% respectively. Since then, 31D target performance reported a gradual increase while that of the 62D target returned to its pre-COVID performance followed by another decrease. Contrastingly, the 2WW target performance rose above the operational standard which was followed by a steep decrease to result in the worst performance to be reported since 2009. From the start of the pandemic till November 2020, all CWT target performances have mainly remained below the operational standard.

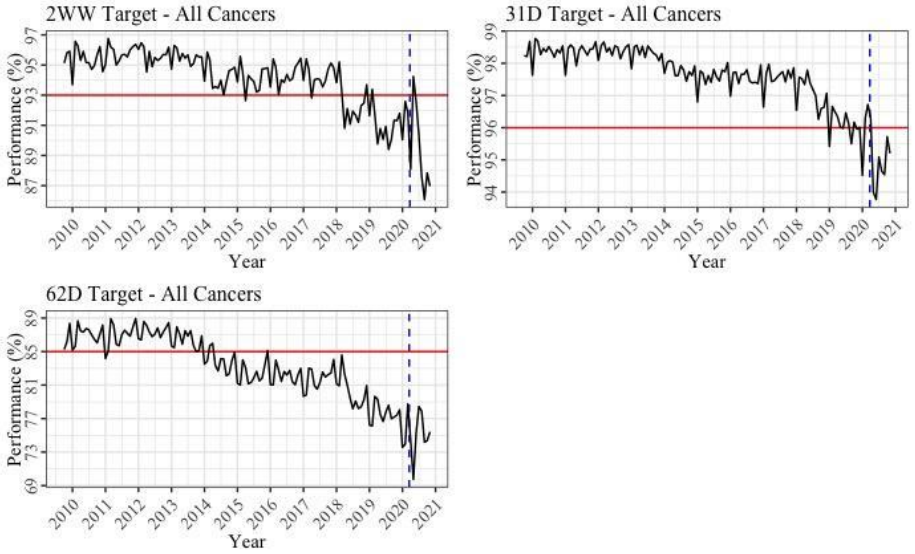

Figure 1. The national levels of performance of provider-based statistics on 2WW, 31 Day and 62 Day targets of all cancers from October 2009 to November 2020. *Red line indicates the operational standard of the target and the blue dashed line indicates the start of the first national lockdown.*

Cancer waiting time performance by cancer type

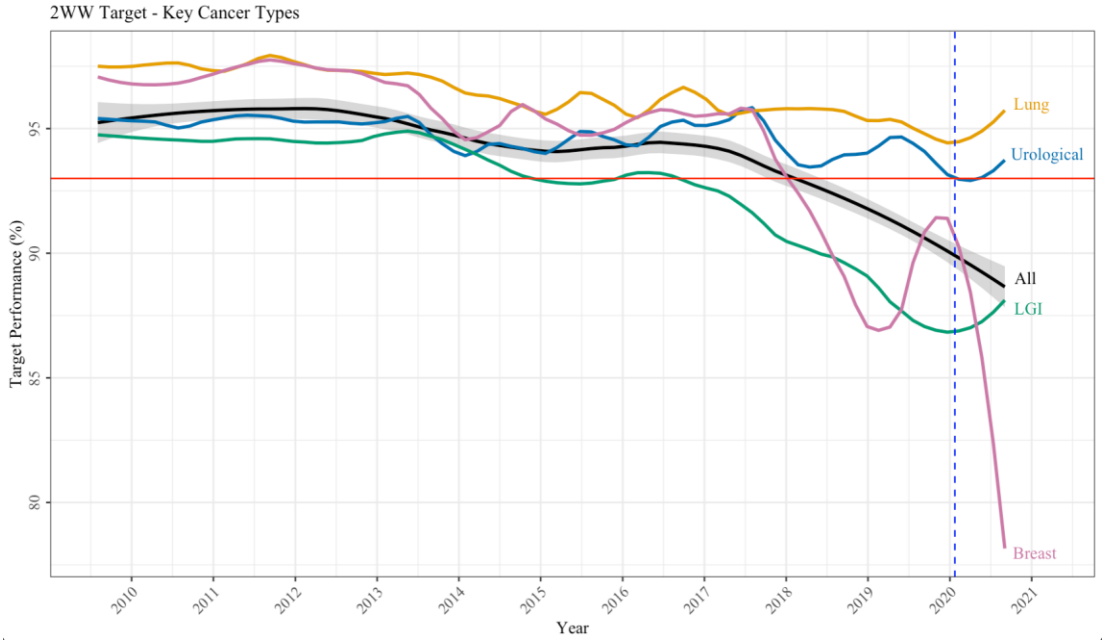

Figure 2. The 2WW national performance of provider-based statistics from October 2009 to November 2020, by cancer. *Red line indicates the operational standard of 93% and the blue dashed line indicates the start of the first national lockdown.*

When stratifying by cancer type, lung and urological cancers have performed consistently above the operational standard, in contrast to lower gastrointestinal (LGI) and breast cancers. LGI cancers have seen a steady decline from June 2016 to an all-time low in April 2020. More variation can be seen for breast cancer where the upward trend from April 2019 to March 2020 becomes a drastic decline after the lockdown. Since lockdown, CWT performance for all cancers collectively appears to be on a downwards trend, however, this is the opposite for lung, urological and LGI cancer which saw an upwards trend in 2WW performance. Despite this LGI and breast cancer continue to perform below the operational standard.

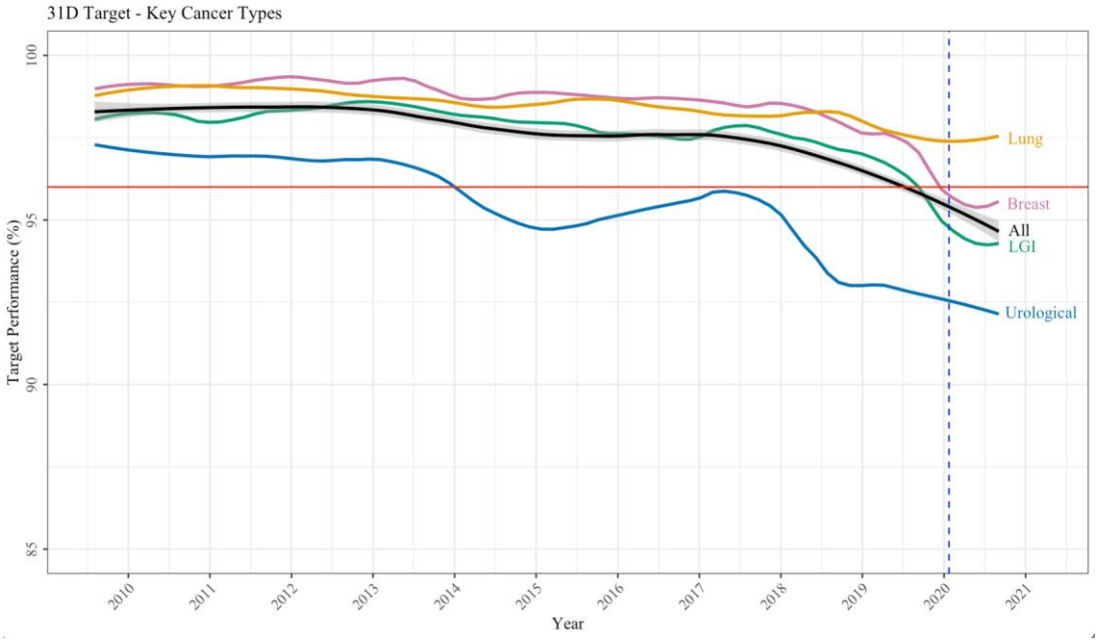

Figure 3. The 31D national performance of provider-based statistics from October 2009 to November 2020 by cancer. *Red line indicates the operational standard of 96% and the blue dashed line indicates the start of the first national lockdown.*

For the 31D target measure urological cancer stands out as the only cancer type consistently below operational standard since 2014, with a decline in performance throughout the pandemic where performance dropped to 87% in June 2020 but has since returned to around 94% in November 2020. Conversely, lung cancer was the only cancer type continuing to perform above standard throughout COVID-19 and has never operated below 96%. For breast cancer, the first decrease to

below the operational target was after April 2020, dropping to 90.56%, however this has returned back to above 96% since October 2020. LGI cancer shares a similar trend to breast, with the biggest drop observed after April 2020 by ~5% to 90.57% but steadily bouncing back to 95% in October.

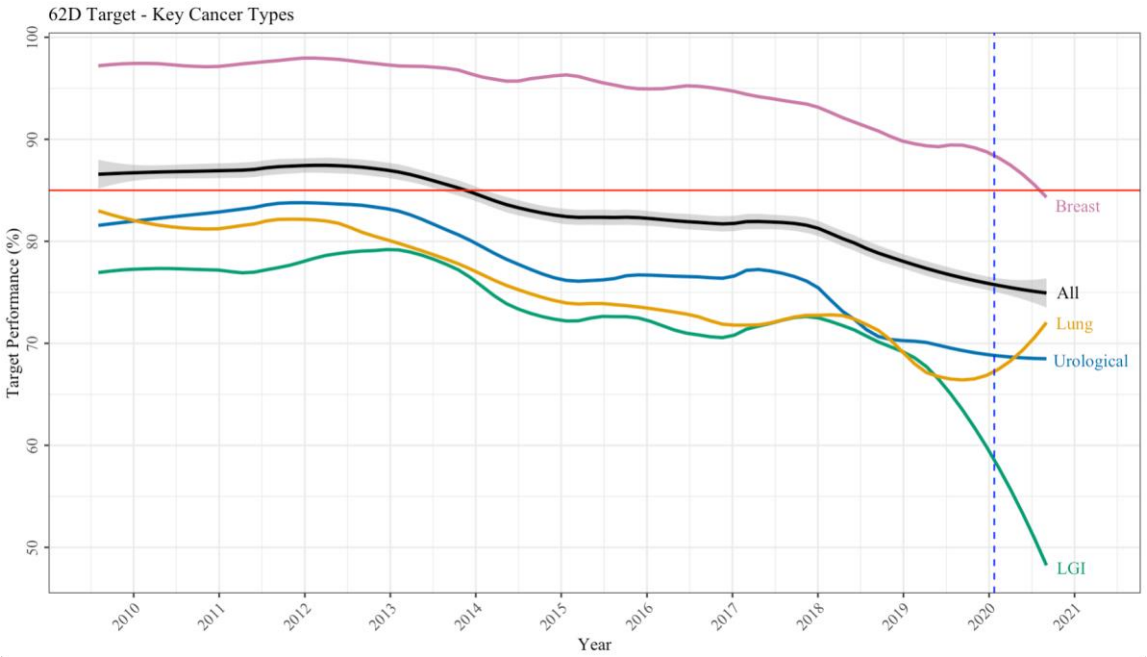

Figure 4. The 62D national performance of provider-based statistics from October 2009 to November 2020, by cancer. *Red line indicates the operational standard of 85% and the blue dashed line indicates the start of the first national lockdown.*

For the 62D CWT measure, breast cancer was the only cancer type to consistently perform above standard, despite displaying a steady downward trend continuing throughout the pandemic, which has been teetering around 85% since November 2020. On the other hand, lung, urological and LGI cancers have been operating below standard since CWT performance was first monitored in October 2009, despite lung cancer showing a slight improvement since July 2020. In particular, LGI cancer has suffered the biggest drop in percentage of patients seen within the 62D target, from March 2019 onwards, and has been performing below 56% since April 2020.

Comparison of cancer waiting time performance trends by cancer alliance

2WW

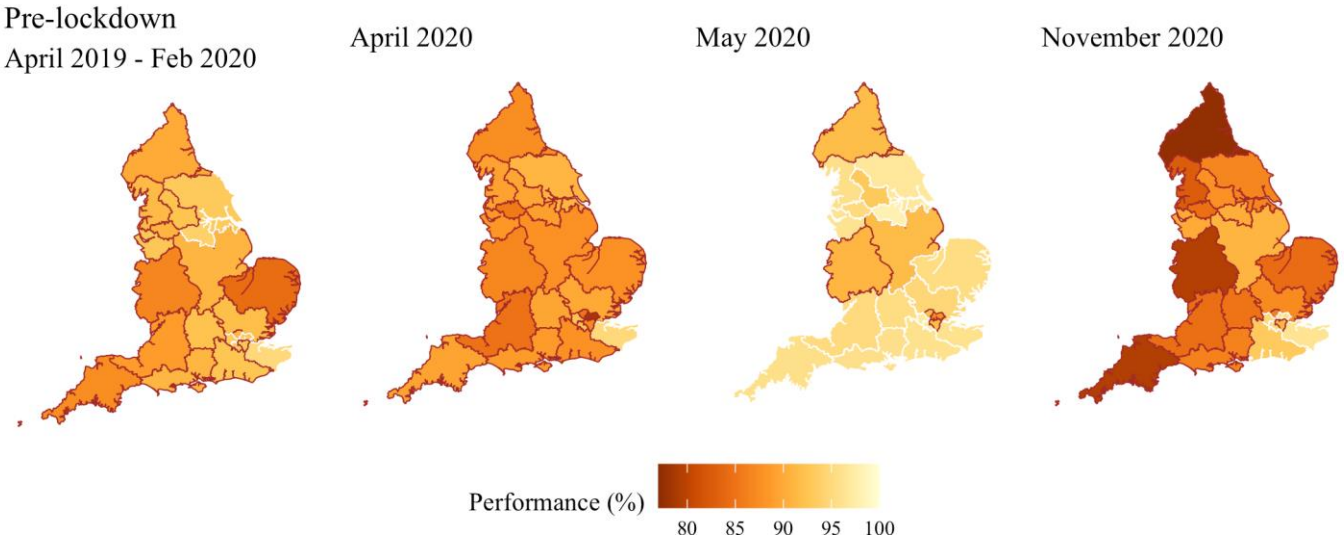

Figure 5. Heatmap of 2WW target performance, by cancer alliance. *Red border indicates the region is below operational standard. See Appendix 4. for key to cancer alliance map.*

2WW	Pre-lockdown	April 2020	May 2020	November 2020
National	90.7%	88.2%	94.4%	87.4%
3 best performing cancer alliances	Kent and Medway (94.9%)	Kent and Medway (95%)	South Yorkshire and Bassetlaw (98%)	Kent and Medway (96.3%)
	South Yorkshire and Bassetlaw (93.9%)	NW and SW London (92.6%)	NW and SW London (97.2%)	North East London (96.03%)
	NW and SW London (93.3%)	Humber, Coast and Vale (91.1%)	Humber, Coast and Vale (96.8%)	NW and SW London (94.9%)
3 worst performing cancer alliances	Peninsula (87.5%)	North Central London (85.4%)	East Midlands (91.6%)	West Midlands (79.5%)
	West Midlands (86.8%)	Somerset, Wiltshire, Avon and Gloucestershire (84.8%)	West Midlands (91.1%)	Peninsula (79.3%)
	East of England – North (84.3%)	North East London (78.6%)	North East London (87.8%)	Northern (77.4%)

Table 1. 2WW CWT performance by cancer alliance, *including the national performance, the 3 best and worst performing alliances.*

31D

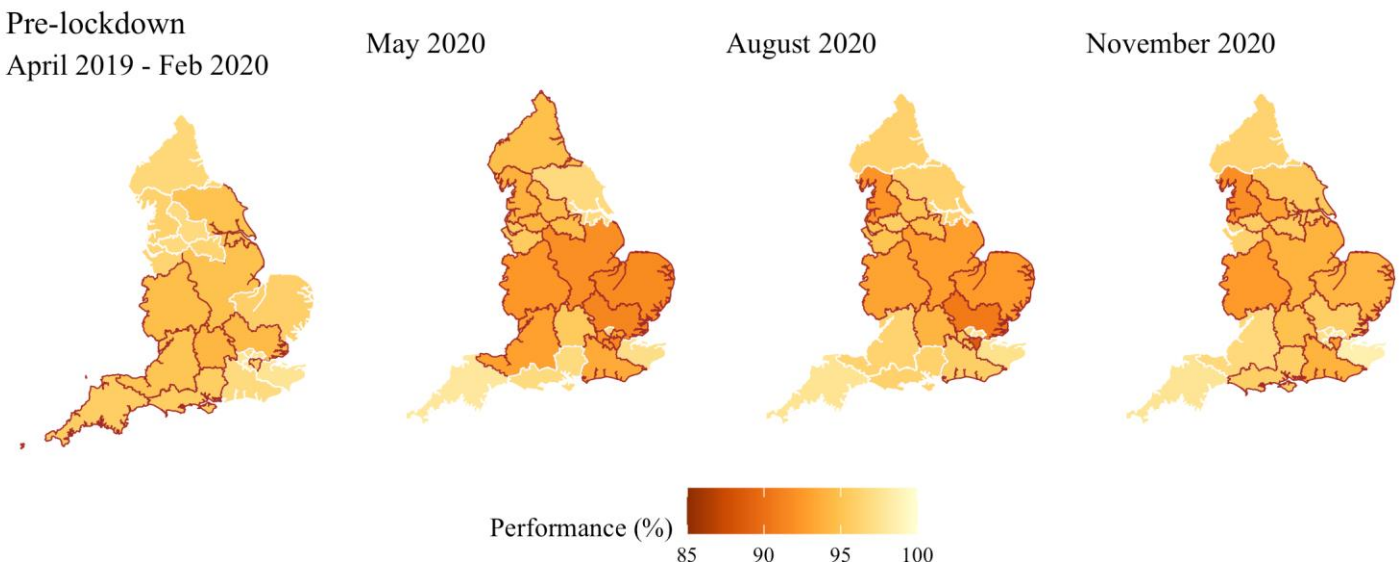

Figure 6. Heatmap of 31D target performance, by cancer alliance. *Red border indicates the region is below standard.*

31D	Pre-lockdown	May 2020	August 2020	November 2020
National	95.9%	94.3%	94.8%	95.4%
3 best performing cancer alliances	NW and SW London (97.8%)	Peninsula (97.9%)	North East London (97.6%)	North East London (98.6%)
	North East London (97.7%)	Kent and Medway (97.2%)	Peninsula (97.6%)	Kent and Medway (98.6%)
	Kent and Medway (97.6%)	Wessex (96.9%)	Kent and Medway (97.3%)	Peninsula (97.6%)
3 worst performing cancer alliances	West Midlands (94.7%)	East of England - North (91.7%)	Lancashire and South Cumbria (92.2%)	South East London (92.8%)
	East of England - South (94.4%)	South East London (91.4%)	East of England - South (90.6%)	West Midlands (92.6%)
	Thames Valley (94.3%)	East of England – South (91.3%)	South East London (88.7%)	Lancashire and South Cumbria (91.9%)

Table 2. 31D CWT performance by cancer alliance, *including the national performance, the 3 best and worst performing alliances.*

62D

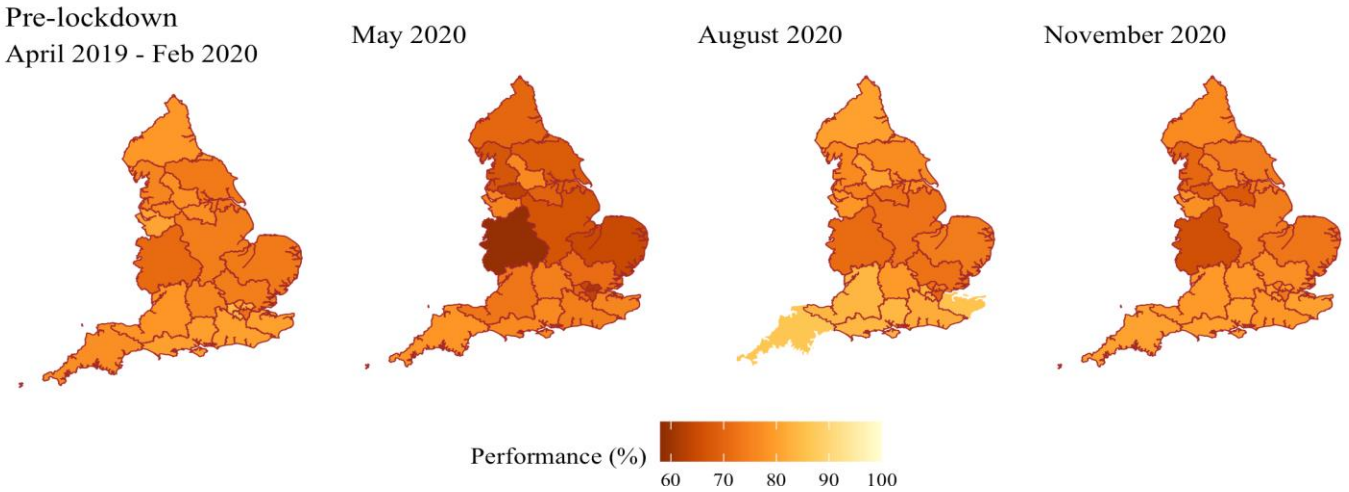

Figure 7. Heatmap of 62D target performance, by cancer alliance. *Red border indicates the region is below standard.*

62D	Pre-lockdown	May 2020	August 2020	November 2020
National	77.0%	69.8%	77.7%	75.6%
3 best performing cancer alliances	NW and SW London (84.4%)	Peninsula (78.4%)	Peninsula (86.6%)	Peninsula (80.5%)
	North East London (83.2%)	Wessex (76.4%)	Kent and Medway (85.9%)	Kent and Medway (80.3%)
	Cheshire and Merseyside (80.9%)	West Yorkshire and Harrogate (76.4%)	Wessex (84.0%)	Wessex (80.3%)
3 worst performing cancer alliances	Humber, Coast and Vale (73.7%)	Greater Manchester (63.5%)	North Central London (72.0%)	Greater Manchester (69.3%)
	South East London (72.6%)	North East London (61.6%)	West Midlands (71.1%)	South Yorkshire and Bassetlaw (67.8%)
	West Midlands (70.9%)	West Midlands (58.9%)	South East London (70.5%)	West Midlands (65.9%)

Table 3. 61D CWT performance by cancer alliance, *including the national performance, the 3 best and worst performing alliances.*

National trends in the number of suspected and diagnosed cancer patients each month

The number of patients being seen each month after an urgent referral by a GP has more than doubled since October 2009 in a remarkably linear fashion, a trend reflected in the 31 day and 62 day pathways. In all cases, there is a huge reduction in monthly recorded patient numbers following the onset of COVID-19 in March 2020. Whilst monthly patient numbers have almost recovered to normal in the two week wait pathway, monthly figures for the 31 day and 62 day pathways remain lower than expected.

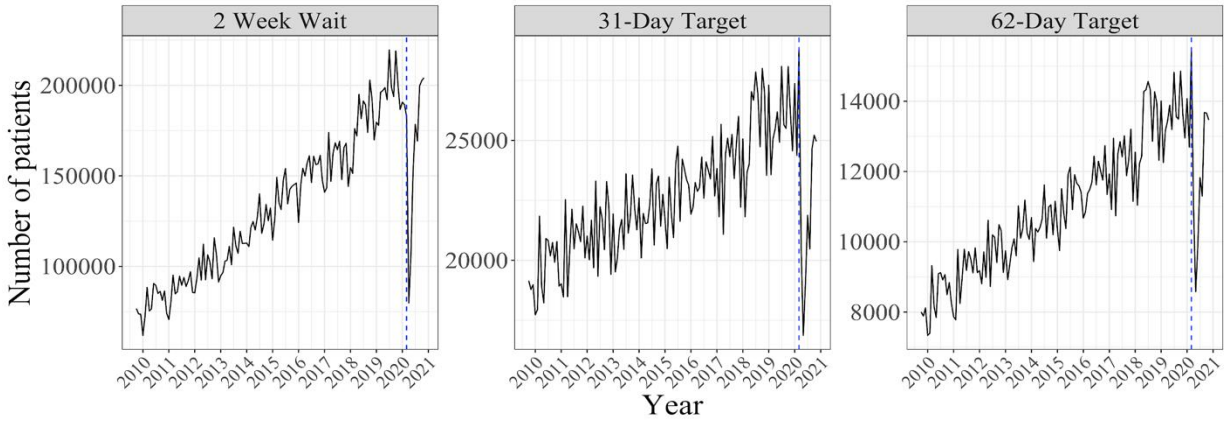

Figure 8. Number of patients seen or treated on each of the three main cancer waiting time pathways for each month from October 2009 to November 2020. *The dashed blue line indicates the first month of COVID-19 as defined in this report (March 2020).*

Actual patient numbers seen on the two week wait pathway were below the lower bound of the 95% prediction interval, even in March, and remained so across the rest of the year, with the exception of August, although only just. Actual patient numbers on the 31D and 62D treatment pathways actually exceeded predictions in March, albeit within the 95% prediction intervals, but fell away from April onwards. As with the two week wait pathway, numbers appear close to the 95% prediction ranges in September, October and November, but remain well below predictions.

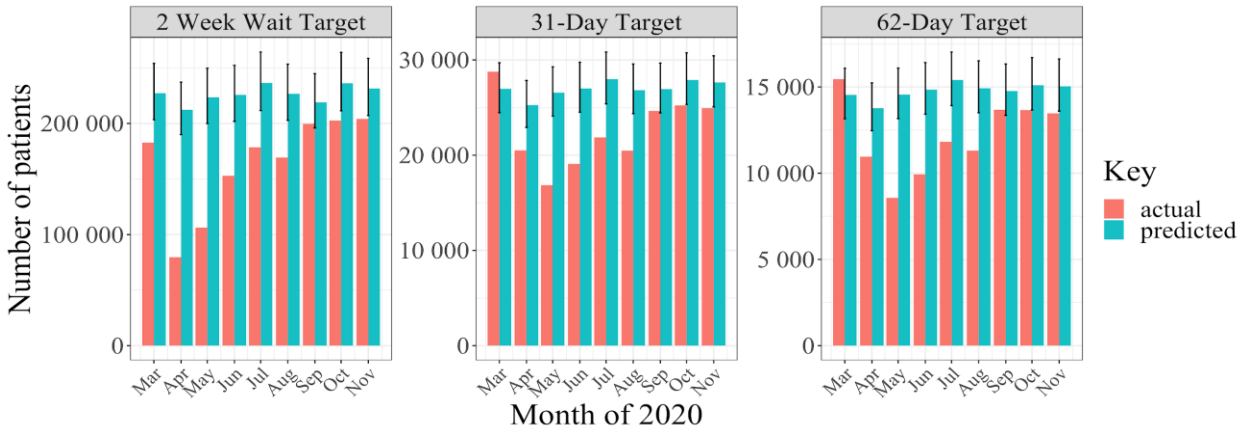

Figure 9. Predicted and actual numbers of patients seen or treated in each month of 2020 after March, on each of the three main cancer waiting time pathways. *Actual numbers of patients for each month are shown in red and predicted numbers are shown in blue. Error bars show 95% prediction intervals for the predicted numbers of patients each month.*

Target	Total actual patients	Total predicted patients	Difference	Upper 95% Prediction Bound	Lower 95% prediction Bound
2 Week Wait	1475720.0	2038825.7	-563105.70	-803167.52	-348332.40
31-Day	202447.0	243123.5	-40676.51	-65456.21	-18188.82
62-Day	108873.5	132961.6	-24088.10	-38155.28	-11366.81

Table 4. Table of the sum and difference of actual and predicted numbers of patients on the three cancer waiting time pathways. *Actual numbers are sums of the monthly recorded figures for each pathway from March 2020 to November 2020 inclusive. Predicted numbers are sums of the values calculated for March 2020 to November 2020 from the linear regression models built on data from pre-lockdown months (October 2009 to February 2020). The difference was calculated as the predicted numbers subtracted from the actual numbers to give an indication of the shortfall in patients being seen or treated within the NHS. Lower and upper 95% prediction intervals are reported in the final two columns.*

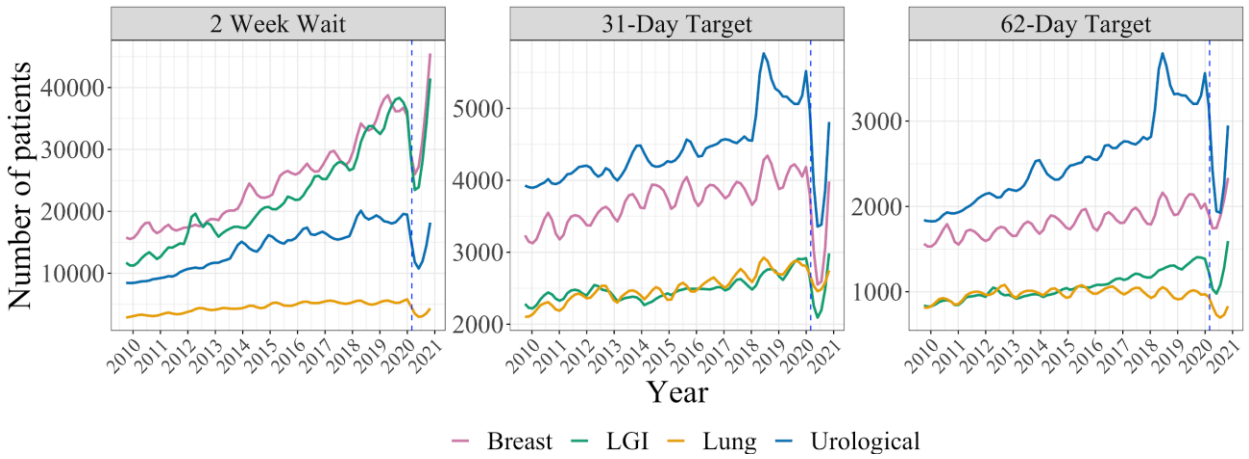

Figure 10. Number of patients seen or treated on each of the three main cancer waiting time pathways for each month from October 2009 to November 2020 split by breast, LGI, lung and urological cancer. *The dashed blue line indicates the first month of COVID-19 as defined in this report (March 2020). Breast cancer trend is shown in pink, LGI in green, lung in yellow and urological in blue.*

All cancers see reductions in monthly patient numbers for all three cancer waiting time targets, but the absolute and relative size of the reductions varies by cancer and by target. All four cancers saw similar relative reductions of patient numbers on the two week wait pathway, although breast and lower gastrointestinal cancers saw the largest absolute reductions as they represented the greatest number of patients on that pathway to begin with. Despite this, they both seem to have returned to normal levels, whilst lung and urological cancers have not.

Interrupted time series analysis of national cancer waiting time trends

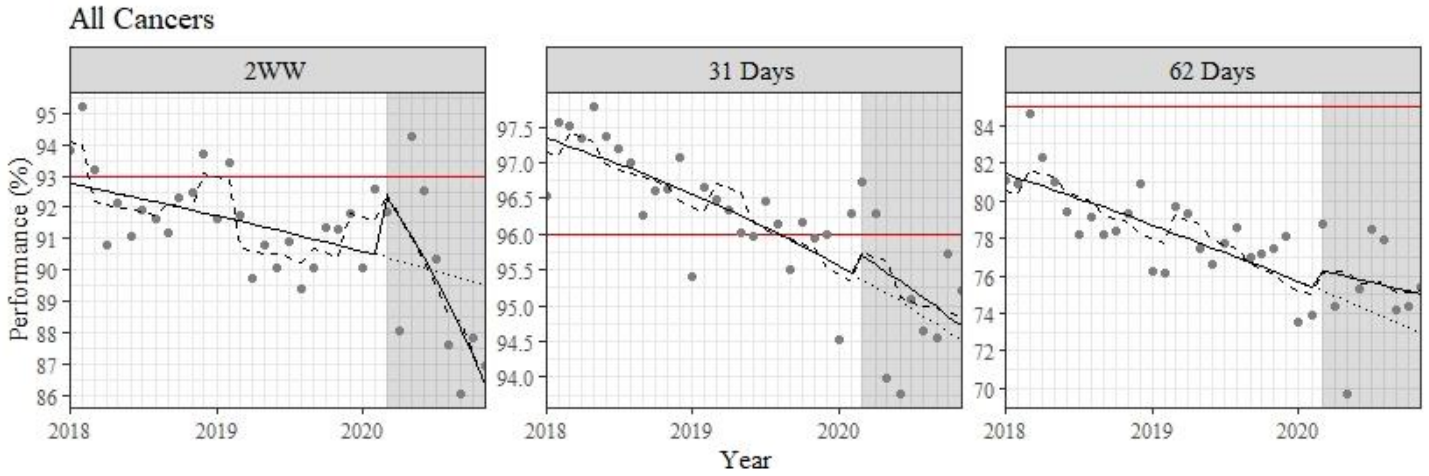

Figure 11. CWT performance for all cancers from January 2018 to November 2020 plotted from models created for interrupted time series analysis. *Red line indicates the operational standard for each CWT target. Shaded area represents the time of COVID-19 pandemic. Points track observed average monthly performance. Solid lines plot the estimated values from a deseasonalized model. Dashed lines plot the estimated values from a seasonal model. Dotted line represents the counterfactual prediction, plotting the estimated values from a model with a constant intervention variable.*

All Cancers - All CWTs

After carrying out ITS analysis on aggregated data for all cancers, varying magnitudes of change to the performance trends were observed across the three CWTs during COVID. The 2WW target saw a negative slope change after March 2020. During the pre-COVID-19 period, the operational standard was 1.5% less likely to be met per month. This likelihood significantly decreased by a further 6% per month during the pandemic ($p<0.001$). The 62D pathway saw an improvement from its pre-COVID performance trend, although its general performance continued to decline. While neither level nor slope change reach statistical significance, the overall trend in performance for the 31D target is also decreasing.

Specific cancer types - 2WW

Immediately after March 2020 breast and urological cancers saw significant decreases in performance trends. Breast cancer was most affected, with the likelihood of breaching the target operational standard going from 2.6% to 24.1% per month ($p<0.001$). Lower GI displayed the opposite pattern whereby the pre-COVID negative performance trend became positive after March 2020, with a 7.8% increase in the likelihood of meeting the operational standard per month($p<0.001$). Due to this rising trend, the observed performance for LGI cancer was higher than that expected if the pandemic had not occurred. To a smaller but significant degree, this pattern was also seen for lung cancer ($p=0.024$).

Specific cancer types - 31D

All four cancer pathways saw decreasing performance trends prior to March 2020. Since then, breast and lung cancer performance experienced an increase. However, this change was only significant for breast cancer, where the operational standard was 8.4% more likely to be met per month ($p<0.001$). Despite this, lung cancer performance is exceeding the expected trend if its pre-COVID-19 performance had continued. Both LGI and urological cancers performance continue to decline, at a similar trend as before the pandemic.

Specific cancer types - 62D

From March 2020, lung and urological cancer experienced increasing performance trends. In particular, lung cancer saw a 7.8% ($p<0.001$) increase in likelihood of meeting the operational standard per month. These changes meant that the target performances of both cancers improved during the pandemic such that by November 2020, the observed performances were higher than those predicted by the counterfactual trendline. Although the change in slope for LGI did not reach statistical significance this pathway suffered a striking and statistically significant negative level change of 4.9% at the interruption point ($p<0.001$). Breast cancer was the only cancer type that showed a significant decrease in performance trend during the pandemic ($p<0.001$), making it the last of the four investigated cancer types in the 62D pathway to fall below operational standard.

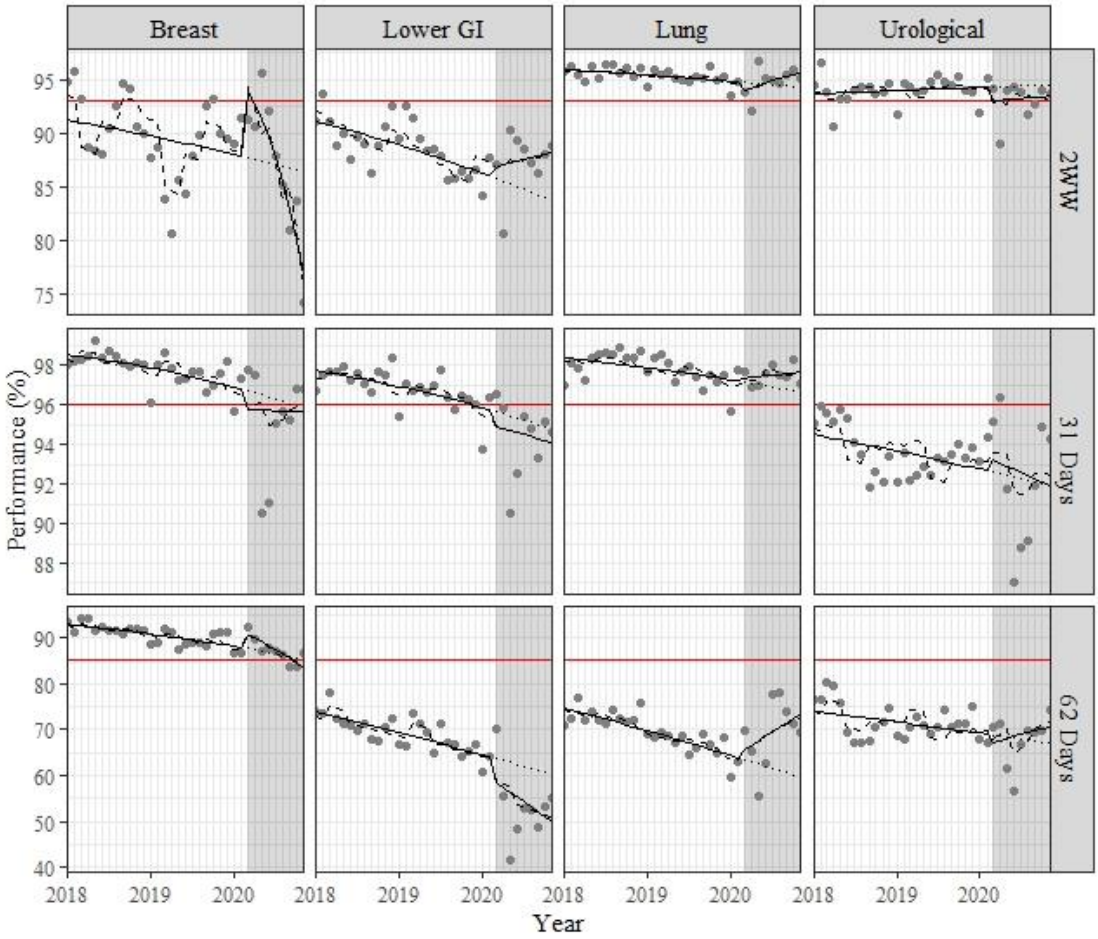

Figure 12. CWT performance from January 2018 to November 2020 split by cancer type and CWT pathway. Plotted from models created for interrupted time series analysis. *Red line indicates operational standards. Points indicate average monthly performance. Shaded area represents time during the COVID-19 pandemic. Solid line indicates a deseasonalized model. Dashed line indicates a seasonal model. Dotted line indicates the counterfactual prediction.*

Forecasting of future cancer waiting time performance

From the forecasting results, it was found that the cancer types with greater variance before and after the COVID-19 pandemic also resulted in ARIMA prediction models with greater variance and uncertainty. All forecasting trends either followed a downward trajectory or were stable, and there is no CWT target or cancer type that would see an increase in performance in the near future. Although most trends did see a significant drop in performance during the COVID-19 peak right after the first lockdown, most targets and cancer types did counteract this soon after to hinder a snowballing effect in future trends, with the notable exception of breast cancer 2WW performance.

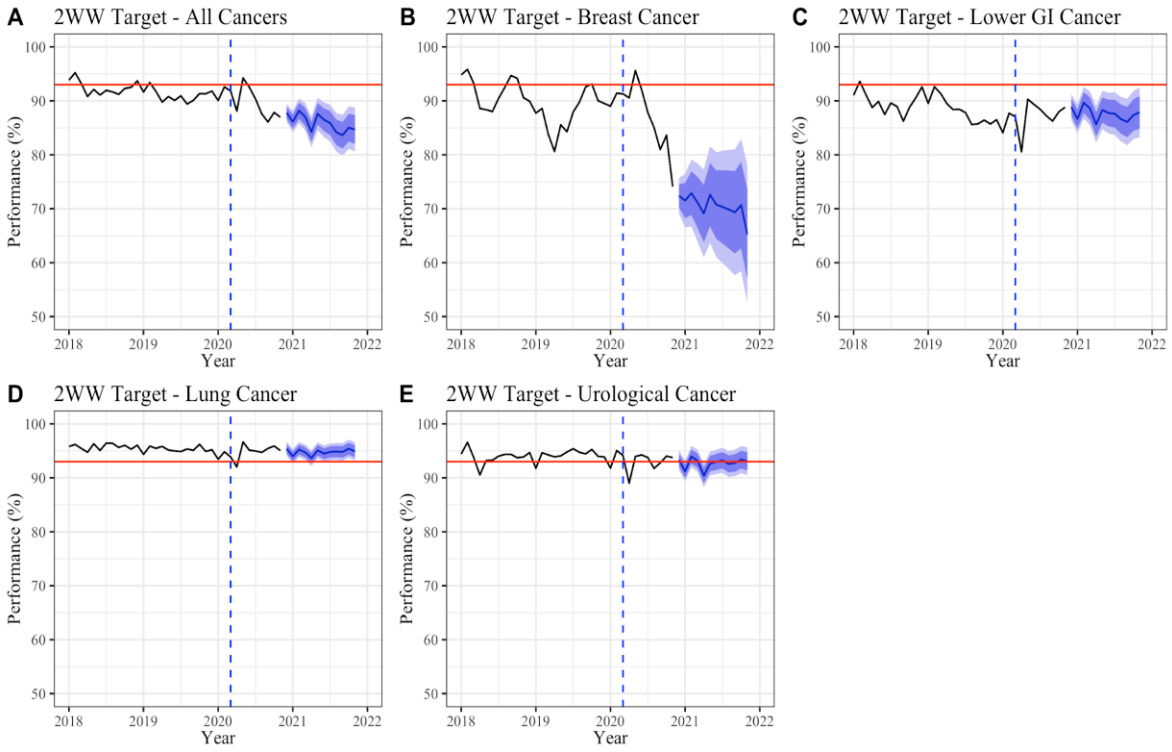

Figure 13. Predicted forecast in the 2-week-wait pathway for all cancers (A) and each of the key cancer types (B, C, D, E). *The red line is the operational standard at 93%. The blue dotted line marks the date of the national lockdown in March 2020. The shading around the forecasting plot indicates the confidence intervals, where dark blue is 80% CI and light blue is 95% CI.*

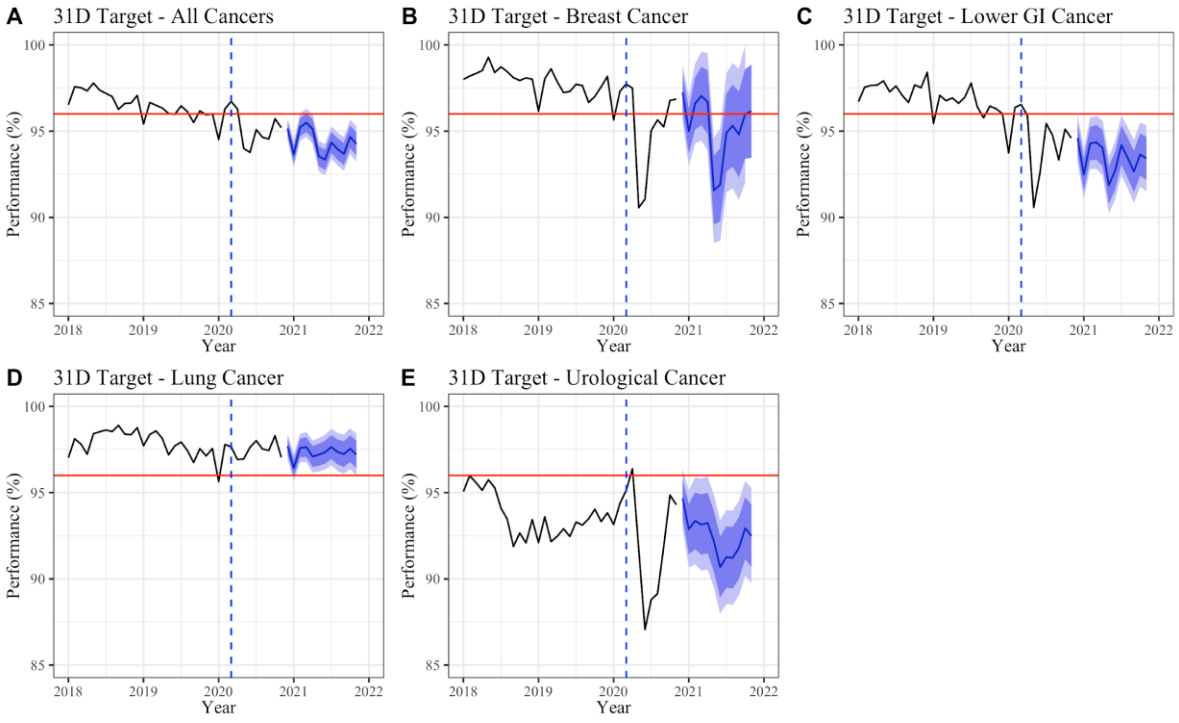

Figure 14. Predicted forecasts of the 31-day pathway for all cancers (A) and each of the key cancer types (B, C, D, E). *The red line is the operational standard at 96%. The blue dotted line marks the date of the national lockdown in March 2020. The shading around the forecasting plot indicates the confidence intervals, where dark blue is 80% CI and light blue is 95% CI.*

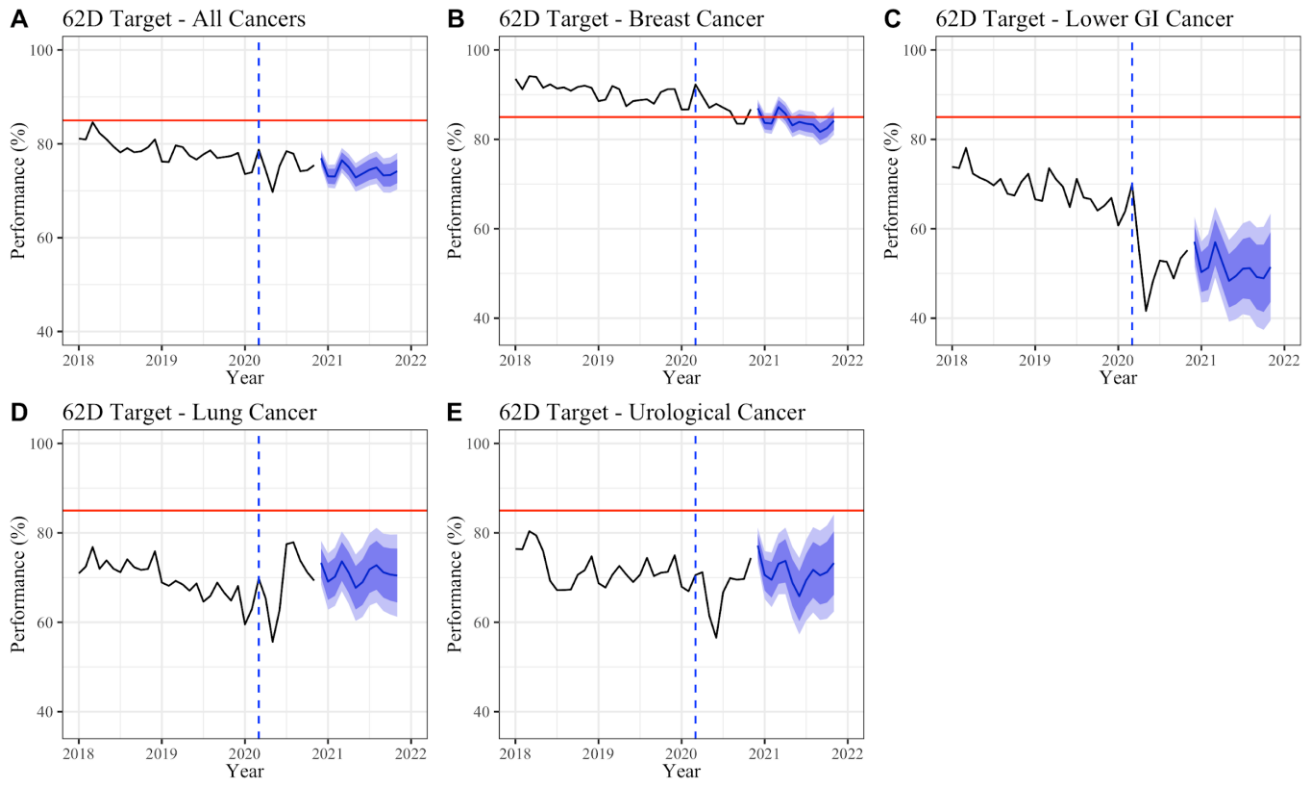

Figure 15. Predicted forecasts of the 62-day pathway for all cancers (A) and each of the key cancer types (B, C, D, E). *The red line is the operational standard at 85%. The blue dotted line marks the date of the national lockdown in March 2020. The shading around the forecasting plot indicates the confidence intervals, where dark blue is 80% CI and light blue is 95% CI.*

Discussion

National trends in cancer waiting time performance for all cancers by CWT measure

2WW

Due to the pandemic and government advice to stay home, a decline in the number of patients entering the 2WW pathway across the key cancers was observed (Morris et al., 2021). Moreover, access to specialist appointments across cancer services have been limited (Gathani et al., 2020). Together, these facts are likely to be behind the decrease in the 2WW performance trend since the start of COVID-19. Out of the four key cancer types focused on in this report, breast cancer is the worst affected in the 2WW target (Figure 2). This could be explained by the fact that breast cancer predominantly affects women who are more likely to be in situations of care and therefore come into contact with populations more vulnerable to COVID-19. As a result, they may choose to miss or delay their outpatient appointments. Urological cancer saw a decrease in performance and a decrease in patient numbers, contributing to the overall national trend, however, LGI and lung cancers saw increases in trend performance. Both are high risk cancers and patients are more likely to present with more severe symptoms (Cancer Research UK, 2021a), and therefore may have been prioritised over other cancer types. The increase in performance for lung cancer may have been related to the decrease in patients seen, which in turn may have been a result of government guidance for COVID-19, which asks people with a cough, a common symptom of coronavirus, to stay at home (Gourd, 2020).

31D

The change in trend observed for 31D performance pre- and during COVID-19 was non-significant (Figure 11). This may be because, although surgeries were halted, other treatment options, such as chemotherapy or radiotherapy, may have been more feasible to deliver and replaced surgeries as the first treatment option. That said, numbers of patients on the 31-day pathway still declined during the pandemic, likely due to the cancellation of all provisioned treatments due to the reallocation of hospital resources in response to the pandemic. Once treatment was resumed, cancer patients were prioritised over many

other diseases, explaining the exponential response in increasing the number of patients seen within this pathway. Both breast and LGI cancer suffered a steep decrease in the number of patients, but while performance during COVID-19 improved for breast cancer, that for LGI has not. This could be because other treatment options, such as hormone therapy which are less resource intensive (Cancer Research UK, 2021b), became the first choice of treatment for breast cancer. On the other hand, such treatment options are not an option for LGI cancers, where curative treatments, such as radiotherapy or surgery, remain to be the main form of standard treatment. Contrastingly, the changes seen in the trends for breast and LGI cancers are not observed for lung and urological cancer. Although fewer patients with lung or urological cancer are being treated during COVID-19, compared to pre-COVID-19 levels, hospitals may still be able to treat them at the same pre-COVID-19 rate. As lung cancer is deemed a high-risk cancer, the non-significant level and slope changes meant that these patients were still prioritised as much as possible throughout the COVID-19 pandemic.

62D

The national 62D target saw a significant increase in trend performance and this is likely to be because the 62D pathway allows for more time for the target to be met, compared to the 31D target. Moreover, pauses in breast and bowel screening services and campaigns have led to a reduced number of patients attending their GP with possible cancer symptoms and suspension of surgeries by hospitals in April due to strain on hospital services as a result of the pandemic (NHS England, 2020a). The decline in the number of patients entering this pathway meant that hospitals were more likely to be able to meet the 62D performance criteria. This potential explanation of the improvement in performance trend was especially seen in lung and urological cancer. As the 62D pathway directly includes the 2WW and 31D pathway, we expect the impact of COVID-19 on the performance of these two pathways to be reflected in the 62D performance. This is evident in breast cancer where the significant decrease in performance for the 62D target is likely to be caused by the impact of poor performance during COVID-19 on the 2WW performance while the performance in the 31D target remained stable. At the point of the first lockdown due to COVID-19 in March 2020, LGI cancer performance saw a 5% decrease. Even though a non-significant difference in slope change was observed, the 5% level change alone can conclude that the pandemic has impacted the overall performance. As no improvement is observed, we could deduce that hospitals are limited to non-surgical but other curative treatments, such as radiotherapy.

Comparison of cancer waiting time performance between cancer alliances

Generally, all cancer alliances saw similar trends to each other for all three CWT measures, with a marked decline in performance immediately after March, noticeable improvement during the summer, before major declines as the autumn arrived (Figures 5-7). However, there were some clear regional patterns that were observed. Kent and Medway cancer alliance is consistently one of the top 3 performing areas above operational standard for all CWT measures (Figure 5). North West and South West London alliances were two of the best performing regions for 2WW after the lockdown. Peninsula was a top performing alliance for the 31D and 62D measure. By contrast, West Midlands, containing Birmingham, the second largest city in England, was one of the worst performing regions, consistently below operational standard for all targets.

There are several reasons that may account for such geographical disparities, namely a combination of varying R rates of infection, deprivation, population density and ethnic diversity, but differences cannot be explained with a single variable. For example, Peninsula is one of the most deprived areas in the UK but has performance on a par with NW and SW London, which contain some of the least deprived areas nationally (Ministry for Housing, Communities & Local Government, 2019). High levels of ethnic diversity in Birmingham could contribute to its comparatively lower CWT performance (Department for Communities and Local Government, 2021), as these patients often have worse outcomes following COVID infection and require more hospital resources. Thus, reducing hospitals' capacity to provide cancer services (Public Health England, 2020). Ultimately, though, causal relationships of factors relating geographical variations in CWT performance, especially in the face of COVID-19, require more data on such factors and a quantitative analysis to be drawn, which was not feasible in this report.

Forecasting of future cancer waiting time performance

The forecasted predictions of CWT performance for the next 12 months take into account both the pre-COVID-19 performance and performance during the pandemic, therefore predictions are a product of combining both of these trends. From these predictions, we can see that certain cancers on certain pathways are of much greater concern than others. The worst predicted outcome on the 2WW pathway is breast cancer, where performance could be as low as 52% in November of 2021 (Figure 13). This is particularly concerning, as breast cancer patients make up a majority of patients referred by GPs on the 2WW pathway (Figure 10). LGI cancer is also predicted to perform below the 2WW operational standard for the next 12 months, but only by about 5% below the target level and with no decline in performance. Both lung and urological cancers are predicted to maintain performance above or on the operational standard, and therefore are of less concern for the time being.

Although its 2WW performance is predicted to continue to decline for the foreseeable future, breast cancer's 62D performance is predicted to be quite strong, and even above the operational standard in most scenarios. This is in direct contrast to the national trend in the 62D target, which is predicted to remain well below the standard. Although lung and urological cancer will likely have an impact on the forecasted decreasing trend for the 62D target, LGI cancer will have the largest impact as its performance is the worst out of all cancer types in any of the targets (Figure 12).
As for urological cancer, its predicted 2WW performance does appear to be quite robust, whereas its predicted 31D and 62D performance is anything but. However, this appears to be as a result of long-standing trends, rather than a direct impact of COVID-19 (Figure 3). Although the performance for urological cancer in 31D did drop significantly in the months immediately following March 2020, performance has bounced back as sharply and as a result the overall trend has not changed (Figure 12). This suggests that improving performance for urological cancer within the 31D and 62D targets will require a longer-term plan, even once the effects of the pandemic on wider society have reduced.

Without access to individual level data, or knowledge of whether interventions put in place especially for the pandemic will be kept in the future and the progression of the pandemic, we cannot be sure to fully explain the justification and accuracy of the predicted forecast.

Limitations of the report

The main limitation of this report was the nature of the data used. Whilst using the publicly available CWT data on the NHS England website was very convenient, as it was freely accessible and had already been cleaned, pre-processed and aggregated to a largely useful degree, there were many variables that were not included that would have allowed for a more insightful analysis. For example, although we were able to determine differences in performance in various subsections of our analysis, we were unable to make any clear suggestions as to why they might be, with reference to factors such as age, gender, socioeconomic status or comorbidities.

The data only included patients that *completed* the CWT pathways, with no indication of the number of patients entering or already on each pathway. This made it very difficult to accurately assess increases in the backlog of patients being untreated or undiagnosed patients presenting for consultation. The comparison of predicted to observed numbers of patients was able to give some idea of the scale of this issue, but information on how many patients were already on these pathways is necessary to really answer this question.

Unfortunately, because of the COVID-19 pandemic, the introduction of the 28-day FDS has been delayed and therefore was unable to be included in this report. This had already been identified as a key part of understanding cancer waiting time performance, as currently no targets include the time it takes for a patient to receive a diagnosis (or lack thereof), which would likely help explain performance in the overall 62D target performance.

The data on the 31D and 62D pathways only included a small selection of cancers, with some cancers reported on as a group, for example urological and LGI cancers. This limited our ability to speak about prostate and bowel cancers

specifically, but our assumption is that either those specific cancers comprise the majority of those groups, or the overall trends for the group are also true for the individual cancers. Either way, it would be important to verify our results using data specific to those cancers. Furthermore, we were unable to discuss esophageal cancer at all.

Whilst it was hypothesised that the type of first treatment modality would change in response to the stresses on healthcare providers during the pandemic, this information was not directly available as part of the 31D target data. Treatment type of second or subsequent treatments is reported, as is whether or not patients were admitted or non-admitted during treatment, but it was decided that these were not reliable enough proxies to answer the original question and therefore this question remains unanswered in this report.

With respect to predicted trends, it is important to keep in mind that there has been a large amount of month-on-month variation during the pandemic and that there are only nine months' worth of post-COVID-19 data versus 124 months of pre-COVID-19 data. Therefore, actual future trends are likely to change with subsequent months of data.

Final Conclusions

It is certainly true that COVID-19 has had serious negative effects across the scope of cancer waiting times. However, this report has shown that certain performances have been more or less resilient in certain cancers, certain parts of the country and certain CWT targets. It is also true that CWT performance has been declining already for a long time and decreasing trends in performance during the COVID-19 pandemic should not be assumed to be directly as a result of the pandemic alone. This suggests that any approach to improve the performance of cancer waiting times in England must take into account the specific variables that affect different cancers and different regions and different targets, differently. A less specific approach risks not only being less effective, but also wasting limited NHS resources by being less efficient.

Whilst this report has been able to bring to light the changes in performance in CWT targets and how these have, or haven't, been affected by the COVID-19 pandemic, it was majorly limited by the aggregate nature of the data used. Therefore, in order to begin devising strategies for combating the negative effects of COVID-19 on cancer waiting time performance and improving performance outside the context of the pandemic, we suggest a comprehensive analysis of the demographic characteristics that represent specific cancer types and regions, as well as the regional provision for treating different cancer types. Focus should be placed on the areas of greatest concern that have been identified, such as the breast cancer 2WW pathway, the LGI 62D pathway, the 62D pathway more generally, and the West Midlands cancer alliance.

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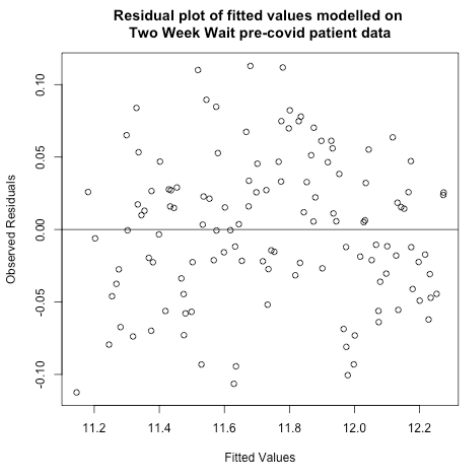
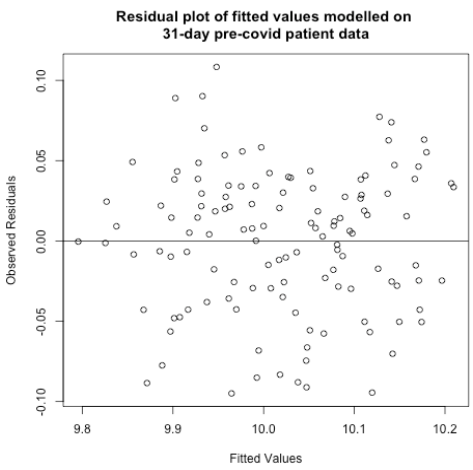
Appendix

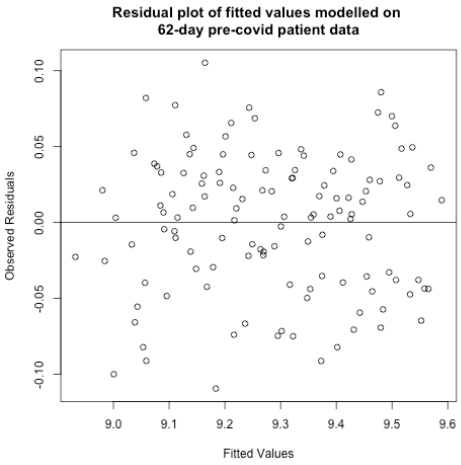
Appendix 1. Table of the nine cancer waiting time performance measures measured by NHS England. The first column indicates the time period within which the patient must satisfy the requirements of the measure. The second column details the point at which the clock is 'started', whilst the third column details the point at which the clock is 'stopped'. The fourth column reports the aggregate average performance for all providers across all cancers for each measure, for the year April 2019 to March 2020. The final column details the operational standard associated with each measure i.e. the proportion of patients NHS England targets to complete each pathway within the relevant time period.

Waiting Time Measure				Performance 2019/20	Operational Standard
Time Period	**From**	**To**			
Two week wait	Urgent referral with suspected cancer	First outpatient attendance		**90.8%**	**93%**
	Urgent referral breast symptoms, but no suspected cancer	First hospital attendance		**83.7%**	**93%**
31-day wait	Decision to treat	First definitive treatment of any kind		**96.0%**	**96%**
		Second or subsequent treatment where treatment is	Surgery	**91.3%**	**94%**
			Chemotherapy	**99.1%**	**98%**
			Radiotherapy	**96.4%**	**94%**
62-day wait	Urgent referral with suspected cancer	First definitive treatment of any kind		**77.2%**	**85%**
	NHS screening programme	First definitive treatment of any kind		**84.6%**	**90%**
	Upgrade of non-urgent referral by a consultant	First definitive treatment of any kind		**82.3%**	**N/A**

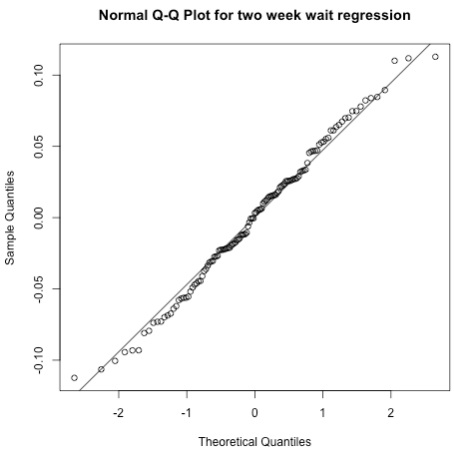
Appendix 2. Scatter plots of fitted values against residuals of the linear regression models for the two week wait, 31 day and 62 day pathways.

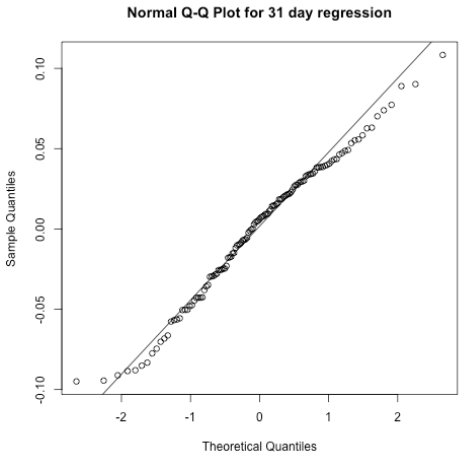


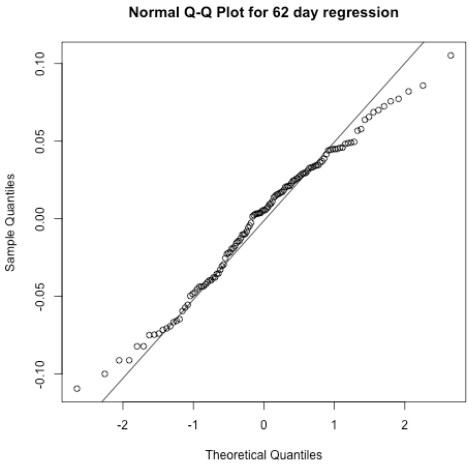




Appendix 3. Normal quantile-quantile plots of the linear regression models for the two week wait, 31 day and 62 day pathways.



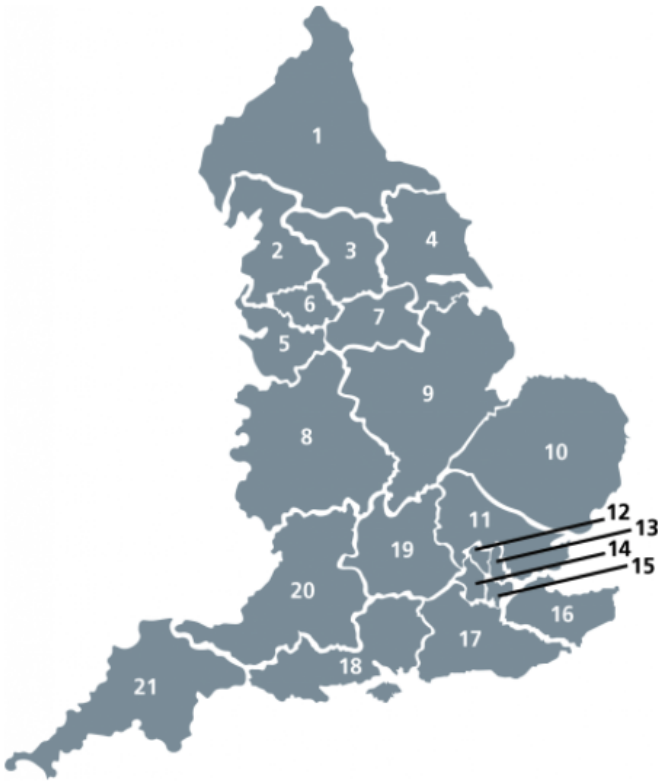




Appendix 4. Key of cancer alliance map in England. Retrieved from https://www.england.nhs.uk/cancer/cancer-alliances-improving-care-locally/#map (NHS England, 2020b).

Map of Cancer Alliances in England

1. Northern Cancer Alliance
2. Lancashire and South Cumbria Cancer Alliance
3. West Yorkshire and Harrogate Cancer Alliance
4. Humber, Coast and Vale Cancer Alliance
5. Cheshire and Merseyside Cancer Alliance
6. Greater Manchester Cancer Alliance
7. South Yorkshire and Bassetlaw Cancer Alliance
8. West Midlands Cancer Alliance
9. East Midlands Cancer alliance
10. East of England – North Cancer Alliance
11. East of England – South Cancer Alliance
12. North Central London Cancer Alliance
13. North East London Cancer Alliance
14. RM Partners
15. South East London Cancer Alliance
16. Kent and Medway Cancer Alliance
17. Surrey and Sussex Cancer Alliance
18. Wessex Cancer Alliance
19. Thames Valley Cancer Alliance
20. Somerset, Wiltshire, Avon and Gloucestershire Cancer Alliance
21. Peninsula Cancer Alliance



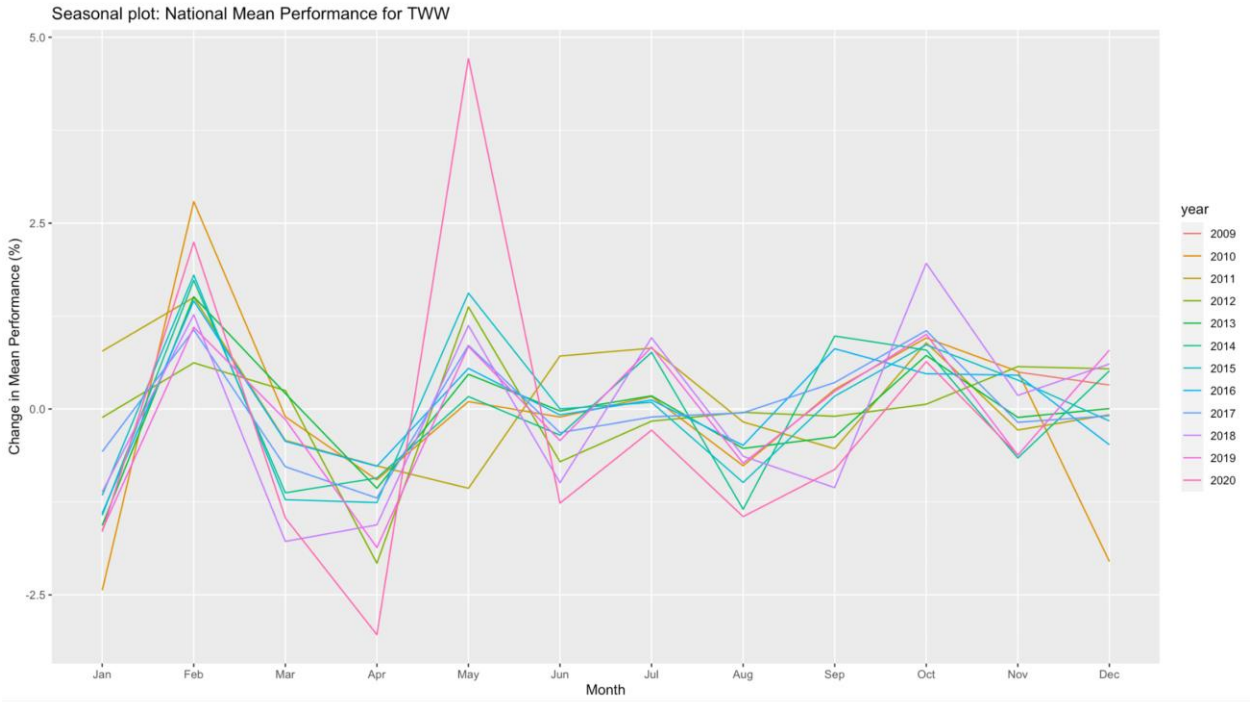
Appendix 5. Table of selected regression outputs from the seasonality-adjusted model. Level changes are the exponentiated value of the regression coefficients for the pandemic status (absent/present) term. Pre- and COVID slopes are the exponentiated values of the regression coefficients for the time variable and the interaction term respectively**.** Exponentiated logistic regression coefficients correspond to Odds Ratios. Significance values are provided for level change and COVID slope. All pre-covid slope calculations reached statistical significance.

Target	Level change (change in %)	p-value	Pre-covid slope	Covid slope	p-value
ALL CANCERS					
2WW	1.489 (-2.036)	<0.001***	0.985	0.925	<0.001***
31 Days	0.977 (-0.371)	0.413	0.98	1.007	0.159
62 Days	0.980 (-0.995)	0.269635	0.987	1.015	<0.001***
BREAST CANCER					
2WW	4.008 (-6.537)	<0.001***	0.974	0.759	<0.001***
31 Days	0.595 (0.824)	<0.001***	0.972	1.056	<0.001***
62 Days	1.331 (-3.270)	<0.001***	0.977	0.942	<0.001***
LUNG CANCER					
2WW	0.886 (0.767)	0.0385 *	0.989	1.045	<0.001***
31 Days	1.130 (-0.128)	0.26525	0.978	1.017	0.36901
62 Days	1.131 (-2.009)	0.0459 *	0.979	1.057	<0.001***
LOWER GASTROINTESTINAL CANCER					
2WW	0.053 (-0.998)	<0.001***	0.98	1.058	<0.001***
31 Days	-0.266 (0.821)	0.00233 **	0.977	1.007	0.65106
62 Days	-0.354 (4.980)	<0.001***	0.984	0.995	0.603
UROLOGICAL CANCER					
2WW	-0.089 (1.408)	0.002 **	1.002	0.982	<0.001***
31 Days	0.025 (-0.971)	0.627	0.988	1.007	0.408962
62 Days	-0.214 (0.815)	<0.001***	0.992	1.055	<0.001***

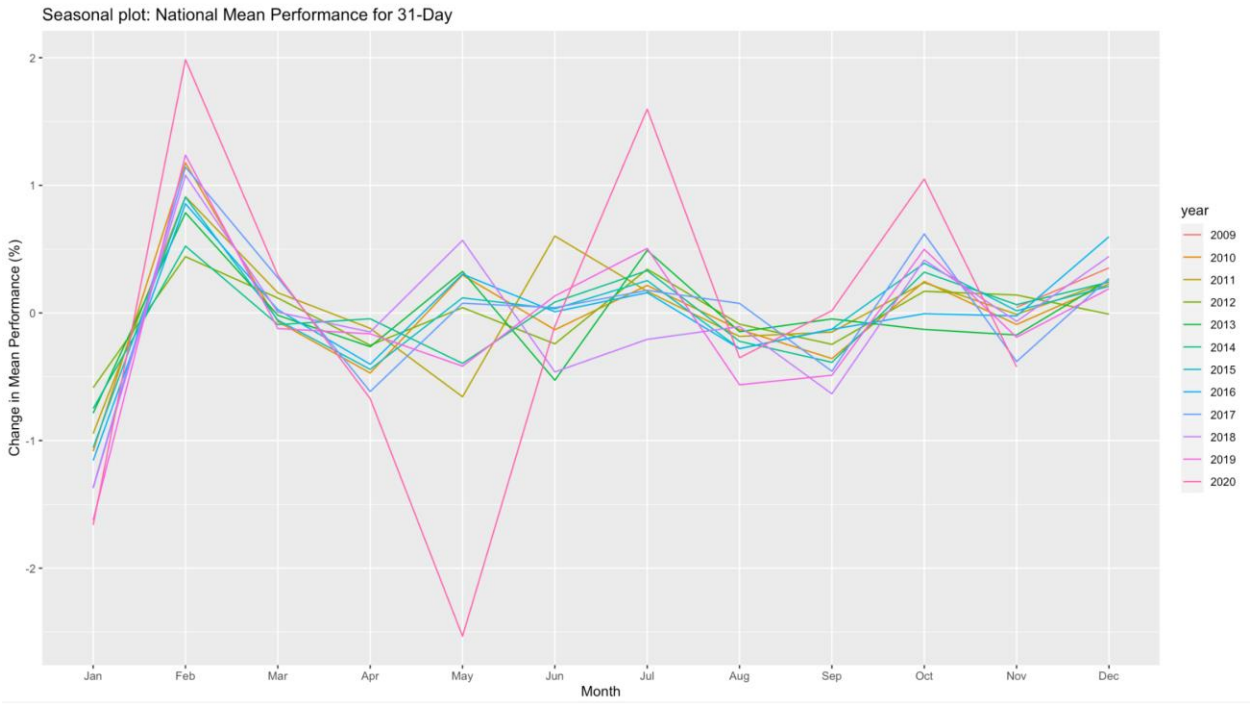
Appendix 6. Table of the chosen ARIMA model parameter along with the corresponding cross-validation root mean squared error (CV RMSE), residual RMSE, variance (sigma^2), Akaike's Information Criterion (AICc) and Bayesian Information Criterion (BIC) simplified to 2 d.p. The lower the analysis result, the better the fit of the model. The ARIMA model parameter is made up of the order (p, d, q) and seasonality (P, D, Q); where AR(p/P) is the order of the autoregressive polynomial, I(d/D) is a measure of how many non-seasonal differences are needed for stationarity of the data, and MA(q/Q) is the order of the moving average polynomial.

Target	ARIMA model	CV RMSE	Residual RMSE	Sigma^2	AICc	BIC
ALL CANCERS						
2WW	(0,1,1)(0,1,1)[12]	1.19	0.78	0.69	306.71	314.89
31 Days	(0,1,2)(0,1,1)[12]	0.45	0.30	0.10	75.80	86.64
62 Days	(2,1,1)(0,1,1)[12]	1.60	0.86	0.85	343.32	356.78
BREAST CANCER						
2WW	(0,1,1)(0,1,1)[12]	3.67	1.57	2.77	475.82	484.01
31 Days	(0,1,1)(0,1,1)[12]	1.05	0.80	0.71	307.35	315.54
62 Days	(0,1,2)(0,1,1)[12]	1.41	0.93	0.97	350.46	361.30
LOWER GASTROINTESTINAL CANCER						
2WW	(0,1,1)(0,1,1)[12]	1.76	1.15	1.50	408.21	416.39
31 Days	(0,1,1)(0,1,1)[12]	0.88	0.66	0.49	267.23	275.41
62 Days	(3,1,0)(0,1,1)[12]	4.79	2.65	8.02	617.48	630.94
LUNG CANCER						
2WW	(0,1,1)(0,1,1)[12]	0.79	0.62	0.43	258.06	266.24
31 Days	(0,1,1)(0,1,1)[12]	0.52	0.34	0.13	111.83	120.02
62 Days	(2,1,1)(0,1,1)[12]	3.69	2.33	6.23	584.10	597.56
UROLOGICAL CANCER						
2WW	(0,1,1)(0,1,1)[12]	1.17	0.88	0.86	338.40	346.58
31 Days	(0,1,4)(0,1,1)[12]	1.46	0.80	0.75	326.81	342.85
62 Days	(0,1,2)(0,1,1)[12]	3.69	1.90	4.11	526.84	537.68

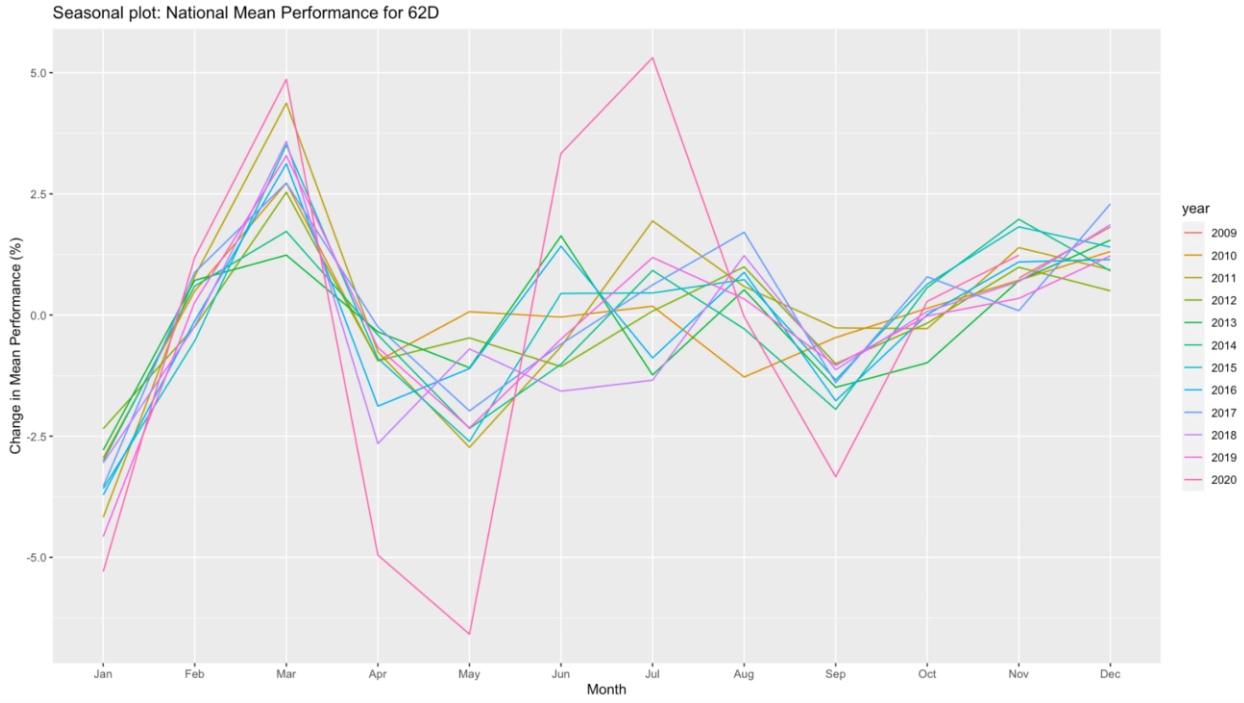
Appendix 7. Monthly percentage change in mean two week wait performance of all providers in England from October 2009 to November 2020. Each coloured line represents a different year. Each point represents the percentage increase or decrease in performance of a single month within a year, relative to the previous month. Trends are largely similar across years, with peaks in February, May, July and October and troughs in January, April, June, August and November.



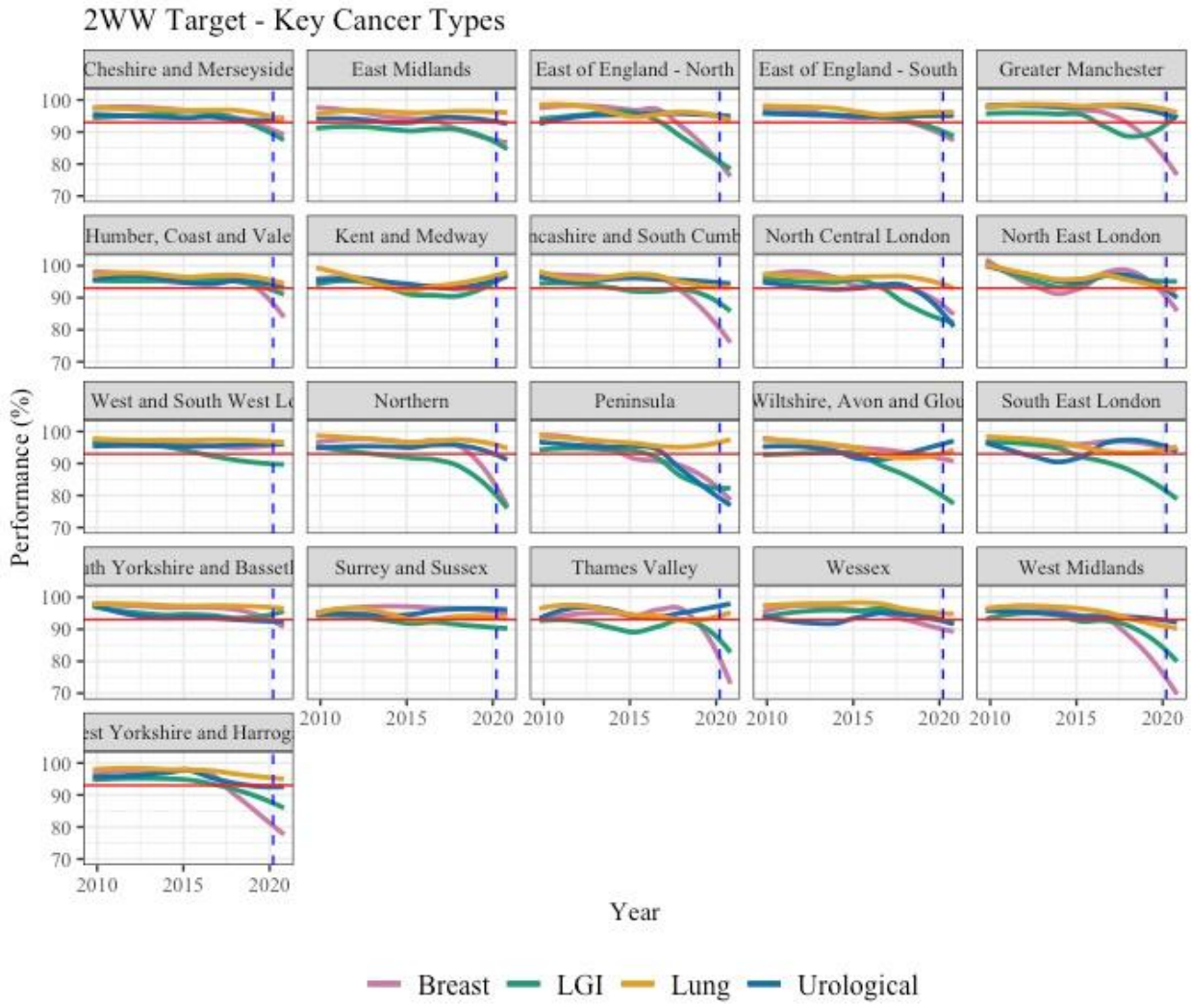
Appendix 8. Monthly percentage change in mean 31 day performance of all providers in England from October 2009 to November 2020. Each coloured line represents a different year. Each point represents the percentage increase or decrease in performance of a single month within a year, relative to the previous month. Trends are largely similar across years, with peaks in February, May, July, October and December and troughs in January, April, June, August and November.



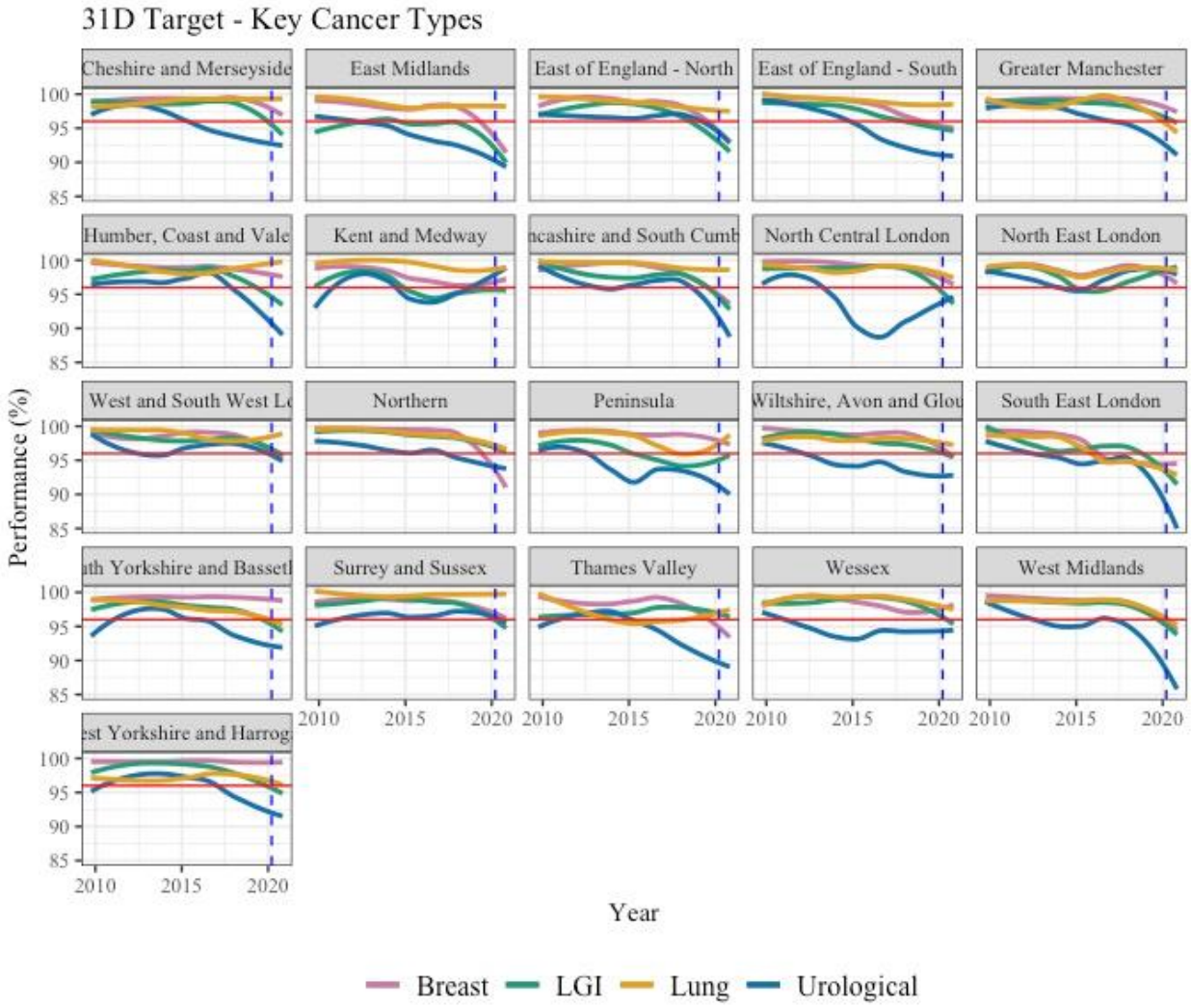
Appendix 9. Monthly percentage change in mean 62 day performance of all providers in England from October 2009 to November 2020. Each coloured line represents a different year. Each point represents the percentage increase or decrease in performance of a single month within a year, relative to the previous month. Trends are largely similar across years, with increases in February to a peak in March, followed by a trough in April. June and August see increases whilst July and September see decreases, with performance increasing month on month from September to December.



Appendix 10. Line plots of cancer alliance performance by cancer type – 2WW



Appendix 11. Line plots of cancer alliance performance by cancer type – 31D



Appendix 12. Line plots of cancer alliance performance by cancer type – 62D