3. Additional Results

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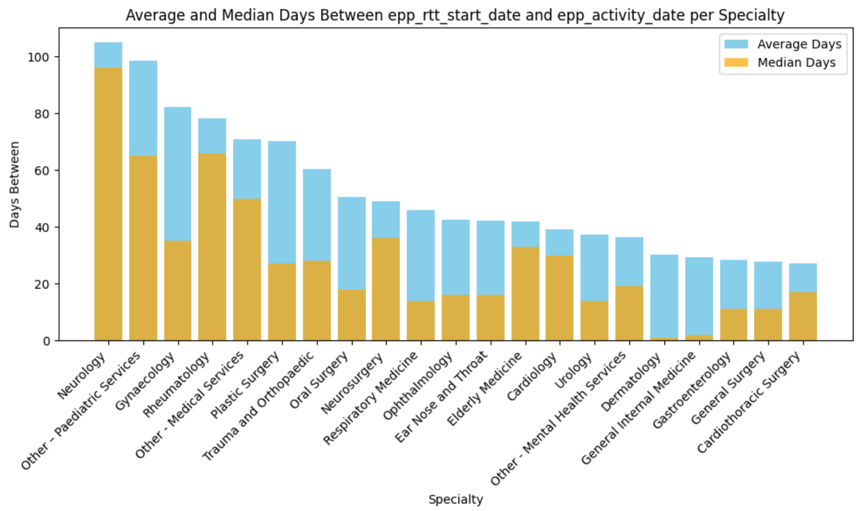
The waiting list data were linked with SUS events to derive Time to First Appointment (TFA), cancellation, and Did Not Attend (DNA) rates.

3.1 Time to First Outpatient Appointment

The waiting list data was linked with SUS events based on patient IDs, TFCs, and start and end dates. SUS activity was organized during the waiting period, and the first non-DNA outpatient appointments were selected to calculate the time between the start of the clock and the appointment. Figure 1 illustrates the average waiting time versus the median waiting time for each specialty.

Figure 1Time to First Outpatient Appointment



Neurology, paediatric services, and gynaecology have the longest waiting times, with average delays exceeding 80–100 days, while specialties like cardiothoracic surgery and general surgery experience significantly shorter waits (around 30 days). The noticeable gap between average and median values in some specialties (e.g., rheumatology and plastic surgery) suggests skewed distributions, influenced by a subset of patients experiencing extreme delays (see Table 1).

Table 1 Descriptive stats Waiting time per specialty

Specialty	Mean	Median	Std Dev	IQR
Cardiothoracic Surgery	27.0	17	41.0	21
Neurosurgery	49.0	36	58.0	70
General Internal Medicine	29.0	2	63.0	22
Trauma and Orthopaedic	60.0	28	93.0	58
Ear Nose and Throat	42.0	16	62.0	42
Rheumatology	78.0	66	72.0	140
Urology	37.0	14	58.0	29
Gynaecology	82.0	35	102.0	102

Ophthalmology	43.0	16	64.0	53
Neurology	105.0	96	77.0	135
Elderly Medicine	42.0	33	38.0	53
Other – Paediatric Services	99.0	65	94.0	133
Plastic Surgery	70.0	27	111.0	69
Dermatology	30.0	1	77.0	14
Cardiology	39.0	30	32.0	35
General Surgery	28.0	11	46.0	34
Respiratory Medicine	46.0	14	62.0	73
Oral Surgery	51.0	18	60.0	75
Gastroenterology	28.0	11	50.0	20
Other - Medical Services	71.0	50	77.0	69
Other - Mental Health Services	36.0	19	81.0	29

3.2 Cancelation and Do Not Attend

Figure 2 illustrates the percentages of Did Not Attend (DNA), patient-initiated cancellations, and hospital-initiated cancellations across various specialties. The blue bars show DNA percentages, which tend to be higher across most specialties compared to cancellation rates. Specialties such as Ophthalmology, Oral Surgery, and Urology have DNA rates of approximately 3-4% of pathways with a DNA coded event. The orange bars represent patient-initiated cancellations, which are generally low across most specialties. However, Other-Mental Health Services has an unusually high patient cancellation rate, nearing 10%, which is significantly higher than other specialties. The green bars depict hospital-initiated cancellations, which remain low and consistent across specialties, with only minor variations. For the majority of specialties, the percentage of hospital cancellations is higher than patient cancellations.

Figure 2 DNA and Cancelation per Specialty

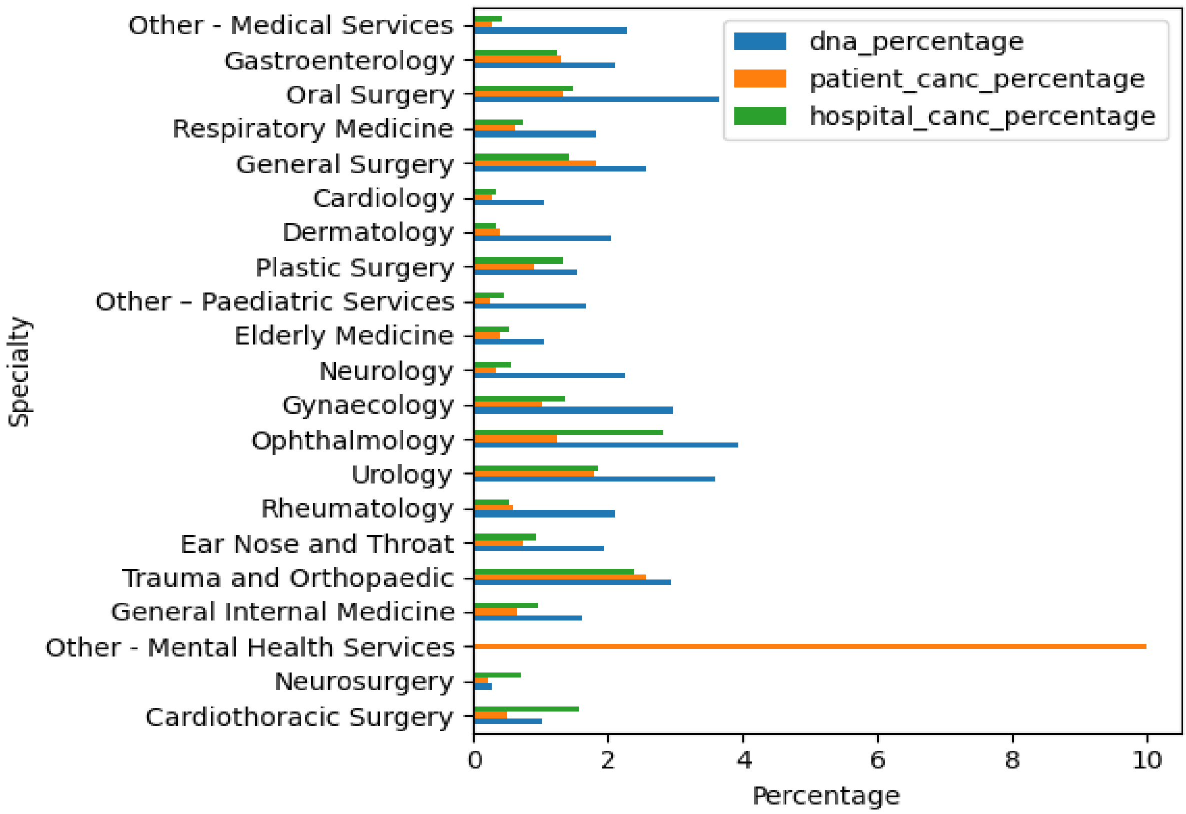


Figure 3 shows that specialties Gynaecology, Ophthalmology, Other-Medical Services, Trauma and Orthopedics and Urology have consistently show higher Do Not Attend (DNA) counts throughout the year. There is an observable increase in DNA counts during mid-to-late 2023 across multiple specialties, suggesting possible seasonal or operational influences like action strikes and weather condition (November 2023).

Figure 3 DNA Counts per Specialty

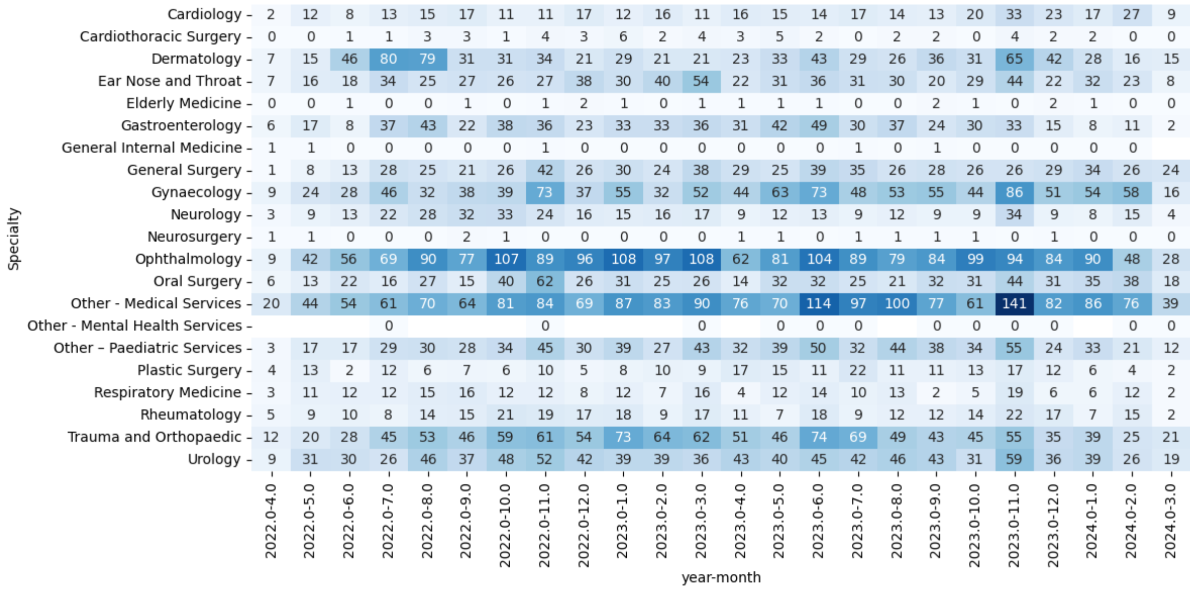


Figure 4 shows patient cancellations across various specialties from 2022 to 2024. Cardiology experienced fluctuating cancellation rates, peaking in the summer months of 2022 and 2023, and a sharp increase in 2024 in the early months. Dermatology cancellations were higher in the spring and summer months, particularly in 2023, where cancellations spiked in April and October. Gastroenterology showed substantial peaks, particularly in 2023, with a notable rise during the winter months. Gynaecology experienced a pattern of consistent cancellations across months, with a marked increase during summer. Trauma and Orthopaedic saw high cancellations throughout 2023, especially in June to August. Ophthalmology had a steady increase in cancellations over the years, with a significant rise in the summer months. Other specialties like Ear, Nose and Throat, General Surgery, and Plastic Surgery also had noticeable peaks during certain months, while specialties like Elderly Medicine and Neurosurgery showed relatively low and consistent cancellations. These patterns suggest that seasonal factors might contribute to patient cancellations, with notable peaks during summer and winter months across multiple specialties.

Figure 4 Patient Cancelation vs Specialty

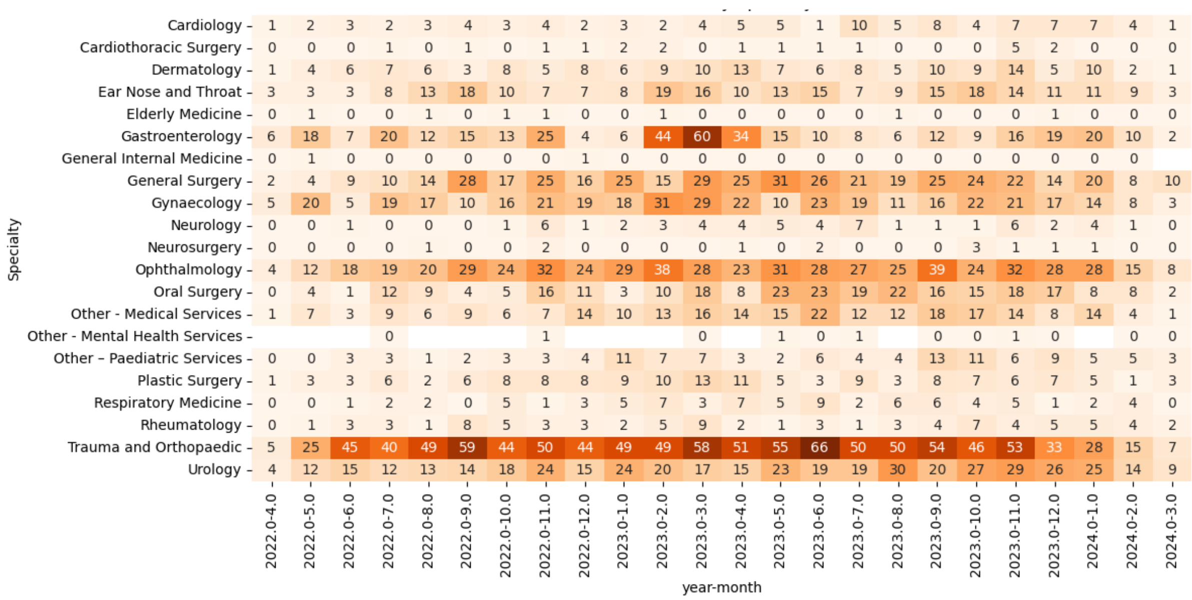


Figure 4 shows key trends in patient cancellations from 2022 to 2024. Gastroenterology, Ophthalmology, General Surgery, Gynecology, and Trauma and Orthopaedics have high cancellation rates, peaking in 2023. In contrast, Elderly Medicine, General Internal Medicine, and Neurosurgery have low and stable cancellation numbers, with some months showing none.

Figure 5 Hospital cancelation vs Specialty

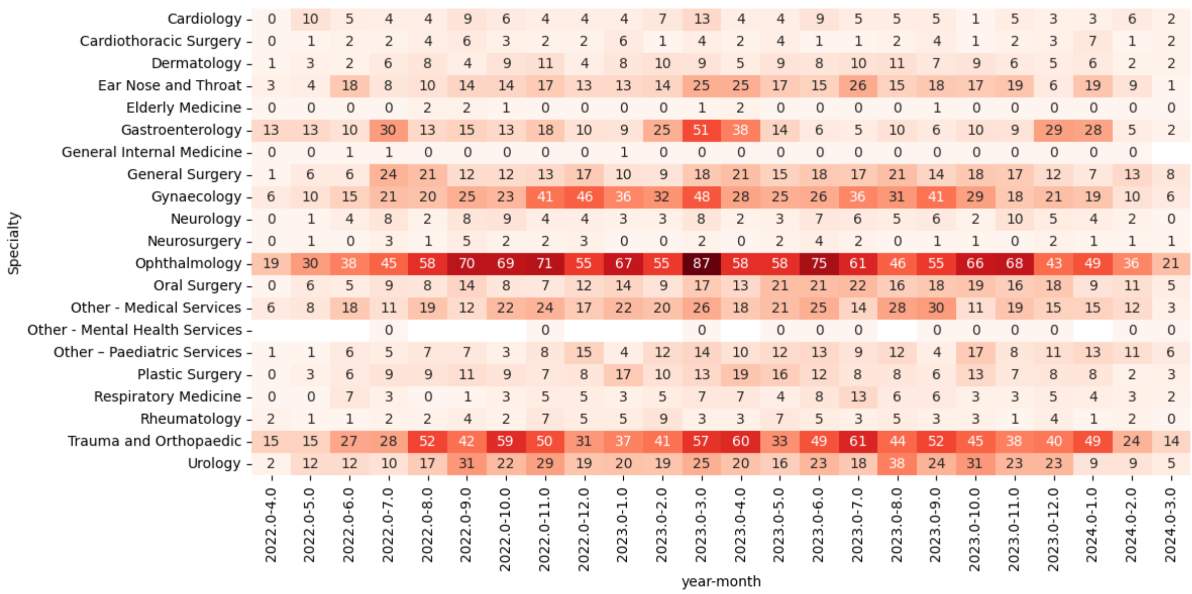


Figure 5 shows hospital cancellation counts. Ophthalmology and Trauma and Orthopaedic consistently accounted for the largest proportion of hospital cancellations, with sustained high volumes over multiple months. Cancellations were generally higher between mid-to-late 2022 and early 2023, with a noticeable decline after mid-2023 across most specialties. Other specialties such as Elderly Medicine, Mental Health Services, Neurology, and Cardiology showed minimal hospital cancellations throughout the period. It is consistent with above Figures and can be related to the fact that this speciality has the lowest count of patient waiting for treatment (see core analysis).

3.3 Deaths

Figure 6 shows death occurrences by specialty. General Internal Medicine has the highest rate at 1.19%, followed by Elderly Medicine (0.74%) and Respiratory Medicine (0.66%). Urology's death rate is 0.52%, Ophthalmology is 0.29%, Other - Medical Services is 0.39%, and Cardiothoracic Surgery is 0.34%. The lowest rates are in Oral Surgery, Gynaecology, and Other – Paediatric Services at 0.02%. High death rates are seen in General Internal Medicine, Elderly Medicine, and Respiratory Medicine, while much lower rates occur in Gynaecology, Oral Surgery, and Paediatrics. Core Analysis indicates that General Internal Medicine and Elderly Medicine have the highest rates of seeing patients within the target of 18 weeks, suggesting prioritization due to the likelihood of death events in these specialties.

Figure 6 Death Percentage per Specialty

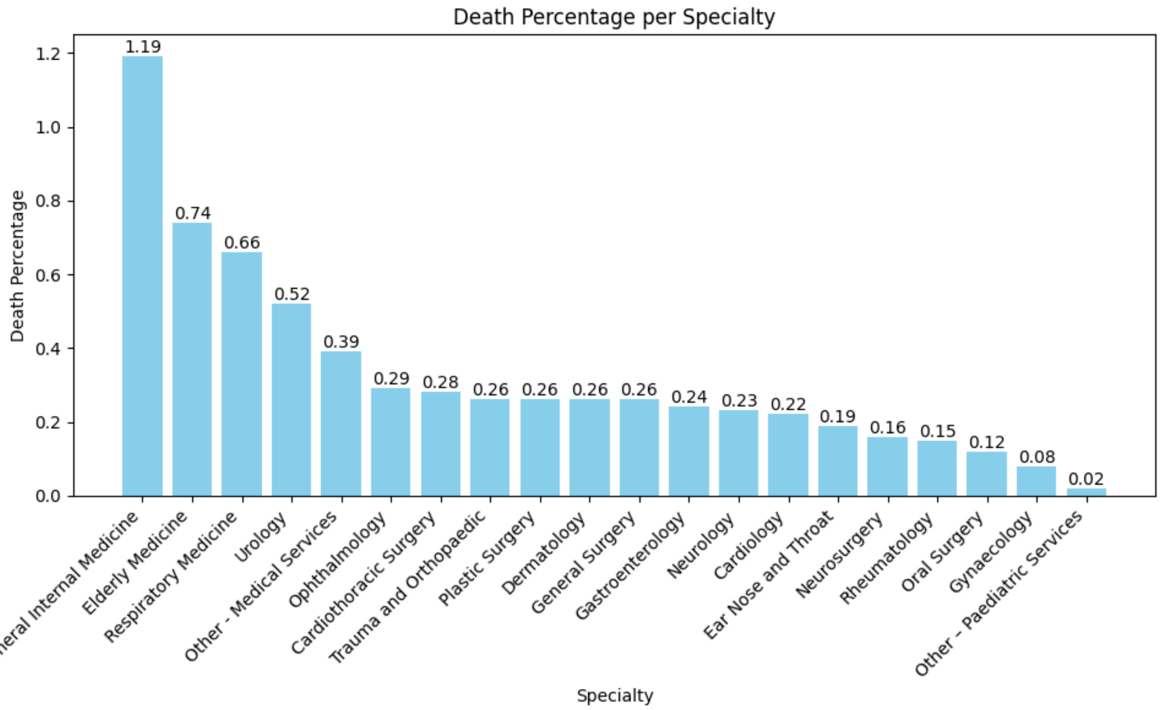
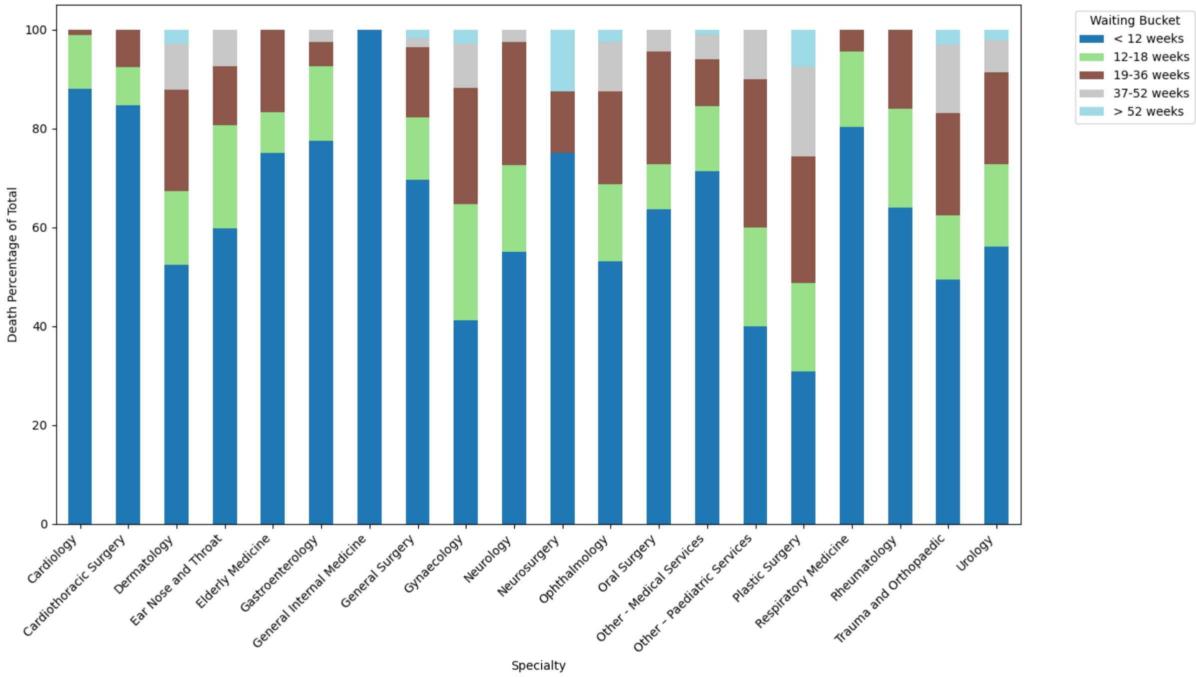


Figure 7 illustrates the distribution of early deaths across various specialties. The highest proportion of deaths occurs within the < 12 weeks waiting period (dark blue), suggesting that many deaths happen early in the waiting period, possibly due to severity or urgent conditions. Specialties such as Cardiology, Neurosurgery, and Cardiothoracic Surgery show a concentration of deaths predominantly within the < 12 weeks bucket, indicating these areas may handle more critical or time-sensitive cases. Other specialties, like Gastroenterology, General Surgery, and Respiratory Medicine, display a relatively higher proportion of deaths in the 12-18 weeks and 19-36 weeks buckets. Plastic Surgery and Respiratory Medicine have a greater distribution of deaths over longer waiting times, with a notable percentage occurring in the 37-52 weeks and > 52 weeks buckets. The proportion of deaths occurring > 52 weeks (light blue) is minimal across all specialties, suggesting that extremely long waits are not a significant factor in death percentages.

Figure 7 Death Percentage of Total per waiting Group



Specialty	Mean Time to Death	Median Time to Death	Std. Dev. Time to Death	Min Time to Death	Max Time to Death
Cardiology	42.8	37.0	32.2	1	153
Cardiothoracic Surgery	57.3	54.0	33.7	24	146
Dermatology	114.4	80.0	102.1	3	466
Ear Nose and Throat	83.9	65.0	72.6	8	308
Elderly Medicine	62.0	43.0	57.7	13	190
Gastroenterology	60.5	44.0	59.1	3	333
General Internal Medicine	41.6	38.0	10.9	33	54
General Surgery	82.0	67.5	76.0	2	421
Gynaecology	124.1	99.0	93.9	11	416
Neurology	91.0	74.5	70.6	5	276
Neurosurgery	83.6	25.5	126.0	2	370
Ophthalmology	109.9	75.0	93.2	2	421
Oral Surgery	100.1	68.0	85.3	11	278
Other - Medical Services	78.1	49.5	79.62	2	434

Figure 8 shows the percentage of pathways with deaths across different specialties, categorized by referral priority. Other - Medical Services (cancer) has the highest percentage of pathways with deaths at 2.65%, followed by Respiratory Medicine (cancer) at 1.82% and Cardiology (cancer) at 1.47%. In terms of urgent referrals, General Internal Medicine has 1.19%, and Urology has 0.97% for cancer-related deaths. Several other specialties, such as Ophthalmology (routine), Dermatology (urgent), and Plastic Surgery (routine), have lower death rates of around 0.2% to 0.4%. Among specialties with routine referrals, Ophthalmology (routine) stands out with a death rate of 0.39%, while Other – Paediatric Services has the lowest death rate at just 0.02% for routine referrals.

Time to Death

The time to death per specialty was presented in Table 2 acute conditions: Cardiology, General Internal Medicine, and Respiratory Medicine have the shortest time to death. Chronic and Elective Care: Gynaecology, Plastic Surgery, and Paediatric Services show longer survival durations. High Variability: Neurosurgery and Dermatology exhibit extreme variability in time to death.

Table 2 Descriptive Statistics for the Time to Death

Specialty	Mean Time to Death	Median Time to Death	Std. Dev. Time to Death	Min Time to Death	Max Time to Death
Cardiology	42.8	37.0	32.2	1	153
Cardiothoracic Surgery	57.3	54.0	33.7	24	146
Dermatology	114.4	80.0	102.1	3	466
Ear Nose and Throat	83.9	65.0	72.6	8	308
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General Internal Medicine	41.6	38.0	10.9	33	54
General Surgery	82.0	67.5	76.0	2	421
Gynaecology	124.1	99.0	93.9	11	416
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Oral Surgery	100.1	68.0	85.3	11	278
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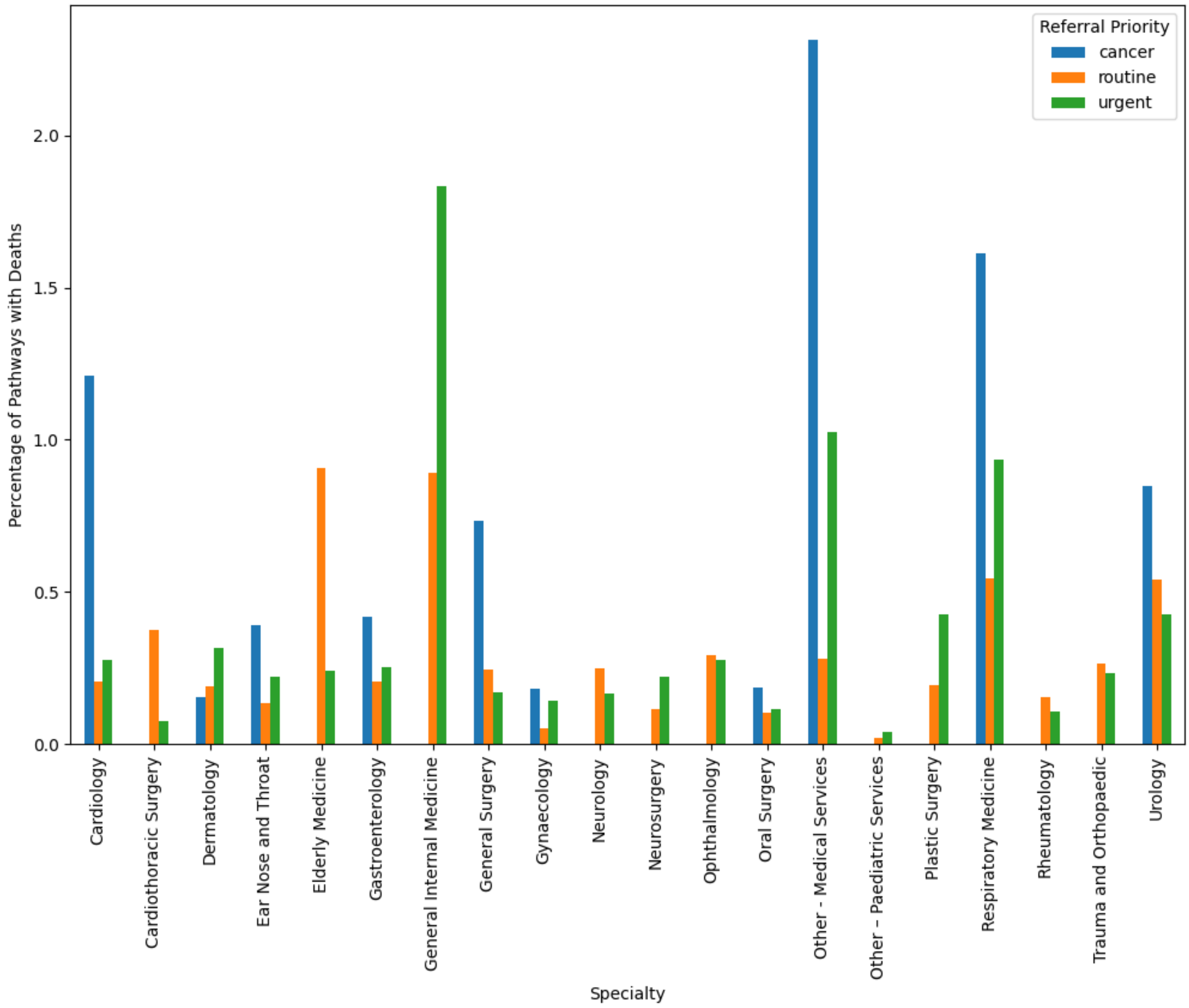
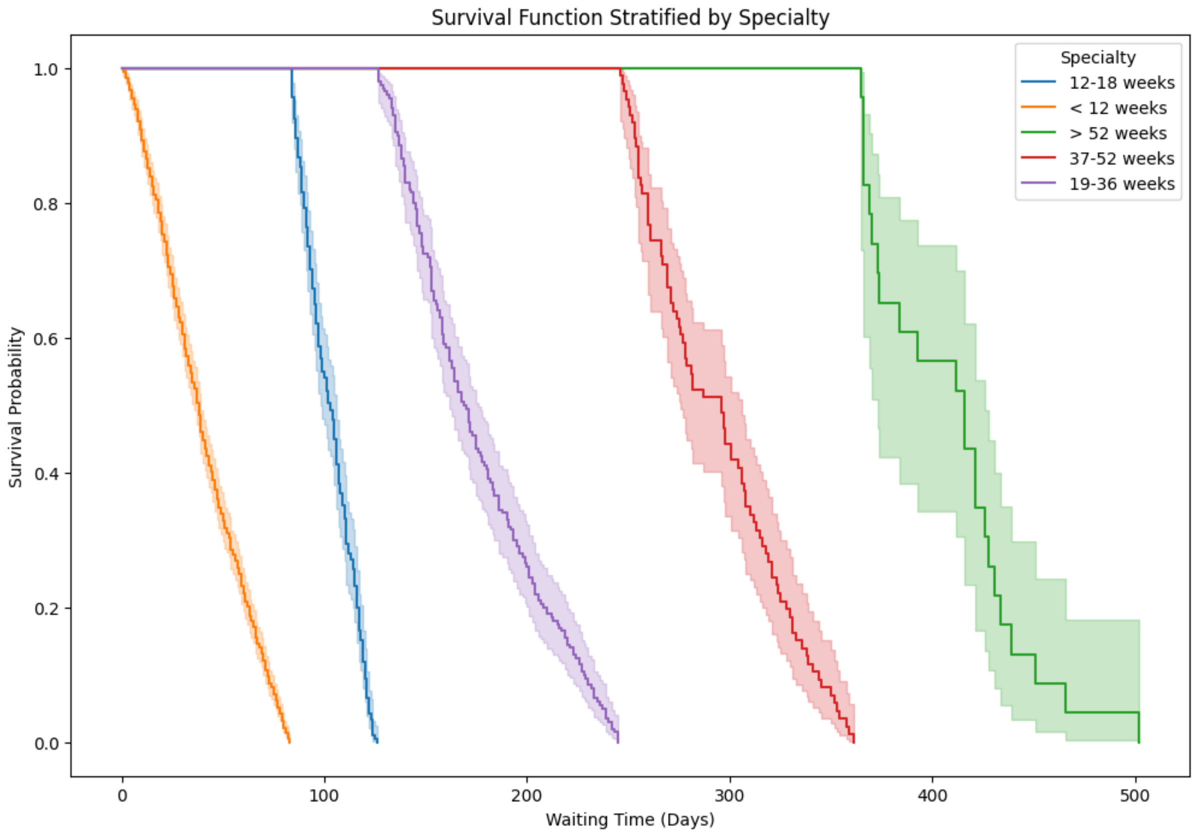
Figure 8 Percentage of Pathways with death vs Specialty



Kaplan-Meier survival analysis stratified by pre-treatment waiting time (Figure 9) indicated an association between waiting duration and patient survival. Patients with shorter waiting times, less than 12 weeks and 12-18 weeks, showed a steeper decline in survival probability, indicating a higher hazard rate compared to those with longer waiting periods. Patients with waiting times exceeding 52 weeks exhibited the most favorable survival outcomes, with a sustained high survival probability over the observed period. Intermediate waiting times (19-36 weeks and 37-52 weeks) demonstrated moderate survival patterns. These results suggest that pre-treatment waiting time is an important prognostic factor, possibly reflecting disease severity, treatment prioritization, or selection bias. Further investigation is needed to clarify the causal mechanisms and address potential confounding variables, ensuring accurate clinical interpretation and informing effective patient management strategies.

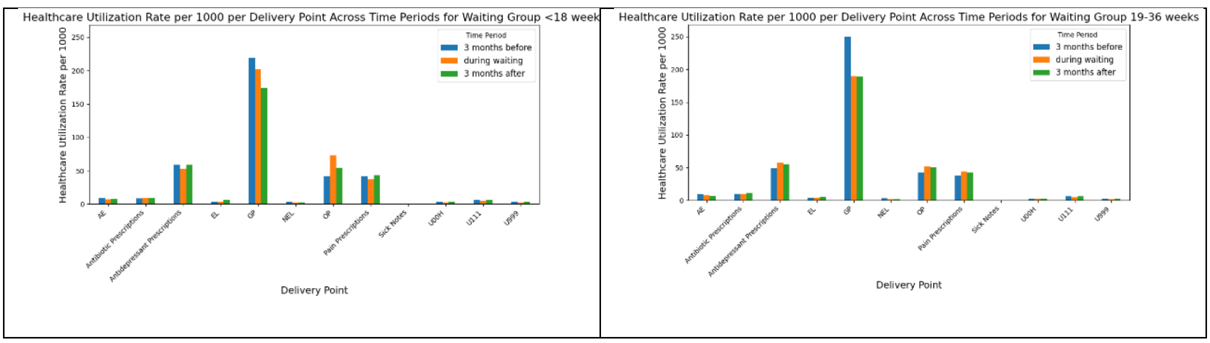
Figure 9 Survival stratified by waiting time

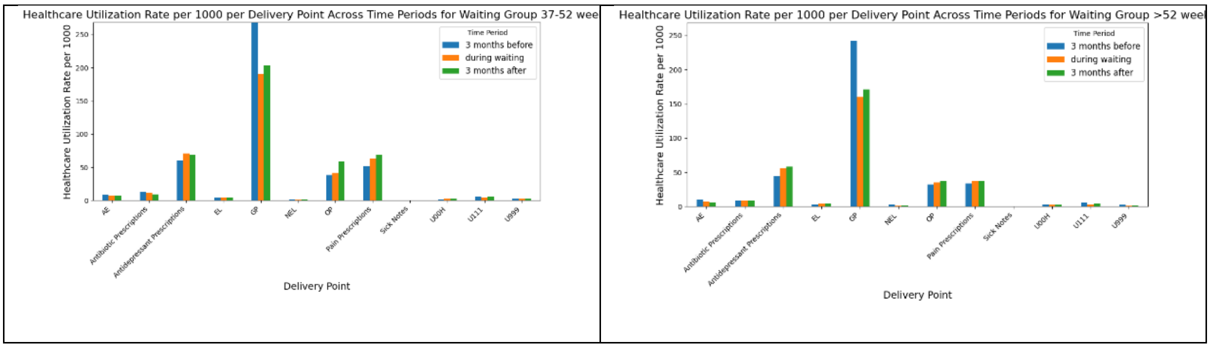


3.4 Gynaecology - DID

Core analysis of Cohort 3 was used to understand gynecology patients, their waiting times, and healthcare utilization. Figure 10 shows healthcare utilization per 100 person-weeks by delivery point. AE and GP rates are higher before the waiting period starts. GP and OP contacts have increased during the waiting time for those waiting less than 18 weeks. For those waiting longer than 18 weeks, pain killers and antidepressants show higher utilization compared to the pre- and post-waiting periods.

Figure 10 Healthcare utilization per 1000 person- week per delivery point





Difference in Differences

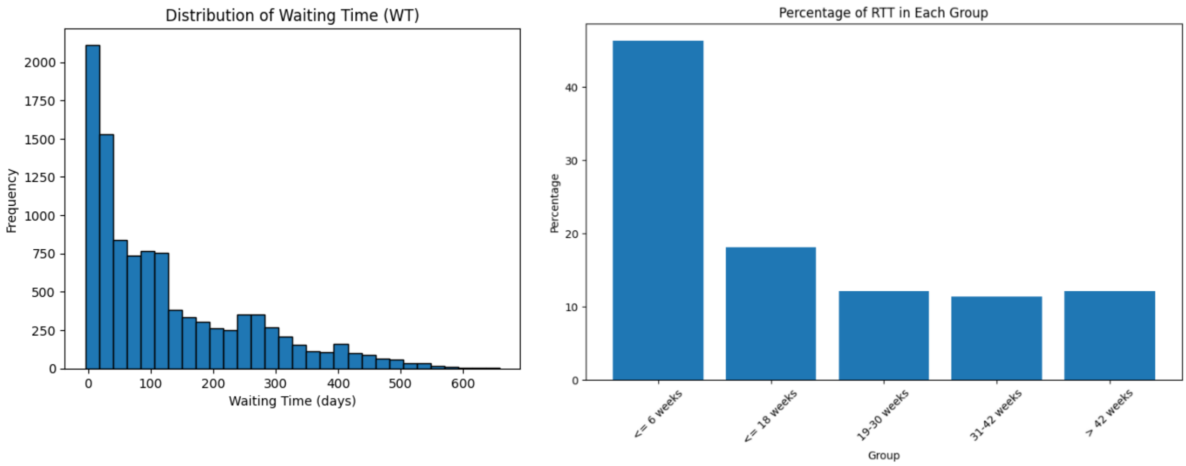
There were 10401 pathways identified during the study period, with the provided treatment (see Table 3). Among the remaining cases, half were treated as urgent cases (≤ 6 weeks), around 43% of patients. The group of patients waiting longer than 42 weeks accounted for 12) (see Figure 11).

Table 3 Distribution of wait lengths for Genealogy

Total	**0-3 weeks**		**4-6 weeks**		**7-9 weeks**		**10-12 weeks**		**13-15 weeks**		**16-18 weeks**		**19-21 weeks**		**22-24 weeks**		**25-27 weeks**	
n	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
10401	2481	23.85	1320	12.69	725	6.97	693	6.66	727	6.99	760	7.31	372	3.58	321	3.09	300	2.88
	28-30 weeks		**31-33 weeks**		**34-36 weeks**		**37-39 weeks**		**40-42 weeks**		**43-45 weeks**		**46-48 weeks**		**49-51 weeks**		**52+ weeks**	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
	261	2.51	215	2.07	330	3.17	319	3.07	313	3.01	222	2.13	171	1.64	124	1.19	747	7.17

The urgent cases were removed from dataset, there were 10 deaths during the waiting time, 3 in group <- 18 weeks and 6 on 31-42 weeks and 1 in group waiting > 42 weeks. Next, the pathways with no follow up period, were filter out, resulting with remaining final 3709 pathways.

Figure 11 Distribution of the waiting time and pathway percentage in each of waiting group for hysteroscopy.



Patient Characteristics

Table **4.3_gynea_all** (Additional Supplementary Material) shows disparities across different demographic and clinical groups. Patients aged 25-34 years have the highest proportion of ≤18 weeks waiters (53.24%), but their share reduces significantly with increasing wait times (9.23% after 43+ weeks). Patients aged 65+ show a different trend, where the likelihood of waiting >31 weeks rises dramatically: 38.38% of 65-74 years and 42.23% of 75-84 years wait 31-42 weeks. For those 84+ years, 43.33% wait 31-42 weeks, indicating prolonged waiting for older adults.

Lower IMD quintiles (1 and 2 – more deprived) have higher proportions of longer waiters. IMD 1: 14.09% wait > 43 weeks. IMD 2: 13.1% wait > 43 weeks. Lower proportions of long waiters (~11.8%) are seen in less deprived groups.

The largest proportion of patients across all waiting groups are from a white background (36.98% ≤ 18 weeks, decreasing to 13.15% for 43+ weeks). Black Background: 14.29% of patients from black backgrounds wait > 43 weeks, higher than most groups. Asian Background: 27.86% wait 31-42 weeks, indicating delays in receiving care.

A higher proportion of fit patients receive care ≤ 18 weeks (42.33%), but this drops steadily with longer waits (12% for 43+ weeks). Moderate Frailty: 42.05% wait 31-42 weeks. Severe Frailty: 25% of severe frail patients wait > 43 weeks, suggesting that more complex patients experience delays.

Patients with no LTCs tend to receive care faster, with 44.87% seen ≤ 18 weeks, dropping to 10.58% for 43+ weeks. Patients with multimorbidities experience delays, with 33.37% waiting 31-42 weeks and 16.5% waiting > 43 weeks.

Overall, Older and frailer patients face prolonged waits, potentially reflecting prioritization challenges for complex cases. Higher deprivation groups (IMD 1-2) are disproportionately represented among longer waiters, pointing to access inequalities. Ethnic minority groups, particularly black and Asian patients, are overrepresented among longer waiting times, highlighting potential disparities. Patients with multimorbidities experience significantly longer wait times, reflecting care complexity and resource limitations.

Difference-in Differences

A Difference-in-Differences (DiD) model (see **Table_4.1_Table_4.2_gynea_all Supplementary Materials**) was applied to analyse changes in healthcare utilization across different waiting time bands (19-30 weeks, 31-42 weeks, and >42 weeks) for a cohort of 1830 control and 123, 1134 and 622 intervention patients. The analysis focused on various healthcare categories, including General Practitioner (GP) visits, Out-of-Hours (UOoH) services, Accident & Emergency (AE) attendance, outpatient (OP) appointments, prescriptions, and elective and non-elective admissions (EL and NEL). Associated costs for each service were also evaluated to assess excess utilization.

General Practitioner (GP) utilization showed minimal differences between control and intervention groups. The DiD estimator revealed no statistically significant excess utilization across waiting periods, with point estimates close to zero (e.g., 19-30 weeks: -0.025, p = 0.83). Similarly, GP costs did not show significant changes, although a moderate positive excess was noted for >42-week waiters (DiD = 2.68, p = 0.68). Out-of-Hours (UOoH) services and NHS 111 (U111) contacts exhibited negligible changes across all waiting bands, with no statistically significant deviations from baseline utilization.

Accident & Emergency (AE) attendance showed mixed results. While utilization differences were not statistically significant, AE costs revealed a notable negative trend in the >42-week group, with a DiD estimate of -10.99 (p = 0.11), suggesting lower costs post-intervention. Similarly, non-elective (NEl) admissions exhibited a slight reduction in utilization, particularly in the >42-week group, where a statistically significant decline was noted (DiD = -0.0336, p = 0.03), indicating a modest decrease in admissions. Elective (EL) admissions and costs showed no substantial changes across any of the waiting time bands, with DiD estimates remaining statistically insignificant.

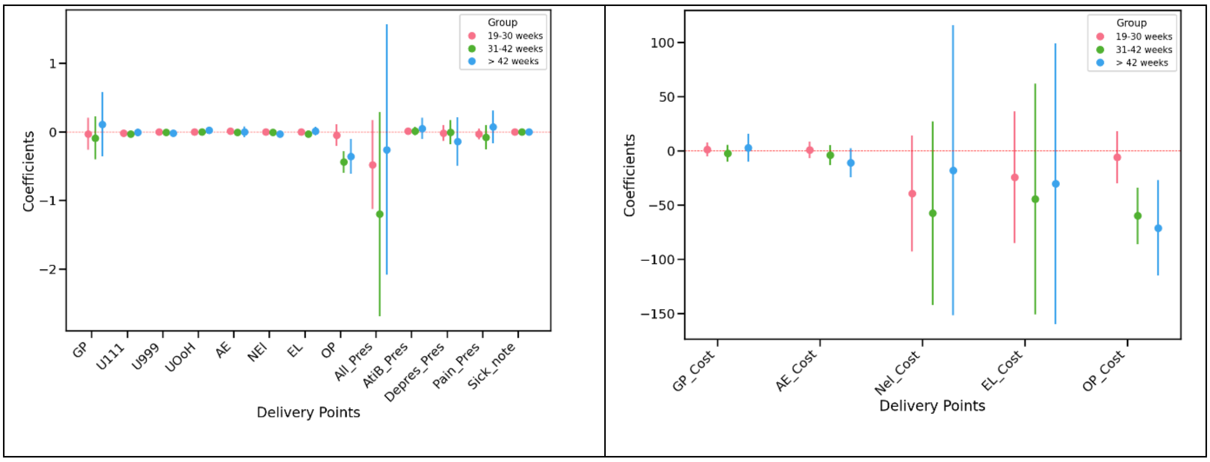
Outpatient (OP) utilization and costs demonstrated the most pronounced trends. OP utilization significantly declined in the 31-42 and >42-week groups (DiD = -0.44, p < 0.001 and DiD = -0.36, p = 0.007, respectively). OP costs exhibited a notable reduction, with a large negative DiD estimate in the >42-week group (DiD = -71.12, p = 0.001), suggesting reduced spending on outpatient services after extended waits.

Prescription patterns (total, antibiotics, antidepressants, and pain medications) showed marginal differences, with no statistically significant changes in most categories. However, all prescriptions combined indicated a slight decline in utilization, particularly in the 31-42 week group (DiD = -1.20, p = 0.11). Antibiotic prescriptions showed no substantial change, while pain prescriptions exhibited a slight increase in the >42-week group (DiD = 0.07, p = 0.59), though the effect was not statistically significant.

Sick notes showed minimal differences between the control and intervention groups, with insignificant DiD estimates across all time periods. Costs associated with all service categories generally followed a downward trend in the intervention groups across extended wait periods, with OP and AE costs contributing the most to this decline.

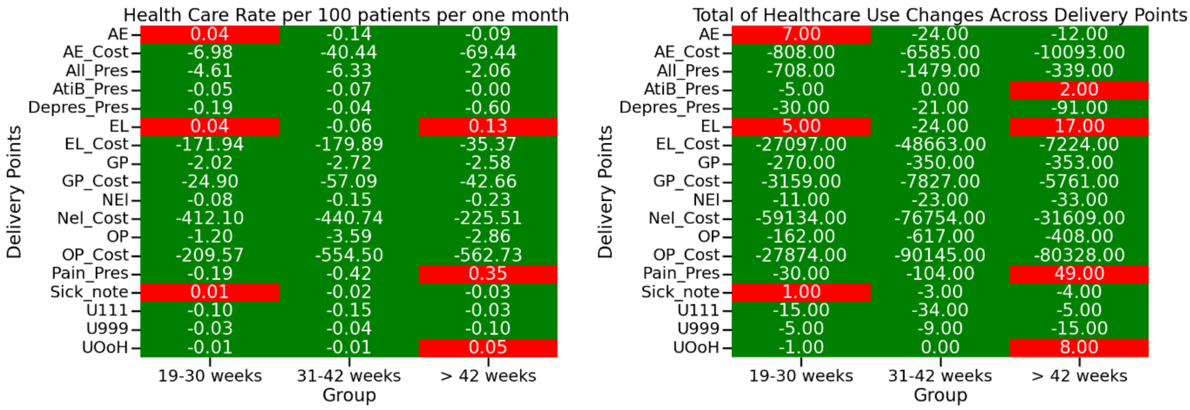
In conclusion, the DiD analysis highlights significant reductions in outpatient utilization and costs for longer waiters (>42 weeks), while non-elective admissions and associated costs also showed a statistically significant decline. Minimal changes were observed in GP utilization, emergency contacts, and prescription patterns, suggesting that longer wait times may primarily affect outpatient and acute care resource utilization rather than primary or emergency care services. Figure 12 shows the DID estimates with the standard errors.

Figure 12 Coefficients of Features w/ 95% Confidence Intervals for hysteroscopy



The analysis of healthcare utilization (see Figure 13) shows the total excess on the right and 100 person-months on the left. The significant aspects include AE admissions and pain prescriptions, both indicating an increased trend. Both plots reinforce the trend, demonstrating a consistent pattern of decreased healthcare utilization rates with longer waiting times. This decrease could be due to various factors such as prioritization of patients with the highest needs for immediate treatment, leaving those who do not require frequent health care to wait longer, seeking alternative care options, or improvement in symptoms during the waiting period. Additionally, the increase in pain prescription rates in the "> 42 weeks" group suggests that patients waiting longer may experience more pain-related issues.

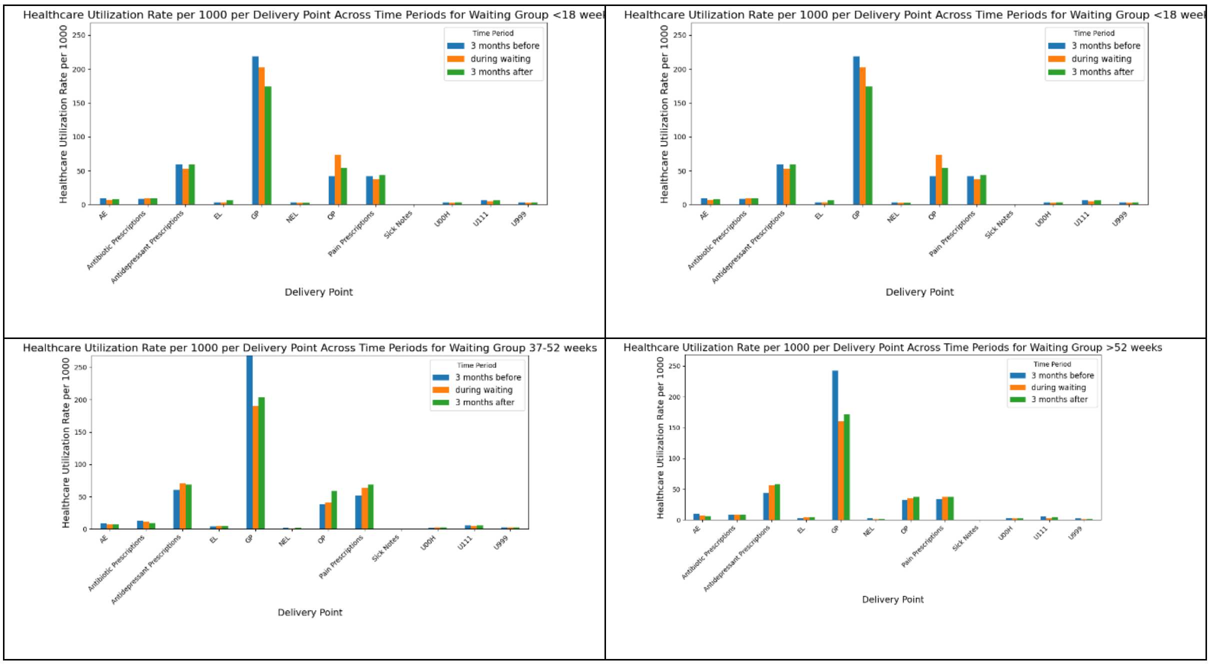
Figure 13 Excess of the healthcare use(left) per 100 patients per month, (right) total excess for hysteroscopy



3.3 Trauma and Orthopaedics - DID

Core analysis of Cohort 3 has been used to understand gynecology patients, their waiting times, and healthcare utilization. Figure 14 shows healthcare utilization per 100 person-weeks by delivery point. AE and GP rates are higher before the waiting period starts. GP and OP contacts have increased during the waiting time for those waiting less than 18 weeks. For those waiting longer than 18 weeks, pain killers and antidepressants show higher utilization compared to the pre-waiting periods, and the rate remaining higher for post- waiting period.

Figure 14 Healthcare Utilization per 1000 person- week per delivery point



Difference in Differences

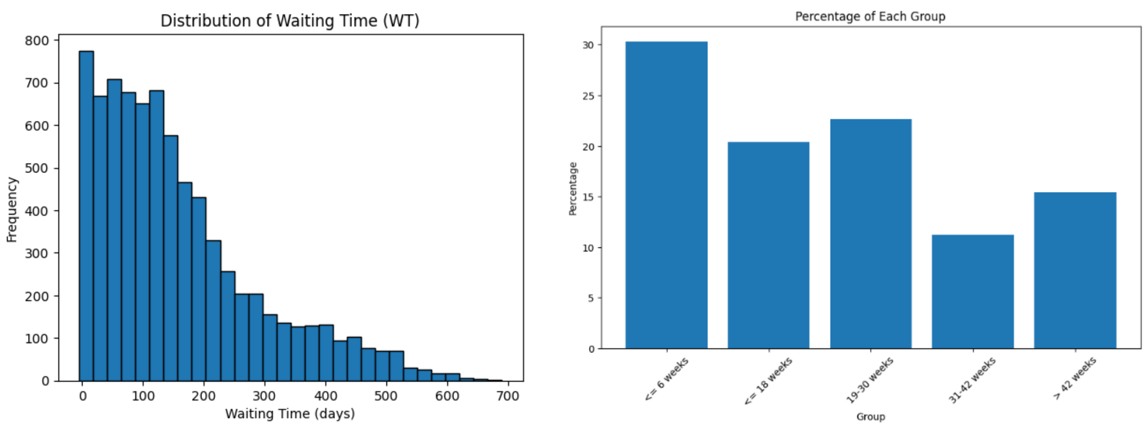
There were 7839 pathways identified during the study period, with the provided treatment (see Table 4). The cancer-related pathways and the short waiters (< 6 weeks) 30% were removed from the dataset (see Figure 15).

Table 4 Distribution of wait lengths for Trauma and Orthopedics

Total	**0-3 weeks**		**4-6 weeks**		**7-9 weeks**		**10-12 weeks**		**13-15 weeks**		**16-18 weeks**		**19-21 weeks**		**22-24 weeks**		**25-27 weeks**	
n	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
7839	866	*11.05*	*631*	*8.05*	*643*	*8.2*	*609*	*7.77*	*626*	*7.98*	*606*	*7.73*	*546*	*6.96*	*466*	*5.94*	*402*	5.13
	28-30 weeks		**31-33 weeks**		**34-36 weeks**		**37-39 weeks**		**40-42 weeks**		**43-45 weeks**		**46-48 weeks**		**49-51 weeks**		**52+ weeks**	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
	360	*4.59*	*281*	3.58	*234*	*2.98*	*188*	*2.4*	*172*	*2.19*	144	*1.84*	*121*	*1.54*	*126*	*1.61*	*8.18*	10.43

There were 18 deaths during the waiting time, five in group <- 18 weeks three in 19-30 weeks, five in 31-42 weeks and five for > 42 weeks group. Next, the pathways with no follow up period, were filter out, resulting with remaining final 4807 pathways.

Figure 15 Distribution of the waiting time and pathway percentage in each of waiting group for hysteroscopy.



Patient Characteristics

Table 4.3_trauma_all (Additional Supplementary Material) presents a comparison across different demographic and clinical groups. Males and females exhibit similar waiting time patterns, with slightly more females (13.28%) waiting over 43+ weeks compared to males (11.52%), both sexes having the highest proportion in the 19-30 weeks group (~36%).

The youngest group (11-17 years) shows the highest proportion in the 19-30 weeks group (55.1%), with very few waiting 43+ weeks. The age groups of 18-24, 25-34, and 35-44 follow similar patterns with 19-30 weeks being the dominant group (~33-38%). Older age bands (75-84 and 84+) may have a higher likelihood of waiting longer, with 14.91% of 75-84-year-olds and 10.66% of those aged 84+ waiting 43+ weeks.

Deprivation correlates with longer waits, showing higher proportions in the 19–30-week category across all quintiles (~34-39%). Quintile 1 (most deprived) has the highest proportion of 43+ week waiters (14.71%), followed by Quintile 4 (11.75%). Quintile 5 (least deprived) shows a lower proportion of 43+ week waiters (11.09%).

Individuals from an Asian background have the highest proportion of <=18 week waiters (41.42%), with fewer waiting 43+ weeks (8.88%). Individuals from a Black background have a higher proportion of 43+ week waiters (16.39%) compared to other groups. Those from a Mixed background have a small sample size but show a higher proportion of <=18 week waiters (38.46%) and notable percentages in the 31-42 weeks group. The White background group is most evenly distributed across wait times, with 37.54% in 19-30 weeks and 12.41% in 43+ weeks.

Fit individuals predominantly wait 19-30 weeks (37.38%) with fewer waiting 43+ weeks (11.29%). Those with mild and moderate frailty have higher proportions in the 19-30 weeks group (~38%) with increased likelihood of longer waits. Individuals with severe frailty have a lower proportion waiting 43+ weeks (9.59%), suggesting prioritization. Those with unknown frailty have a higher likelihood of longer waiting times, with 21.32% in the 31-42 weeks category.

Individuals with no long-term conditions (LTCs) and single LTCs show a similar distribution, with a higher percentage waiting 19-30 weeks (~36%) and fewer waiting 43+ weeks (~11%). Those with comorbidities and multimorbidities have a higher likelihood of longer waits, with 13.81% of multimorbid individuals waiting 43+ weeks, compared to 12.31% of those with comorbidities.

Overall, those waiting <=18 weeks include less deprived, fit individuals, and those with no/mild frailty or no LTCs. The 19-30 Weeks group forms the largest category across all demographics, particularly middle-aged adults, those with comorbidities, and moderate frailty. The 31-42 Weeks group has a higher proportion of unknown characteristics, multimorbidities, and those from deprived populations.

Difference-in Differences

A Difference-in-Differences (DiD) model (see **Table_4.1_Table_4.2_trauma_all** Additional Supplementary Materials) was applied to analyse changes in healthcare utilization across different waiting time bands (19-30 weeks, 31-42 weeks, and >42 weeks) with target (< 18 weeks).

The results show a mixed trend in GP contacts. In the 19–30 weeks group, there was a slight decline in GP contacts, with an excess change of -0.08 (p = 0.44), suggesting a minimal reduction in primary care consultations. However, for the 31–42 weeks group, there was a moderate increase (+0.30, p = 0.06), while the >42 weeks group recorded a notable increase (+0.54, p = 0.03), indicating higher engagement with primary care for those experiencing longer waits.

For AE visits, there is a minimal increase in healthcare use, as reflected by the DiD estimators being positive but small (e.g., 0.0443 in the >42-week period), with only modest statistical significance (p-value = 0.2036). This indicates that, while the intervention may have contributed to a slight rise in AE visits, the effect is not conclusive. Similarly, outpatient (OP) visits show some fluctuations, with a significant positive change in the 19–30-week period (DiD estimator = 0.1295, p-value = 0.039), but this effect does not persist in later periods.

The medication prescription data reveal mixed trends as well. For antibiotics (AtiB_Pres), there is a slight increase in prescriptions in the 31-42 and > 42 week periods, with DiD estimators of 0.0666 and 0.0406, respectively, but these effects are only modestly significant. In contrast, prescriptions for depression (Depres_Pres) and pain (Pain_Pres) show less variation. Pain prescriptions, for example, exhibit positive DiD estimators in the > 42 week period, indicating an increase in usage, with a DiD estimator of 0.3308 (p-value = 0.0592), although not fully reaching statistical significance at the 0.05 level.

Healthcare costs across various services tend to show more consistent increases, with AE-related costs, for example, showing significant positive DiD estimators in the >42 week period (DiD estimator = 3.0843, p-value = 0.6908). Other service categories, such as EL and NEl costs, show similar trends with large increases in the later periods, particularly with DiD estimators of 46.9727 for EL costs in the 19-30 week period, suggesting a strong intervention impact on healthcare spending.

Figure 16 Coefficients of Features w/ 95% Confidence Intervals for hysteroscopy

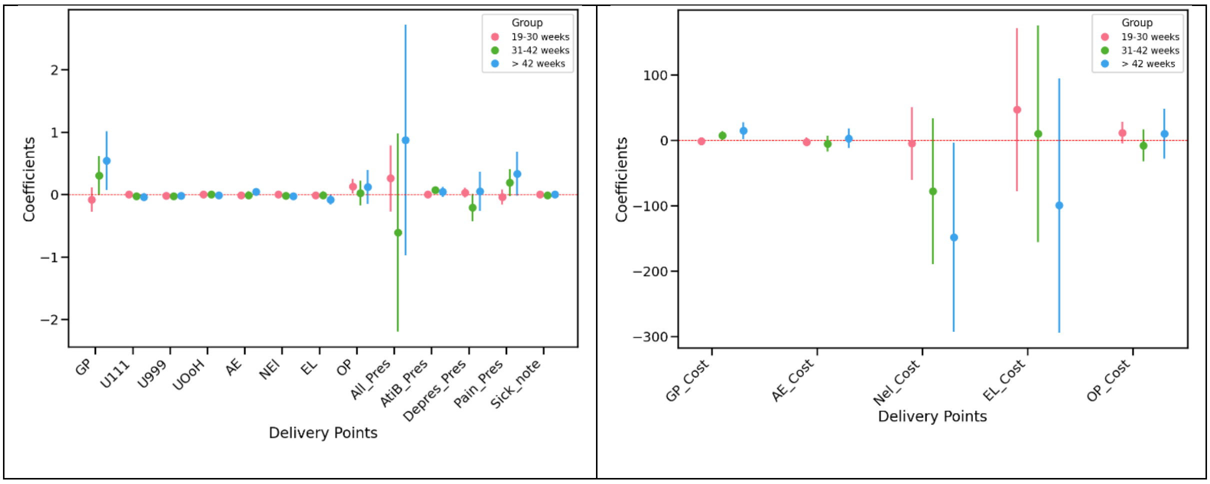
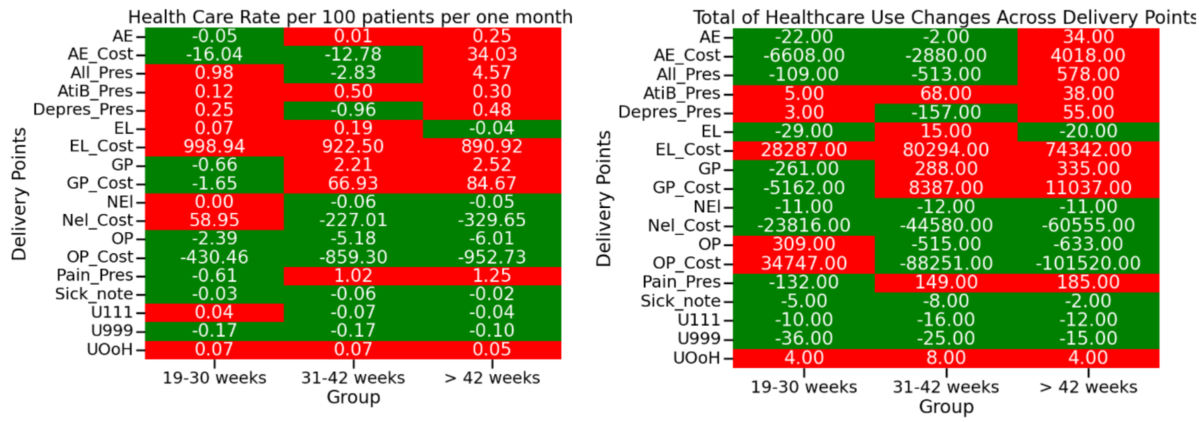


Figure 17 shows hit maps of excess utilization: on the left, 100 person-weeks per month; on the right, total excess comparing long waiting groups to the target (18 weeks) group. Analysis revealed significant shifts in healthcare service usage compared to the < 18 weeks baseline. Emergency liaison (EL_Cost) and general practitioner services (GP_Cost) saw substantial increases in total excess costs with longer waits. Conversely, accident and emergency services (AE_Cost), not elsewhere identified services (NEI_Cost), and outpatient services (OP_Cost) showed cost reductions in longer waiting groups, suggesting savings. Accident and emergency service utilization (AE) decreased initially but increased for the > 42 weeks group. Prescription patterns varied, with some increasing and others decreasing.

Figure 17 Excess of the healthcare use(left) per 100 patients per month, (right) total excess for T&O



3.5 OLS

This study aims to investigate the impact of prolonged waiting times (specifically waiting > 18 weeks for treatment) on healthcare utilization and recovery outcomes. The study compares patients who waited longer than 18 weeks (treatment group) with those who waited 18 weeks or less (control group). Both groups have a reference period during the first 12 weeks of waiting, which captures early healthcare utilization. Healthcare utilization metrics (such as GP visits, prescriptions, and hospital admissions) are then analysed during the post-treatment period from 12 weeks to 2 years. This follow-up period includes both the remaining waiting time (if applicable) and the post-treatment recovery phase.

Using a Difference-in-Differences (DiD) approach, the study seeks to determine whether longer waiting times lead to increased healthcare utilization and whether delays in treatment impact recovery outcomes over time. Additionally, the analysis will explore the potential modifying effects of frailty and long-term conditions (LTC) on the relationship between waiting times and healthcare utilization.

The model aims to investigate the relationship between healthcare utilization (measured as *avg_weekly_use*) and various factors such as waiting group, time period, frailty level, long-term conditions (LTC), and ethnicity, while considering their interactions.

Variables and Constructs:

- Dependent Variable (Outcome):
    - avg_weekly_use: This is the average weekly healthcare utilization, which measured frequency of GP visits, prescriptions, or hospital admissions.
- Independent Variables (Predictors):
    - C(group): A categorical variable representing the waiting group, such as those who waited longer than 18 weeks for treatment (*group > 18 weeks*) versus those who waited 18 weeks or less (*group ≤ 18 weeks*). The matching control group was selected for this study.
    - C(time_period): A categorical variable representing the time period of interest: reference period: 0-12 weeks, intervention period 12 weeks to 2 years.
    - C(Frailty_level): A categorical variable representing the frailty level of the patient, which includes categories such as fit, mild, moderate, or severe frailty.
    - C(ltc): A categorical variable representing long-term conditions (LTC), which was classified into multiple categories such as "no LTC", "single LTC", “comorbidities”, "multimorbidities", or "unknown".
    - C(ethnicity): A categorical variable for the ethnicity of the patient, with categories such as "white", "black", "mixed background", or "unknown".

Model Specification:

The model is specified as a linear regression with interaction terms between the different predictor variables. The formula is as follows:

$$\begin{aligned}\text{avg\_weekly\_use} &= \beta_0 + \beta_1 \text{C(group)} + \beta_2 \text{C(time\_period)} + \beta_3 \text{C(Frailty\_level)} + \beta_4 \text{C(ltc)} \\ &+ \beta_5 \text{C(ethnicity)} + \text{interaction}\end{aligned}$$

We've designated time_period = 0, frailty_level = "Fit," ltc = "Comorbid," and ethnicity = "Asian" as our reference groups.

Cholecystectomy - ***Gallbladder Removal***

The same dataset as per core analysis has been used to include patients with a 2-year follow-up period starting from 13 weeks of waiting, resulting in 870 patient pathways.

The analysis of healthcare utilisation patterns across different activity types (GP visits, Accident & Emergency (AE) admissions, Non-Elective (NEL), antibiotic prescriptions, and antidepressants prescriptions) reveals several significant findings. Significant trends in GP healthcare use reveal a variety of factors influencing healthcare consumption. Time period was found to have a significant impact, with a decrease in GP healthcare use in period 1 (follow up) (p-value <0.0001). Frailty levels also exhibited notable effects: patients with moderate frailty had a significantly higher likelihood of using GP services (p-value < 0.0001), while those with severe frailty showed a significant decrease in usage (p-value = 0.022). Ethnicity and multimorbidity status did not have significant effects on GP healthcare use, with p-values greater than the threshold of 0.05, although the presence of single LTCs and no LTCs had some minor, but non-significant, effects on GP use.

AE healthcare use showed limited but notable effects. Time period again played a significant role, with a decrease in AE use during period 1 (follow up) (p-value < 0.01). For patients with mild frailty, there was a marginally significant increase in AE healthcare use (p-value < 0.05). In contrast, those with severe frailty did not exhibit significant changes in AE use (p-value = 0.294). LTC status did not have significant effects on AE usage, although there were some indications that people with single LTCs used AE services slightly more, with a p-value of 0.03, which is borderline significant.

NEL healthcare use demonstrated several key insights. The presence of mild frailty showed a weak trend towards a decrease in NEL healthcare use (p-value = 0.1), while moderate frailty had a slightly more significant trend (p-value = 0.34). Multimorbidity status did not affect NEL healthcare use significantly, but individuals without LTCs showed a decrease in their NEL healthcare use (p-value < 0.05), which is noteworthy. Again, ethnicity did not appear to influence NEL usage significantly.

Antibiotic prescription counts showed a few significant trends linked to frailty and LTC status. Individuals with multimorbidities exhibited a significant increase in antibiotic prescriptions (p-value < 0.001), while those with no LTCs or a single LTC did not have any significant changes in antibiotic prescriptions. Ethnicity did not have a significant effect on antibiotic prescriptions, as indicated by the higher p-values (> 0.05). Additionally, the time period showed a trend toward fewer prescriptions, although this was not statistically significant at the 0.05 level.

Lastly, trends in antidepressants prescription counts highlighted significant differences due to frailty and multimorbidity status. Mild frailty was associated with an increase in antipsychotic prescriptions (p-value < 0.05), while severe frailty led to a decrease, although the result was less pronounced (p-value < 0.1). Individuals with multimorbidities were significantly more likely to receive antipsychotic prescriptions (p-value < 0.0001), indicating that the presence of multiple chronic conditions may drive the prescription of such medications. Ethnicity did not significantly affect antipsychotic prescription counts, with all p-values exceeding 0.05.

These findings suggest that frailty level and multimorbidity status are significant predictors of healthcare use across various settings, while ethnic background and the time period show less consistent effects. Additionally, the presence of severe frailty appears to have a reducing effect on selected delivery point of healthcare use, while moderate frailty tends to increase service utilization. This can be an effect of the community support for the frailty group – that this study did not include in the analysis. Table 5 shows statistical significant estimates for the models measuring GP, AE , NEL and pain and antidepressants prescriptions (see **OLS_gb_all.xls** in Additional_Supporting_materials).

Table 5 Statistically Significant Estimates for Cholecystectomy

Activity	Term	Estimate	Standard Error	p-value
GP Health Care Use	(Intercept)	0.19	0.027	< 0.001
GP Health Care Use	time_period = 1	-0.05	0.011	0.018
GP Health Care Use	Frailty_level = Mild	0.04	0.016	0.014
GP Health Care Use	Frailty_level = Moderate	0.12	0.029	< 0.001
GP Health Care Use	Frailty_level = Severe	-0.14	0.063	0.022
GP Health Care Use	ndl_ltc = No LTCs	-0.05	0.017	0.007
AE health Care Use	(Intercept)	0.02	0.005	0.002
AE health Care Use	time_period = 1	-0.01	0.002	0.002
AE health Care Use	ndl_ltc = Single LTC	-0.01	0.003	0.032
AE health Care Use	group = > 18 weeks, Frailty_level = Mild	0.01	0.004	0.041
NEL health Care Use	(Intercept)	0.01	0.003	0.024
NEL health Care Use	ndl_ltc = No LTCs	0	0.002	0.027
NEL health Care Use	Frailty_level = Mild	0.04	0.018	0.025
Antidepressants Prescription	ndl_ltc = Multimorbidities	0.08	0.019	< 0.001
Antidepressants Prescription	ndl_ethnicity = Unknown	0.08	0.033	0.01
Antidepressants Prescription	group = > 18 weeks, Frailty_level = Mild	-0.08	0.023	< 0.001
Pain Prescription	Frailty_level = Mild	0.04	0.015	0.004
Pain Prescription	ndl_ethnicity = Unknown	0.06	0.028	0.039
Pain Prescription	group = > 18 weeks, Frailty_level = Moderate	0.12	0.037	< 0.001
Pain Prescription	group = > 18 weeks, ndl_ethnicity = Unknown	-0.07	0.035	0.037

Hip Replacement

The same dataset as per core analysis has been used to include patients with a 2-year follow-up period starting from 13 weeks of waiting, resulting in 942 patient pathways.

The Difference-in-Differences (DiD) model assessed the impact of waiting times (>18 weeks vs. ≤18 weeks) on various healthcare utilization outcomes, incorporating interactions with frailty levels, long-term conditions (LTCs), and ethnicity. For general practitioner (GP) use, frailty was a significant predictor, with mild, moderate, and severe frailty levels associated with increased GP contact compared to the reference group (p < 0.001). However, the interaction between waiting time and frailty showed no significant differences, except for a marginally non-significant reduction in GP use for those with mild frailty (p = 0.053). For Accident and Emergency (AE) use and non-elective admissions (NEL), no significant effects were observed for waiting time group, frailty, LTCs, or ethnicity, with p-values consistently above 0.1. Antibiotic prescription (AB) use showed no notable differences across groups, though individuals from black backgrounds had a marginally higher prescription rate (p = 0.06), but this was not statistically significant. Pain prescriptions were significantly higher for moderate frailty (p < 0.001), with a reduction in prescriptions during the waiting period (p = 0.01), although the interaction effects of waiting time and frailty were not significant. Antidepressant use was higher in moderate frailty levels (p < 0.001), but there was a notable reduction in prescriptions for those with moderate frailty waiting >18 weeks (p = 0.007). Overall, the findings suggest that frailty remains a key driver of healthcare utilization, while extended waiting times did not significantly alter most healthcare utilization patterns across frailty, LTC, and ethnicity subgroups. Table 6 shows statistically significant variables. See **OLS_hip_all.xls** (Additional_Supporting_materials) for all variables estimates.

Table 6 Statistically Significant estimates for Hip Replacement

Activity	Term	Estimate	Standard Error	p-value
GP Health Care Use	time_period = 1	-0.032	0.016	0.05
GP Health Care Use	Frailty_level = Mild	0.069	0.020	< 0.001
GP Health Care Use	Frailty_level = Moderate	0.166	0.034	< 0.001
GP Health Care Use	Frailty_level = Severe	0.181	0.106	0.1
GP Health Care Use	group = > 18 weeks Frailty_level = Mild	-0.044	0.023	0.053
GP Health Care Use	group = > 18 weeks ndl_ltc = Multimorbidities	0.042	0.025	0.1
AE Health Care Use	Frailty_level = Mild	0.004	0.002	0.1
NEL Health Care Use	Frailty_level = Mild	0.002	0.001	0.1
NEL Health Care Use	group = > 18 weeks ndl_ltc = Multimorbidities	0.003	0.002	0.052
Antibiotics Prescription	ndl_ltc = unknown	-0.000	0.000	0.1
Antibiotics Prescription	ndl_ethnicity = black_background	0.048	0.025	0.1
Antibiotics Prescription	group = > 18 weeks ndl_ltc = Multimorbidities	0.007	0.004	0.1
Antibiotics Prescription	group = > 18 weeks ndl_ltc = Single LTC	0.008	0.005	0.1
Antibiotics Prescription	group = > 18 weeks ndl_ethnicity = black_background	-0.049	0.027	0.1
Antidepressants Prescription	Frailty_level = Moderate	0.141	0.039	< 0.001
Antidepressants Prescription	group = > 18 weeks Frailty_level = Moderate	-0.119	0.044	0.01
Pain Prescription	time_period = 1	-0.055	0.021	0.01
Pain Prescription	Frailty_level = Moderate	0.252	0.044	< 0.001
Pain Prescription	ndl_ltc = Single LTC	-0.062	0.032	0.1
Pain Prescription	group = > 18 weeks Frailty_level = Moderate	-0.108	0.049	0.05

Hysteroscopy – genecology diagnostics

The same dataset as per core analysis has been used to include patients with a 2-year follow-up period starting from 13 weeks of waiting, resulting in 757 patient pathways.

The analysis of healthcare utilization across multiple service categories revealed several statistically significant predictors. Notably, severe frailty consistently demonstrated a strong positive association with healthcare use. Individuals with severe frailty exhibited significantly higher utilization in general practitioner (gp) services (estimate = 0.176, $p < 0.001$), antibiotic prescriptions (antib_pres) (estimate = 0.023, $p < 0.001$), and pain-related prescriptions (pain_pres) (estimate = 0.147, $p < 0.001$). Moderate frailty also significantly increased gp utilization (estimate = 0.140, $p < 0.05$) and anti-prescription use (estimate = 0.074, $p < 0.05$). Regarding long-term conditions (LTCs), the absence of LTCs was associated with a significant decrease in accident and emergency (ae) healthcare use (estimate = -0.015, < 0.001) as was having a single LTC (estimate = -0.011, p = 0.0049). Multimorbidities significantly increased pain-related prescriptions (estimate = 0.085, p = 0.0093). The time period = 1 (follow up) significantly decreased gp utilization (estimate = -0.082, $p < 0.001$) but decreased ae utilization (estimate = -0.0057, p = 0.0269). Ethnicity played a less prominent role, with unstated ethnic backgrounds significantly increasing antibiotic prescription counts (estimate = 0.017, p = 0.0100) and mixed ethnic backgrounds significantly influencing pain-related prescription patterns (estimate = 0.216, p = 0.00025). Furthermore, significant interaction effects were observed. For example, the interaction between age group > 18 weeks and severe frailty positively predicted gp utilization (estimate = 0.176, $p < 0.001$), antibiotic prescriptions (estimate = 0.023, $p < 0.001$), and pain-related prescriptions (estimate = 0.147, $p < 0.001$), demonstrating that the impact of severe frailty is more pronounced in older individuals. The interaction between age group > 18 weeks and multimorbidities significantly increased anti-prescription service utilization (estimate = 0.108, p = 0.00073). These findings highlight the complex interplay of frailty, LTCs, time periods, ethnicity, and age in predicting healthcare utilization. See **OLS_hyster_all.xls** (Additional_Supporting_materials) for all variables estimates.

Table 7 Statistically Significant Estimates for Hysteroscopy

Activity	Term	Estimate	Standard Error	p-value
GP Health Care Use	Intercept	0.243	0.045	< 0.001
GP Health Care Use	time_period = 1	-0.082	0.020	< 0.001
GP Health Care Use	**Frailty_level = Moderate**	**0.140**	**0.049**	**0.005**
GP Health Care Use	**Frailty_level = Severe**	**0.176**	**0.028**	**< 0.001**
GP Health Care Use	**group = > 18 weeks, Frailty_level = Severe**	**0.176**	**0.028**	**< 0.001**
AE Health Care Use	Intercept	0.017	0.006	0.005
AE Health Care Use	ndl_ltc = No LTCs	-0.015	0.004	< 0.001
AE Health Care Use	ndl_ltc = Single LTC	-0.011	0.004	0.005
Antibiotics Prescription	**Frailty_level = Severe**	**0.023**	**0.004**	**< 0.001**

Antibiotics Prescription	**group = > 18 weeks, Frailty_level = Severe**	**0.023**	**0.004**	**< 0.001**
Antibiotics Prescription	Antibiotics Prescription	-0.056	0.020	0.006
Antidepressants Prescription	group = > 18 weeks, Frailty_level = Severe	-0.056	0.020	0.006
Antidepressants Prescription	group = > 18 weeks, ndl_ltc = Multimorbidities	**0.108**	**0.032**	**< 0.001**
Pain Prescription	Frailty_level = Severe	**0.147**	**0.023**	**< 0.001**
Pain Prescription	ndl_ltc = Multimorbidities	**0.085**	**0.033**	**0.009**
Pain Prescription	ndl_ethnicity = mixed_background	**0.216**	**0.059**	**< 0.001**
Pain Prescription	group = > 18 weeks, Frailty_level = Moderate	**0.136**	**0.048**	**0.005**
Pain Prescription	group = > 18 weeks, Frailty_level = Severe	**0.147**	**0.023**	**< 0.001**

Acknowledgments:

- West Yorks ICB in Leeds NDL team - Helen Butters, Alex Brownrigg, Frank Wood
- Waiting List Patients and Carers Panel
- HealthWatch Leeds – Tatum Yip, Isaac Grinnell
- Leeds Health Partnership Stakeholders - Sophie Blow, Tom Daniels, Liz Micklethwaite
- Women Health - Eloise Pearson (WYorks ICB in Leeds), Charlotte Waite (LTHT)
- Leeds Data Model Team – James Lodge, Souheila Fox, Klaudia Sutcliffe
- South Yorks ICB Analytical Team – Barbara Coyle, Matthew Hird
- NHS E EPP Team – Suchi Collingwood, Sandra Rochfort
- NECS DSCRO Team