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A service evaluation investigating the effect of complexity factors on treatment times for radical lung cancer patients

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Original Article

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Abstract

Introduction: Radiotherapy departments need to allocate appropriate treatment appointment times to maintain quality of care. Lung cancer patients typically exceed their appointment time due to their increased co-morbidities. Modern radiotherapy methods have reduced treatment time; however, different complexity factors cannot be predicted, indicating that time allocation for treatment appointments requires regular monitoring.
Methods: Quantitative data were collected for 4 weeks, including treatment time allocated, actual treatment time required, and different complexity factors of radical lung cancer patients. Descriptive statistics were employed to analyse the treatment times recorded. The Wilcoxon signed-rank test was deployed to determine statistical significance.
Results: Nineteen cancer patients were included in data collection, and 76 treatment times were recorded. Over 70% of patients' treatment appointments exceeded the allocated 15 minutes. 11 out of the 15 complexity factors recorded were statistically significant. The overall treatment appointment time was statistically significant and showed that on average, patients required 3 minutes longer than allocated.
Conclusion: Most treatments recorded exceeded their allocated appointment time. Patient complexity factors significantly influenced time, indicating that appointment allocation needs to be considered on a patient-to-patient basis. This evaluation determined that appointment allocation needs to be investigated for all cancer patients in individual departments, to ensure high-quality care.

Introduction

Background

50% of all cancer patients in England would benefit from radiotherapy as part of their primary care; however, the most recent data show that only 27·3% of patients receive it.[1,2] Access to appropriate modern radiotherapy techniques is required to improve patient outcomes, meaning high-quality, safe, and timely services must be delivered.[3] Cancer incidence rates are increasing, meaning radiotherapy department capacity must be considered. New treatment techniques have reduced treatment appointment times; however, radiotherapy departments typically allocate 15 minutes for cancer patients' treatment. Recent studies investigating the growing incidence rates of cancer state that modern radiotherapy techniques have improved treatment time, but with increasing patient numbers, more time consideration is required to optimise patient care.[4–6] Cancer incidence is also increasing in the UK; a UK study reported that while patient numbers declined during the COVID-19 pandemic, cancer diagnoses have since increased.[7] This highlights that more time consideration is required to both optimise patient care and appropriately manage increasing patient numbers.

The most recent data show that 63·9% of patients are treated within the 62-day target.[8] Lung cancer patients should be commencing treatment within the 62-day treatment time, yet evidence shows that many patients are not meeting this target and extended treatment wait times for cancer patients increase with mortality risk.[9,10] Additionally, lung cancer patients are classified as category one patients, and guidance states that these patients should be treated within seventeen days from the date of decision to treat radiotherapy.[11] New radiotherapy planning and treatment set-up techniques have improved the quality of patient care; however, the implementation of them is slow and complex, which puts a greater strain on wait time targets.[12–14] The Cancer Research UK (CRUK) Vision for Radiotherapy states that the NHS aims to increase timely access to treatment for cancer patients by 2024, therefore treatment appointment allocation must be investigated to ensure patients receive safe and timely treatment.[4,12,15]

Radiotherapy complexity is difficult to measure and factor into patient appointment times. Studies report that lung cancer patients typically have significant co-morbidities and a poor performance status (PS), which often declines further during treatment.[16,17] The Basic Treatment Equivalent (BTE) tool developed in 1996 predicts patient appointment times, considering various patient and department complexity factors.[18–20] The tool has been adapted over time and has consistently represented appropriate patient appointment times.[18–20] With the increasing, ageing, patient population, and changes in modern radiotherapy techniques, the BTE tool could prove effective at predicting the appropriate duration for radiotherapy appointments; however, it has not yet been widely adopted in the UK.[5,18,20]

Literature review

There is a strong correlation between radiotherapy-induced toxicities and co-morbidities.[21] Patients with greater co-morbidities typically experience more radiotherapy-induced toxicities, increasing their need for support during treatment.[21] A study investigating the prevalence of co-morbidities in patients prior to treatment, found that lung cancer patients had significantly more co-morbidities prior to treatment when compared with other cancer sites.[22] This study only investigated four cancer sites from the years 2009–2013; however, it clearly shows that lung cancer patients are more likely to have multiple co-morbidities when compared with the other cancer sites.[22] These studies highlight the importance of appropriately considering the impact lung cancer patients' co-morbidities may have on their treatment and how they may require additional support throughout their treatment. To overcome this, regular interventions must be investigated.

Literature addressing lung cancer patients' treatment duration times are limited; however, several studies identify this as a global growing concern.[5,6,23] Two studies conducted in Canada concluded that lung cancer patients required greater treatment time than what was allocated; however, these results also include data for other thoracic sites.[6,23] A similar study conducted across multiple UK radiotherapy centres found that most patients were treated within the time allocated.[5] These patients had a longer standard treatment appointment time than the Canadian studies; however, 34% of all times still exceeded the time allocated.[5] Evidently, treatment appointment time allocation should be regularly monitored within departments to ensure high-quality care is delivered[5].

Organisational issues, shortage of staff, and time constraints are growing concerns in modern radiotherapy departments.[24] A study identified that job stress has a significant impact on allied health professionals, and evidence shows that satisfaction levels have significantly declined over the past decade.[25] Staff experienced physical and mental strain due to a decreasing workforce and increasing patient numbers; to reduce strain on Therapeutic Radiographers (TR) and minimise the risk of errors, appointment time allocation must be carefully considered.[24,25]

Materials and Methods

Study design

A quantitative service evaluation was undertaken at a single radiotherapy department, in North-West England. It aimed to determine the efficiency of the current radiotherapy service to treat radical lung cancer patients within the allocated treatment appointment time and to determine whether the current allocated time should be amended.

Patient selection

Convenience sampling was conducted to identify eligible patients, and the linear accelerators (Linacs) used for treatment.[26] Data for all radical lung cancer patients receiving external beam radiotherapy were recorded; patients were identified using the MOSAIQ oncology information system. Patients receiving palliative or specialist treatments (paediatric, electrons or stereotactic ablative radiation) were excluded from the study population due to time constraints. The data entry team within the department identified eligible patient and assigned non-identifiable participant ID numbers. To reduce the risk of bias, data were collected on non-consecutive days, which has been successfully used by similar previous studies.[5,26]

Data collection

Treatment times were recorded using the time the patient entered the treatment room (as shown on MOSAIQ), and the time the patient exited once their treatment had been captured. The time shown on MOSAIQ is the same in each Linac control room, increasing standardisation.

Various patient and treatment complexity factors were recorded to determine their similar studies and clinical experience.[5,6,23] Table 1 shows the different patient and treatment complexity factors recorded, and additional factors collected to aid with data analysis.

Structured observation was employed during data collection.[26,27] A table including different complexity factors (Table 1) was produced and completed when each factor was observed.[26,27] To reduce the risk of missing data, a prompt was added to the electronic notes on MOSAIQ for each eligible radical lung cancer patient on each data collection date. Nominal scales were used to record the data, whereby the values were assigned to categories but had no intrinsic meaning; this enabled unidentifiable participant ID numbers to be applied, maintaining patient anonymity.[26]

A paper data collection table was attached to each eligible patients' notes with an unidentifiable ID number. The reverse side of the data collection table included instructions and information detailing the purpose of the service evaluation. The researchers informed the TRs of the service evaluation and data collection tables before the first data collection day, providing an opportunity for TRs to ask questions.

TRs were asked to record the PS of each patient on each data collection date. Figure 1 outlines the ECOG PS definitions attached to the data collection sheet, for TRs to use as a guide.

Ethical approval was not required as personal data was not collected; however, local governance approval from the department was sought. Following data collection, tables were scanned and securely stored on the clinical researcher's computer, while paper copies were filed in a locked cabinet. This ensured patient information remained anonymous and secure and enabled access to the results for data analysis.

Piloting the collection method

The data collection table was piloted by the clinical education team before adopting the final design. Piloting the intervention led to the addition of information and instructions related to the service

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Table 1. The different complexity factors recorded

Patient factors	Treatment factors	Additional factors
• Gender • PS • Cancer stage	• Fraction number • Treatment modality • Number of arcs • Additional images	• Participant ID • Linac number • Additional comments • Treatment time allocated. • Actual treatment time recorded

evaluation, an example of a completed data collection record, and a comments section.

There were concerns raised regarding the TRs' ability to remember the data collection dates, which resulted in adding prompts on MOSAIQ. Additionally, there were concerns that TRs would be unable to use the PS table; the clinical researcher subsequently informed TRs of the basic criteria for each PS grade to ensure that the observed PS would be appropriately decided.

Data Analysis

Only completed data entries were included and analysed using Microsoft Excel. Incomplete data and outliers, which did not represent a typical treatment day, were excluded. Descriptive statistics were employed to calculate the patients' in-room treatment time and the mean overall treatment appointment time. The treatment appointment times recorded alongside the various complexity factors were individually analysed to calculate the mean and median times and the standard deviation. The distribution of the data was analysed to assess normality using the Shapiro-Wilk test calculator.[28] Statistical analysis was conducted using the Wilcoxon signed-rank test, with a *p*-value for statistical significance of <0·05.

Results

Recorded totals

Data were collected on a total of 12 days over 4 weeks. 19 eligible patients' treatment times were recorded. Table 2 shows 76 different datasets were documented; 18 potential datasets were partially recorded or missed (reasons for this were not disclosed), and 17 datasets were discounted from the results because they included outliers that did not represent a typical treatment day. Reasons for the outliers include the first-day chat being completed in the treatment room, the completion of patient observations in the treatment room, issues with imaging or locating equipment, or the patient changing into a treatment gown.

Average treatment times

Figure 2 shows the average time each patient required for treatment and the time they were allocated. Patient 10 was identified as an outlier and was removed from the final data analysis as the only recorded treatment appointment time was significantly extended by multiple mechanical errors. This resulted in only 18 patient treatment times. All patients recorded were allocated a 15-minute treatment appointment. On average, only 28% of patients' treatment times were equivalent to or less than the time allocated. The average overall appointment time recorded for all patients was 18 minutes. Patient 14 was noted to have an average treatment time that was significantly longer than the time allocated (Figure 2); however, after removing outliers, patient 14 only had one treatment time recorded.

Statistical analysis

Table 3 shows all the complexity factors recorded, and the mean and median time each factor required for treatment. The table also shows the statistical significance of the mean treatment time for each complexity factor and the total data recorded. Considering the whole dataset, the *p*-value indicates that the difference between the average recorded treatment time and allocated time for all patients was statistically significant. The times recorded for males, patients with a PS of 2, or stage 1 or 2 disease, were not statistically significant; this was due to an insufficient sample size, meaning an accurate *p*-value could not be calculated. Statistically significant differences were observed across treatment times recorded for female patients, those with a PS of 0, 1 and 3, VMAT and IMRT modalities, both 'early' and 'late' fractions, disease stages 1 and 2 and for treatments with either 1 or 2 arcs (Table 3).

Discussion

This service evaluation shows that on average, radical lung cancer patients are not allocated an appropriate treatment appointment time and that the actual time required can be significantly influenced by several patient and treatment-related complexity factors. Here, we accurately determined which complexity factors influenced treatment time, providing a valuable insight for other departments. Allocation of treatment time based upon such complexity factors is essential for radiotherapy departments to consider, to ensure the growing demands of Linac throughput are met.

On average, this service evaluation shows that most radical lung cancer patients' treatments exceeded the allocated appointment time. These findings further corroborate conclusions reported in previous studies that investigated the room occupancy time for radical lung cancer patients, whereby the treatment appointment times typically exceeded the allotted time.[6,23] Both studies allocated a standard time of 12 minutes; however, the treatment time required was greater than 15 minutes.[6,23] While these studies were conducted at single centres in Canada and had grouped lung cancer with other thoracic sites, they accurately demonstrated that lung cancer patients require additional time to what is currently allocated.[6,23] Similar findings are reported by a previous UK study, which allocated 20-minute appointments for radical lung cancer patients; the actual time required was 19 minutes, which is comparable to the results in this service evaluation.[5]

Our findings demonstrate that various patient and treatment-related complexity factors have a significant influence on the time required for radical lung cancer patients' radiotherapy appointments.

Patient factors

This service evaluation investigated various patient factors, including gender, PS, and lung cancer stage. On average, females required 1 minute more than males for treatment, a finding that has been previously reported within the primary care setting in England, in a study including 6·9% of the UK population.[29] While the co-morbidities investigated in this study are significantly different from radiotherapy-induced co-morbidities, such findings

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GRADE	ECOG PERFORMANCE STATUS
0	Fully active, able to carry on all pre-disease performance without restriction
1	Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature, e.g., light house work, office work
2	Ambulatory and capable of all selfcare but unable to carry out any work activities; up and about more than 50% of waking hours
3	Capable of only limited selfcare; confined to bed or chair more than 50% of waking hours
4	Completely disabled; cannot carry on any selfcare; totally confined to bed or chair
5	Dead

Figure 1. The performance status table attached to the data collection table[28].

Table 2. The total number of recorded and missed patient occupancy times on each Linac

Linac	Total number of treatment times recorded and included	Total number of treatment times missed	Total number of anomalies recorded
LA1	6	0	5
LA2	13	3	2
LA3	37	13	9
LA6	3	0	0
LA7	16	2	0
LA8	1	0	1
OVERALL TOTAL	76	18	17

further demonstrate that patient sex does not significantly impact appointment duration.[29]

Patient PS was recorded to determine whether patients with greater co-morbidities required a longer treatment appointment. As expected, the data show that patients with a higher PS required a longer treatment appointment time. Studies evaluating patients' mobility status have reported similar results.[5,6] Such findings indicated that when patients required assistance, their appointment time increased by 4 minutes.[5,6] This service evaluation found patients with a PS of 3 required a treatment appointment time at least 3 minutes longer than patients with a PS of 0. Recording of patients' PS at the pre-treatment stage would be beneficial to allow consideration of such complexities when allocating treatment appointment duration.

Lung cancer stage was recorded to determine whether more advanced disease could impact treatment appointment time required. The only statistically significant difference in the time recorded was observed for stage 3 lung cancer patients, whereby treatment times exceeded allotted times by 5 minutes. Similar studies investigating patient appointment times did not analyse treatment times for different cancer stages.[5,6,23] However, two studies including palliative patients found that the treatment appointment time required was 30–60% longer than the time allocated.[5,6] The palliative patients involved in these studies included different diagnoses and did not specify if any were lung cancer, yet these findings are likely to be comparable for palliative patients due to their advanced stage of disease, regardless of primary diagnosis.[5,6] The service evaluation only investigated radical lung cancer patients; however assuming palliative patients have a higher stage of disease, it indicates that such patients may require longer treatment appointments, which should be factored in when allocating appointment times.[5,6] Evidence also suggests that patients with advanced-stage disease typically begin treatment sooner than those with early-stage disease; therefore, more consideration needs to be taken to ensure appointments are appropriately allocated to reduce the impact on radiotherapy department treatment throughput.[30]

Treatment factors

Treatment-related complexity factors investigated in this service evaluation included the treatment modality used, the fraction number treated, and the number of arcs planned. All patients were treated with either VMAT or step and shoot IMRT techniques. All patients had daily kilovoltage cone beam CT imaging. IMRT patients required a treatment appointment time 47% (7 minutes) longer than the time allocated, and VMAT patients required a treatment appointment time 20% (3 minutes) longer. Similar findings were demonstrated in a UK study that reported on average, all cancer patients treated with VMAT required an appointment time 54% longer than the time allocated, and IMRT treatments required a time 44% longer.[5] A study conducted in Canada concluded that breast patients treated with IMRT required 4 minutes less than the 24 minutes allocated, and other oncology

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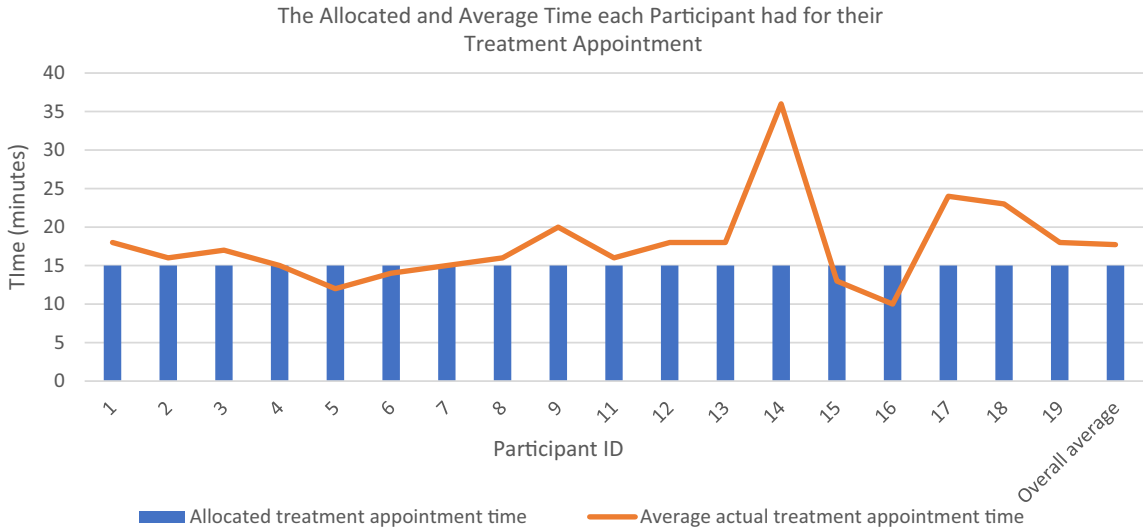

Figure 2. The allocated and actual average treatment time for each participant.

sites treated with VMAT required 2·3 minutes longer than the 12 minutes allocated.[6] While these findings support the results of our service evaluation, these studies are not representative of our patient cohort due to inclusion of other oncology sites.[5,6] Further research is required to definitively determine an appropriate treatment appointment time for lung cancer patients treated with different treatment modalities.

The fraction number was recorded to determine whether patients required longer appointments at the beginning of treatment due to uncertainty of the radiotherapy process, or as treatment progressed, due to increased treatment-induced toxicities. Times recorded for both 'early' and 'late' fractions were statistically significant, and the mean and median values were the same, indicating fraction number does not impact the time required. A study investigating the overall burden of radiotherapy-related toxicities for lung cancer patients found that patients often had severe baseline symptoms, which increasingly worsened during, and after treatment.[31] Prehabilitation has been shown to improve lung cancer patients' PS prior to undergoing surgery and has demonstrated similar improvements for radiotherapy patients.[32] Increased provision of prehabilitation for this patient cohort in the future may reduce lung cancer patients' PS prior to radiotherapy and reduce radiotherapy treatment time. The present evaluation indicates that fraction number does not largely impact treatment times and does not need to be considered.[31]

The treatment modality used for the lung cancer patients involved one or two treatment arcs. On average, patients required 2 minutes longer for two arcs, when compared with a single arc. A similar study investigated the treatment appointment time for different treatment modalities and the use of imaging; however, it did not specifically investigate the number of arcs.[5] This study found that imaging patients increased the treatment appointment time by 50%.[5] Imaging patients requires more time to deliver the treatment, which is comparable to using more treatment arcs.[5] Although imaging is a different technique, this study indicates that when patient's appointments have an additional treatment step, such as imaging or delivering more treatment arcs, they should be allocated a longer treatment appointment.[5]

Future of radiotherapy

During the coronavirus pandemic, the care of cancer patients within the NHS was significantly impacted.[33] A study investigating the impact on UK radiotherapy centres found that during the pandemic patient numbers significantly reduced by 20%.[33] Radiotherapy departments are now facing increased patient volumes to address this backlog of cancer treatment, consequently impacting time management, and patient and staff satisfaction.[33] Currently, radiotherapy departments are facing increasing workload pressures that present challenges in delivering timely treatment. The department this evaluation was conducted at currently allocates catch-up slots within their workflow. However, if patient workload continues to increase, these slots could be removed, which may translate to issues regarding patient care. Increased stress and pressure could also result in reduced staffing and training, which was highlighted as a major problem within the Francis report.[34] Radiotherapy departments need to investigate whether all cancer sites are allocated an appropriate treatment time and determine whether appointment times need to be reasonably adjusted for the increasing patient workload, particularly if departments do not have catch-up loads within their workflow.

Introduction of advanced radiotherapy techniques has the potential to reduce treatment times required. Surface-guided radiotherapy (SGRT) is a technique that uses real-time imaging to accurately position and treat cancer patients.[35] A study investigating the benefit of SGRT for thoracic patients, found that it improves workflow efficiency.[35] The radiotherapy department this service evaluation was conducted at has recently installed SGRT and is currently transitioning to using this technique for thoracic treatments. If the department fully transitions to using SGRT for radical lung cancer patients, this evaluation will need to be repeated to determine accuracy of treatment appointment time

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Table 3. The statistical significance of the total actual treatment appointment time and each complexity factor compared against the standard allocated 15-minute appointment time. LA1-8: Linear accelerators used to deliver treatment within the radiotherapy department. PS0-3: Performance status 0-3. Early #: Fraction 1-9. Late #: Fraction 10-20. Stage 1-3: Lung cancer stage 1-3. 1-2 Arcs: Number of Arcs planned to deliver treatment

	Complexity Factors															
Linac	*Male*	*Female*	*PS 0*	*PS 1*	*PS 2*	*PS 3*	*IMRT*	*VMAT*	*Early #*	*Late #*	*Stage 1*	*Stage 2*	*Stage 3*	*1 arc*	*2 arcs*	*COMPLETE DATA*
LA 1	2	4	4	5	0	0	2	5	3	5	2	0	4	2	4	6
LA 2	3	10	2	6	0	0	1	13	6	7	7	0	6	8	5	13
LA 3	10	26	16	11	5	7	5	31	17	18	12	7	18	25	12	38
LA 6	0	3	2	1	0	0	0	3	3	0	2	0	1	2	1	3
LA 7	5	11	9	5	1	1	2	14	8	7	5	2	9	11	5	15
LA 8	0	2	0	1	0	0	0	1	1	1	1	0	0	1	0	1
Dataset TOTAL	20	56	33	29	6	8	10	67	38	38	29	9	38	49	27	76
Median time (minutes)	15	18	16	18	16	18	18	17	17	17	15	15	19	16	18	17
Mean time (minutes)	17	18	17	18	16	20	22	18	18	18	16	15	20	17	19	18
Standard deviation	6·17	4·15	3·81	5·54	2·83	5·6	12·11	4·40	4·35	5·07	3·55	2·67	5·24	5·13	3·83	475
p-value	0·32708	0·00001	0·0088	0·00578	N/A	<0·05	<0·05	0·00001	0·0010	0·00104	0·13104	>0·05	0·00001	0·01108	0·00008	0·00001

allocation, given the benefits that SGRT provides in reducing set-up and treatment time. This also highlights the importance of investigating treatment appointment times when new treatment technology is introduced to radiotherapy departments, to determine their benefit and impact on the treatment workflow.

Limitations

During data collection, the times and factors recorded relied on the compliance of staff, who may have unintentionally inaccurately recorded times or patient information. Bias cannot be discounted, particularly as TRs do not typically record patients' PS, therefore grading may be inaccurate. This evaluation was only conducted for 4 weeks; therefore, the data recorded may only represent the radiotherapy department that month. Certain patient complexity factors were under-documented, resulting in inaccurate statistical data.

Only 19 patients' treatment times were recorded, meaning the results may not be generalisable to the wider radical lung cancer patient population.

Patient PS was used to determine patient's co-morbidities; however, the ECOG PS scale does not represent all co-morbidities that impact treatment appointments. This means some patients may have been allocated a PS value that did not represent their individual co-morbidities. Additional reasons for the room occupancy time were not considered, despite some longer treatment times potentially being impacted by communication or set-up errors in the room, which were not evaluated.

Conclusion

This service evaluation highlights that the duration of radiotherapy treatment appointments is significantly influenced by various patient and treatment-related complexity factors including disease stage, patient PS, treatment modality, and the number of arcs planned. As radiotherapy technology advances, and the patient workload increases, there is a need for radiotherapy departments to evaluate treatment appointment time allocation for all cancer patients. The results clearly indicate that lung cancer patient factors significantly impact treatment appointment length. It is recommended from this evaluation that treatment appointment allocation needs to be considered on an individual-patient basis, as although technology advances have decreased treatment time, patient factors can still pose a significant impact. The results clearly show that patients with more co-morbidities require additional treatment time. It is recommended from this evaluation that patients' PS/co-morbidity status be assessed at their first planning appointment, prior to treatment, to ensure treatment appointment times are appropriately planned and allocated. Further research is required to definitively determine the impact different complexity factors have on treatment appointment times across all cancer sites.

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