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Original Article

Are extended working days sustainable in radiotherapy?

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Abstract

A number of Radiotherapy Departments have extended the working day on linear accelerators, as a method of increasing treatment capacity. However, reports from the Royal College of Radiologists predict a rate of increase in requirements for radiotherapy, significantly in excess of the rate at which radiographers will become available to run the necessary equipment.

Based on the premise that radiographers are the most difficult staff group to recruit, a number of different patterns of radiotherapy linear accelerator use has been investigated, with an aim of seeing which delivers the greatest return on radiographer time. The requirement for radiographers per linac-hour has been examined for a number of lengths of day and utilising various staffing assumptions.

Given current patterns of work, the greatest manpower efficiency in use of trained radiographers is achieved if machines are run for a 7-h-day or for an 8-h-day if part-time radiographers are available. This working pattern relies on all ancillary tasks being removed from the treatment unit, many of which can be performed by other appropriately trained, non-radiographer, staff groups.

With linac-hour demand projected to rise faster than the rate at which new trained radiographers become available, extended working days are not sustainable without significant change to current work patterns.

Keywords

Radiotherapy utilisation; workload; efficiency; working patterns; time management; theoretical models

INTRODUCTION

Background

The Royal College of Radiologists (RCR) 1997 report on extending the working day[1] gave excellent advice on the advantages and disadvantages of working an extended working day on radiotherapy equipment. The report gave guidance on how to calculate the financial implication of an extended working day, balancing the extra costs (especially staffing costs) with the efficiencies in use of capital. Based on this report, some departments stayed with a standard (8-h-day) some extended the length of working day (to 10 h or more) as a temporary expedient pending the installation of new equipment, and some adopted extended working days as a long-term solution to increase radiotherapy service capacity. The Department of Health (DH) Survey of Radiotherapy Services in England 1999[2] contains an algorithm for calculating megavoltage equipment requirements that allows for a length of working day of 8, 10 or 12 h, and states that a 10-h or 12-h working day makes more efficient use of linear accelerators (LAs).

Capacity

The NHS Cancer Plan published in 2000[3] set targets for the maximum times allowed between diagnosis and start of treatment. To achieve these targets,

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the plan mentioned numbers of accelerators, and numbers of staff, including physicists, radiographers and oncologists. The increase in LA numbers in the NHS cancer plan, to 4 per million population, represented a 14% increase in machines. The RCR report on the provision and replacement of radiotherapy equipment[4] calculated that 301 LA were required in the UK by 2006, a 44% increase.

The Cancer Plan figures were revised in 2005, enhancing the concept to a 31 day maximum time interval between the decision to treat and the first definitive treatment for all cancers.[5] Recent audits have shown that despite the increase in equipment, only 70% of patients are treated within the 31 day target.[6] Waiting times for radiotherapy services have increased as the demand for radiotherapy has exceeded the service capacity.[7] To improve capacity, the RCR is re-examining the concept of extended working days in radiotherapy.

Radiographer staffing levels

The rise in numbers of trained therapeutic radiographers and physicists by 2006 has been only 12% and 16%, respectively.[2] A 1999 survey showed that 12% of therapy radiographer posts were unfilled[8] and the figure has risen to 17% in 2006.[9] The demand for radiotherapy is increasing faster than the rate trained radiographers become available and one of the main constraints to radiotherapy capacity is the number of radiographers available.

The RCR and the College of Radiographers,[10] published a report in 1979 recommending minimum staffing levels for therapy radiographers. This report recommended a minimum of four whole time equivalent radiographers to staff an LA working an 8-h-day. The four radiographers were required to directly carry out treatment delivery tasks, as the computer delivery and verification technology now used was not in existence. Excluding break times, this equates to 0.5 radiographers for every hour the LA is run (linac-hour). The recommendation for extending the working day past 8 h of LA use required additional staff on a pro-rata basis. The Cottier survey,[2] demonstrated that only 20% of departments taking part in the survey were working their LA's for 9 h a day or longer, others claiming that staff shortage resulted in inabilities to cover the shifts required to extend the working day. These figures will be updated by the RCR report "Extended Working Days in Radiotherapy, 2006".

Whilst the current pressure of recruiting trained radiographers remains, it is clear that the emphasis must switch from maximising the return on capital investment, to maximising the number of treatments delivered per trained member of staff. This paper therefore seeks to determine if extended working days in radiotherapy are sustainable using the existing patterns of working practice and investigates models of alternative practice that could optimise the number of radiographers required per linac-hour.

METHODS

A number of different patterns of machine use were investigated, with an aim to seeing which delivers the greatest return on radiographer time.

As the contractual hours recommended by Agenda for Change has not become standard through the UK, for the purposes of this modelling exercise, it is assumed that radiographers work a 35-h-week, divided into 5 days. For most radiographers,[2] this is planned as an 8-h-day with the inclusion of a 1 h lunch break. Regular short breaks are included, in line with the Working Time directive.[11] These are essential as delivering radiotherapy is continually highly demanding, both mentally and physically and most of the tasks are crucial to quality and radiation safety.[12] The analysis can be easily adapted for a 37.5 h working week assumption, but the ranking of the data remains the same.

For the examples given, working patterns are arranged to ensure a given minimum of two radiographers in the LA treatment room[13] of which one is a senior grade. For each working pattern, we have calculated the number of radiographers required per linac-hour. This number includes only those radiographers involved in the tasks directly related to treatment delivery and does not include the additional radiographer numbers required for a complete service, such as those undertaking activities in pre-treatment imaging, dosimetry, planning, management or specialist services.[9] Also excluded are the necessary increases to the radiographer establishment for the department to cover annual leave, sickness and training. Griffiths[12] gives an

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indication of the extra staff necessary for this purpose at 20–25%.

The Cottier survey[2] has shown that a significant number of staff now work part-time (the average WTE per radiographer nationally was 0.91), following initiatives to increase radiographer numbers outlined by previous reports.[3,8,12,13] We have therefore produced some models that utilise part time radiographers, but availability is usually limited to school hours and occasionally term time only.

Where extensions to the working day are modelled, it is assumed that this is achieved by increasing the number of radiographers on a LA rather than overtime arrangements. Usual practice is to maintain the radiographer pattern of working an 8-h-day, and the extensions are achieved by dividing the radiographers into two overlapping shifts. This results in parts of the day where more than two radiographers are present on the treatment unit.

It is acknowledged that effective LA time is reduced by machine breakdowns although an allowance for this has not been included in this model. Unpublished audits by the RCR of the last 5 years have found unplanned breakdowns reduce the effective LA time by 2.5%. For the purposes of this modelling exercise, planned maintenance and time for routine quality assurance procedures are excluded.

RESULTS

Figure 1 shows some examples of working patterns that will cover the daily workload.

Table 1 shows the number of treatment radiographers required per linac-hour for a number of scenarios.

Table 2 shows the results from Table 1 modified for the loss of efficiency when only two radiographers are present on a treatment unit. Evidence has demonstrated that throughput is 12% less during times of the day when a treatment unit has only two radiographers, than during times when three or more are present.[12,14]

Table 3 shows the fractions per day (capacity) achievable using additional LAs, based on data from Delaney et al.[15] demonstrating average throughput nationally of 4.5 fractions per hour. Scenarios are presented showing the capacity achievable using additional LAs compared to extended day operation for equivalent numbers of radiographers.

DISCUSSION

Working patterns

The evaluation shows that the working pattern requiring the least radiographer time per machine hour is a 7-h-day (option 1). Provided part time radiographers are available to cover the lunch breaks, 8-h-days can be achieved as efficiently, while increasing capacity (option 12). Small extensions to the length of the working day beyond this require significant increases in radiographer time per linac-hour. The overlapping shifts that can occur when running an extended day results in more than two radiographers present on the treatment unit; this has the effect of increasing radiographer time per linac-hour; the capacity gained is small compared to the number of radiographers required to achieve it.

The shortage of trained radiographers in some departments, has led into a working practice of closing LAs and operating extending hours on the remaining. This modelling has shown that it would be a more efficient use of radiographer time to operate a second LA, rather than extending hours on fewer machines.

From the scenarios examined, it appears that only very large extensions to the working day are efficient in terms of radiographer resources (options 6 and 14), where the radiographers shift do not overlap. In practice, there are other factors not modelled here, that influence the effectiveness of this working pattern.

Sustainability of extended working days

Operating very extended working days (12 h) has been calculated as economically desirable by reports from the DH and RCR.[1,2] Although nominally efficient in terms of radiographer use also, other issues adversely effect the long-term sustainability of this working practice. The additional hours worked are often when the backup and support

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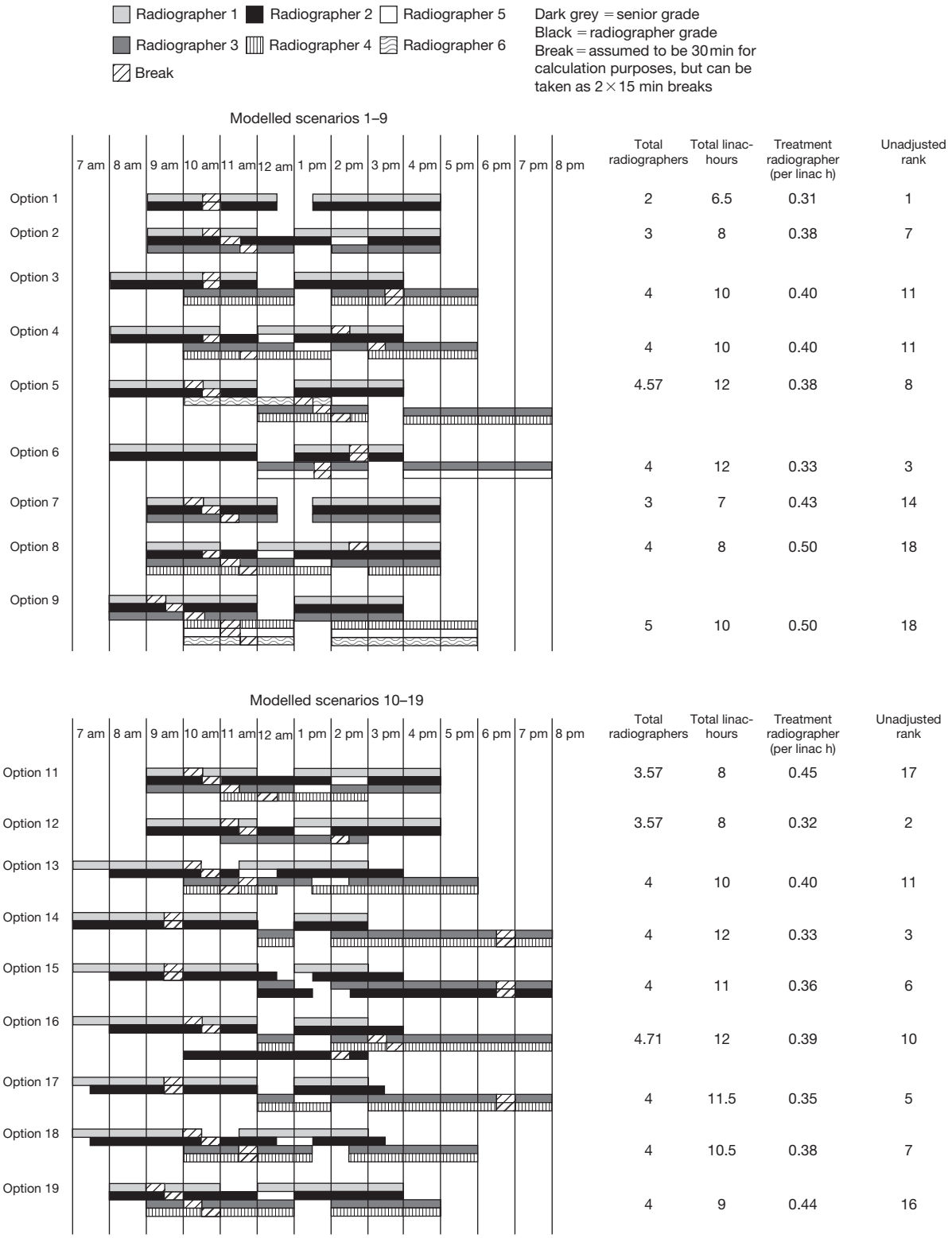

Figure 1. LA working patterns

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Table 1. *Scenarios showing effect of working patterns on efficient use of radiographers*

Options	Total radiographers	Total linac-hours	Treatment radiographer (per linac h)	Unadjusted rank
1	2.00	6.50	0.31	1
2	3.00	8.00	0.38	7
3	4.00	10.00	0.40	11
4	4.00	10.00	0.40	11
5	4.57	12.00	0.38	8
6	4.00	12.00	0.33	3
7	3.00	7.00	0.43	14
8	4.00	8.00	0.50	18
9	5.00	10.00	0.50	18
10	3.43	8.00	0.43	14
11	3.57	8.00	0.45	17
12	2.57	8.00	0.32	2
13	4.00	10.00	0.40	11
14	4.00	12.00	0.33	3
15	4.00	11.00	0.36	6
16	4.71	12.00	0.39	10
17	4.00	11.50	0.35	5
18	4.00	10.50	0.38	7
19	4.00	9.00	0.44	16

Table 2. *Effect of working pattern modified for efficiency reduction*

Options	Total radiographers	Total linac-hours	Treatment radiographers (per linac h)	Unadjusted rank	No. of hours <3 staff	Corrected radiographers/ linac-hours for efficency drop	Final adjusted rank radiographers/ linac-hours
1	2.00	6.50	0.31	1	6.50	0.35	1
2	3.00	8.00	0.38	7	4.50	0.40	8
3	4.00	10.00	0.40	11	5.00	0.43	11
4	4.00	10.00	0.40	11	5.00	0.43	11
5	4.57	12.00	0.38	8	8.00	0.41	10
6	4.00	12.00	0.33	3	11.00	0.37	3
7	3.00	7.00	0.43	14	1.50	0.44	15
8	4.00	8.00	0.50	18	1.00	0.51	20
9	5.00	10.00	0.50	18	1.00	0.51	19
10	3.43	8.00	0.43	14	2.00	0.44	16
11	3.57	8.00	0.45	17	1.50	0.46	17
12	2.57	8.00	0.32	2	7.50	0.36	2
13	4.00	10.00	0.40	11	5.50	0.43	14
14	4.00	12.00	0.33	3	11.00	0.37	3
15	4.00	11.00	0.36	6	8.50	0.40	7
16	4.71	12.00	0.39	10	8.00	0.43	13
17	4.00	11.50	0.35	5	9.00	0.38	6
18	4.00	10.50	0.38	7	6.00	0.41	9
19	4.00	9.00	0.44	16	7.00	0.49	18

services in the hospital are no longer available. Problems with machine breakdowns can affect patient throughput, if technical staff are unavailable or there is no equipment backup. Radiographer illness or absences cause logistical problems, as does lack of access to specialist or technical expertise. Additionally, evidence from time and motion studies such as GRASP[17] show that patient throughput is likely to be reduced for anti-social hour working. Although not modelled here, fatigue reduces throughput by approximately 10%.

There may be difficulties with patient attendance at these times or the absence of complimentary services such as transport and pharmacy. The economics of extended hour working may vary

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Table 3. Fractions per day for different scenarios

No. of LA's	Length of day (no. of operational hours)	No. of radiographers (each LA)	Fractions per day (no. of linac-hours × 4.5 fractions)	Fractions achievable per radiographers per day (no. of fractions per day/radiographers) [modified for loss of productivity]
1	8-h-day	2.57	36	14.01 [13.80]
1	10-h-day	4	45	11.25 [10.58]
1	12-h-day	4	54	13.50 [12.02]
2	8-h-day (16 total)	2.57 (5.14 total)	72	14.01 [13.80]
1	6.5-h-day	2	29.25	14.63 [12.87]
2	6.5-h-day (13 total)	2 (4 total)	58.5	14.63 [12.87]

between departments depending on the additional costs required for the extra staff groups such as oncologist, physicists, technicians, reception staff and porters. Out-of-hours safety may also affect feasibility from such issues as lack of appropriate technical backup to concerns of personal security.

Very extended working days may also adversely impact on staff recruitment and retention in a service with existing staffing difficulties.

If, despite with these feasibility issues, a department were to choose the approach of very extended days, it should only be chosen for a minority of the LAs in the department. This would avoid the problem of backup for equipment breakdowns.

Using additional linear accelerators

If radiographers are the scarcest resource, it is more efficient to operate another treatment unit with a second team of radiographers. Both treatment units running a 9 am to 5 pm working day would result in larger increases in capacity with the same number of staff required for an extended day (table 3). This would have the additional benefit of providing a backup for unplanned machine breakdowns and staff absences.

Operating a second LA would support the objectives of a patient-centred service; patient surveys have shown that the age of patients and travelling times in rural communities affect patient choice for appointment times, the majority prefer appointments during the middle part of the day.[16] A second LA offers double the choice of preferred appointment times. Radiotherapy service capacity allocated to core service hours ensures the availability of support services and access to specialist assistance.

Radiographer efficiency

The reduction in radiographer efficiency when less than three radiographers are operating a treatment unit[14] may be attributable to interruptions in the radiographers' main duties for more administrative tasks such as handling telephone calls and enquiries.[12] It is unclear, however, whether this relationship still holds for machines where staffing with two radiographers is a planned activity, and all ancillary activities are diverted off the treatment unit. It is suggested than using helpers or assistants for some of these duties may mitigate the reduced throughput.[8] When this data was collected, this centre was not using this grade of staff or skills mix and we are therefore unable to include this staff group in the model.

The question of how many radiographers are needed to provide safe operation on a LA is beyond the scope of this discussion, although errors have been found to increase with increasing work speed.[18] For the purposes of this discussion it is important to differentiate between the concepts of efficiency as it relates to total patient throughout and staffing levels, and optimum working practices as they relate to speed of processing and associated errors.

Skills mix

The role of the radiographer is changing within radiotherapy, the radiographer undertaking specialised tasks within the service as their skills increase.[19] A contributing factor to the low numbers of available radiographers is the retention rate once qualified, on which job satisfaction has a large impact. The developing trend towards professional development is likely to affect the overall numbers

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Table 4. *Costings of linac models*

Assume capital costs as per RCR 1997
Linac = £500 k, lifetime = 10 years, capital cost per annum = 66,000
Bunker = 1,000 k, lifetime = 28 years, cost per annum = 66,786
Radiographers = 25,000 per annum (mid senior II, plus on-costs)

Hours/day	Radiographers	Capital charges	Radiographer salaries	Other costs	Total	Days/ year	Hours/ year	Cost/ hour	
7	2	1,32,786	50,000	1,28,816.3	3,11,602	240	1,680	185	
8	3	1,32,786	75,000	1,45,740	3,53,526	240	1,920	184	
10	3	1,32,786	75,000	1,94,237.5	4,02,024	240	2,400	168	91%
RCR costs per 8-h-day linac	(7-h-day)	10 h							
Physics	74,000	64,750	92,500						
Secretaries	10,000	8,750	12,500						
Nurses	–	–	6,000						
Domestics	–	–	1,500						
Porters	–	–	4,500						
Transport	45,600	39,900	57,000						
Spares	10,000	10,000	12,500						
Drugs	1,440	1,260	1,800						
Blood	250	218.75	312.5						
Imaging	4,500	3,937.5	5,625						
	1,45,790	1,28,816.25	1,94,237.5						

All except spares are assumed to scale.
Note: Medical staffing costs are not included. These will increase for the very extended working day.

of radiographers in the workforce. Staff development would be encouraged by adapting current working practice. Optimising the treatment delivery team to two radiographers per shift supported by an assistant practitioner would enable radiographers' redeployment to specialist areas. Rotating radiographers within shifts to undertake other non-treatment tasks could reduce the stress related to the high technical workload of the treatment radiographer. It should be noted, that this practice does not suggest that only two radiographers are required, but that the role of the radiographer should be clarified to ensure that scarce radiographer skills are not wasted by over deployment or duplication of treatment delivery tasks.

Capacity and complexity

The complexity of radiotherapy treatment contributes to the throughput on a LA, with fewer fractions per hour being achievable for more complex treatments.[14] When modelling for radiotherapy capacity, it is important to include measures of treatment complexity. Although an average throughput of 4.5 fractions per hour have been used for these models, the actual throughput will vary according to the variation in complexities of the treatments being undertaken. A predictive model, the Basic Treatment Equivalence (BTE) is used for Australasian capacity calculations.[15] This has assessed positively for UK use.[14,20] Individual department calculations for determining capacity and therefore working patterns, should include measure of complexity and models of random fluctuations in demand, as outlined by Thomas.[21]

Physicist staffing

The arguments relating to numbers of physicists required for extended treatment days are less clear cut. The IPEM staffing formula[22] is based on numbers of items of equipment, and on numbers of patients treated. At first sight, it would appear that the fewer LAs used to treat the patients, the fewer the number of physicists required. However, experience of departments running extended working days have shown that this is not so, since extra physicists are required to ensure cover at the start and end of the day. Running a 7-h or 8-h-day on a LA enables more efficient use to be made

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of physicist time, since necessary measurements can be scheduled during lunch breaks or at the end of the working day.

Cost of extended working day

Extended working days are not necessarily a cheap solution; some analyses have argued that it is more expensive.[12,23] However a number of departments have made calculations showing it to be cheaper than investing in extra capacity (see table 4) and have made business plans accordingly.

CONCLUSIONS

In this modelling exercise, it is demonstrated that the working pattern requiring the least radiographer time per linac-hour is using radiographers running a 7-h-day in core service hours. Provided part time radiographers are available to cover the lunch breaks, 8-h-days can be achieved as efficiently. Small extensions to the length of the working day beyond this require significant increases in radiographer time per linac-hour. From the parameters examined, it appears that only very large extensions to the working day are efficient in terms of radiographer resources, although in practice, other factors influence the effectiveness of this working practice.

In conclusion, effective and efficient staffing of LAs is a very complex subject, with many variables contributing. However, given the current staffing shortages, and where no other staff group is available to support the treatment process, the most efficient use of trained radiographers is achieved if LAs are run for a 7-h-day or for an 8-h-day if part-time radiographers are available to cover lunch breaks. Assuming radiographers are the scarcest resource, more capacity can be gained by increasing the number of LAs used rather than increasing the length of the working day.

With linac-hour demand projected to rise faster than the rate at which new trained radiographers become available, extended working days are not sustainable without significant change to current work and staffing patterns.

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