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FULL PAPER

The use of radiotherapy, surgery and chemotherapy in the curative treatment of cancer: results from the FORTY (Favourable Outcomes from RadioTherapY) project

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Objectives Radiotherapy, surgery and chemotherapy play key roles in the curative treatment of cancer, alone and in combination. Quantifying their roles is essential for equipment provision and workforce planning. The estimate that 40% of cancer patients are cured by RT has been used extensively to inform and influence policy but is relatively old and warrants review.

Methods Patient, tumour and treatment event data was obtained for the 5 year period from 2009 to 2013, allowing a further 5 years for survival outcomes to be known. We analysed patient-level data on utilisation of surgery, radiotherapy, and chemotherapy in cancer patients in England. Data were sourced from Public Health England, using National Cancer Registrations, the National Radiotherapy Dataset (RTDS) and the Systemic Anti-Cancer Therapy Dataset (SACT). All tumour sites (excluding C44) and ages were included. We analysed three cohorts: all patients [$n = 1,029,569$], patients who

survived 5 years or more [$n = 537,970$] and patients who survived <5 years [$n = 491,599$].

Results Overall cancer-specific 5-year survival was 52%, and in those patients, surgery was the most common curative treatment, with 80% receiving surgery, alone or in combination; radiotherapy was delivered to 39% and chemotherapy to 29%; 45% received two and 13% all three modalities.

Conclusions The high proportion receiving multi-modality treatment emphasises the importance of integrated, resourced, multidisciplinary cancer care. Radiotherapy was delivered to almost 40% of patients who survived 5 years which underlines its importance in cancer management.

Advances in knowledge The results are essential in planning cancer services. They also inform the public health narrative.

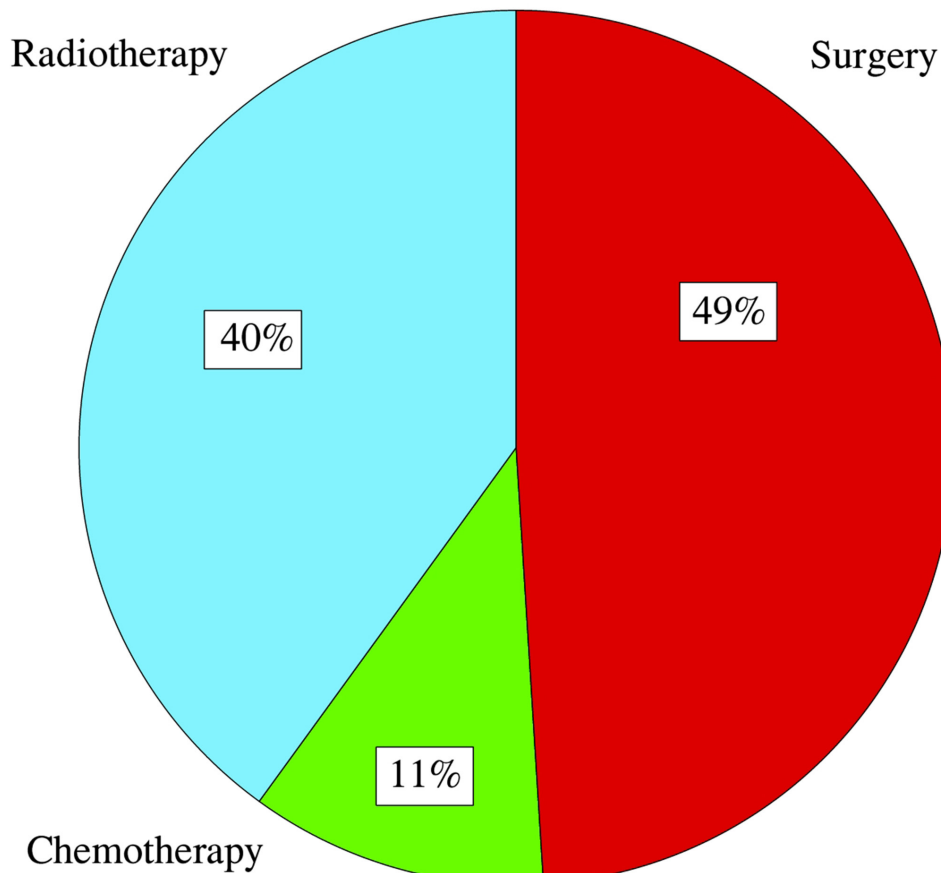
INTRODUCTION

Radiotherapy (RT), surgery and chemotherapy play key roles in the curative treatment of cancer, both individually and in combination.¹⁻⁴ In 1992, it was estimated that RT was the predominant modality involved in the cure of 40% of cancer patients (Figure 1),⁵ with estimated figures for surgery and chemotherapy of 49 and 11%, respectively. These estimates used data from the preceding decade.⁶ However, this estimate of the role of RT in the curative treatment of cancer was the best available, is still used in contemporary literature, and continues to influence policy (for example NHS strategy documents, cancer information and research literature⁷⁻¹⁰).

Cancer management has evolved rapidly since the 1980s, with remarkable technical developments in RT and surgery, alongside discoveries of new drugs, especially cell-cycle checkpoint inhibitors and immune response modifiers. Equally important, the increased integration of multi-modality treatments has structurally modified cancer care, with multi-disciplinary teams providing the basis for treatment decisions on individual patients.

Historically, RT services in the UK have been under-resourced.^{1,11} Thus, quantifying the role of RT, which is used to treat more than 100,000 patients in the UK each year, as well as the two other major treatment modalities,

Figure 1. The three main cancer treatment modalities and their relative contributions as the predominant modality achieving cancer cures, originally recalculated by our group from Tubiana,⁵ and extensively quoted, including in NHS England policy documents.



is critical in approaching future resource planning, with patient outcomes as the key consideration.

Contemporary data are vital for equipment provision, workforce planning, public health messaging and associated research. They are also important for patient confidence and public understanding. Recent improvements in cancer data collection, such as electronic capture of clinical outcome data in real time [e.g. 12], now make new estimates possible.

In this study, we used patient-level data obtained from the National Cancer Registration and Analysis Service (NCRAS), linked to treatments delivered and to survival at 5 years, to assess the role of the three key treatment modalities. Thus, the analysis uses real treatment and outcome data rather than estimates or assumptions.

METHODS

Data were obtained for a 5-year period, 2009 to 2013, allowing a further 5 years for survival outcomes to be known. The most recent cohort available was used in order to reduce as far as possible the effects of changes in technology and practice, accepting that some major developments would certainly have occurred after the collection period. During the collection period, the change from conformal RT to intensity-modulated RT (IMRT) was in progress but not complete, and Stereotactic Ablative Body

Radiotherapy (SABR) and four-dimensional (4-D) CT imaging were being deployed. Surgical techniques were also developing and new drugs were entering the therapeutic arena. However, change in each of the specialties is a continuous process, with no start or finish time points.

The utilisation of surgery, radiotherapy and chemotherapy was analysed in cancer patients in England, whose outcomes at 5 years were known, to provide evidence-based estimates of the role of the three major modalities in achieving 5-year survival. For some tumour types, although not all, 5-year survival is a reasonable surrogate for long-term survival or cure. This methodology can be applied beyond England and could be used for a repeat analysis in due course.

Study design

In this retrospective, population-based study we analysed all patients (including both children and adults, with solid and liquid tumours) diagnosed with their first and only tumour in England over the 5-year period from 2009 to 2013. Patients who developed a second tumour during the 5-year collection period were therefore excluded. These data included 5-year follow-up data for all cancer treatment events and vital status updates. The data were analysed in three patient cohorts:

- (1) All cancer patients,
- (2) Cancer patients who survived for five years or more after diagnosis, and
- (3) Cancer patients who survived for less than five years after diagnosis.

The study received ethical approval from the NHS Research Ethics Committee [Reference number 19/SC/0484]. Our title derives from the Tubiana estimate⁵ and was developed prospectively at the start of the project when there was considerable variation in expected results between the authors.

Data sources

The data were sourced via a data request to Public Health England's Office for Data Release (now part of NHS-Digital). Public Health England (PHE) routinely collects data on the diagnosis and treatment of patients with cancer within the NHS under section 251 of the Health and Social Care Act (2006). In England, the National Cancer Registration and Analysis Service (NCRAS) collects and quality assures cancer data.¹³ Radiotherapy data are collected by the National Radiotherapy Dataset (RTDS). Chemotherapy data are collected by the Systemic Anti-Cancer Therapy Dataset (SACT); data were available through this portal although the collection was mandated only in 2014.¹⁴ We define chemotherapy as cytotoxic treatment using, typically, older drugs and have excluded use of newer targeted agents such as tyrosine kinase inhibitors, cell cycle check point inhibitors and immune response modifiers. Although the use of these agents had started during our collection period, their use was modest and recording incomplete.

Data were extracted for all patients diagnosed with a tumour (International Classification of Diseases (ICD-10) list table - see Supplementary Data – ICD-10 groups). The dataset consisted of patient data, tumour data and treatment event data. [Supplementary Table 1](#) [Data items] presents the full data item list and data tables provided by PHE.

Data analysis

All data analysis was undertaken using R [version 4.1.3]; full R code and packages can be found in [Supplementary File \[R code\]](#) and [Supplementary Table 2](#) [R versions]. The records from the different tables are joined by pseudo-patient IDs. The records are not linked by pseudo-tumour IDs due to the nature of the extraction and pre-processing undertaken by PHE.

In order to capture all treatments, and not only the primary ones, any treatment event within the 5-year data follow-up was included. This methodology is important to capture salvage treatments: for example, a male with prostate cancer, managed initially by Active Surveillance, may relapse and be treated with salvage surgery or RT.

The percentages of patients treated do not add up to 100% because there are more treatment events recorded than only surgery, RT and chemotherapy: these include, for example, specialist palliative care, immunotherapy or active surveillance, and some patients did not receive any treatment at all. However, data on these additional management strategies are

incomplete, and so here we restricted our focus to the three main treatment modalities. The treatment intent records were far from complete and therefore treatment intent could not be included. Other treatment approaches, including active surveillance (such as for low-risk prostate cancer), may not have been routinely recorded. Newer treatments, such as immunotherapy, were not prescribed as frequently as today, their recording is incomplete, and they have therefore not been considered further.

The key steps for generating the patient cohorts are as follows (see also [Supplementary Figures 1s and 2s](#)): (In this list, steps 1-5 match steps 1-5 in Supplementary Figure 1s, step 6 is shown in Supplementary Figure 2s, and step 7 matches steps 6-10 in Figure 1s.)

- (1) Exclude ICD-10 code C44 patients (a large mixed group of non-melanoma skin cancers), although some will have been managed by surgery or radiotherapy.
- (2) Combine patient information with tumour information.
- (3) Exclude patients without a clear alive or dead vital status.
- (4) Exclude patients who died from causes other than their cancer diagnosis, to provide data on cancer-specific survival = step four in [Supplementary Figure 1](#).
- (5) Exclude patients who have a tumour diagnosis outside of our diagnosis period and any patient with a second tumour.
- (6) Add the treatment data to the remaining patient records, or add a record stating N/A if the patient had no treatment record.
- (7) Additional cohort-dependent step: separate patients who did not survive 5 years and those who survived at least 5 years.

After filtering, the whole cohort contained 1,029,569 patients. The patient and tumour tables consisted of 1,974,952 records each, and the treatment event table consisted of 6,538,857 event records. These event records were complemented by separate RTDS and SACT data on 467,479 and 122,771 patients, respectively.

Some patients may have received radiotherapy or chemotherapy without this event being recorded in the treatment table. For this scenario, we analysed the separate radiotherapy and chemotherapy data tables to identify and include patients who have treatment records in those data tables but not in the treatment table. Those patients had a new record created in the treatment table to show they did in fact receive radiotherapy or chemotherapy or both.

After generating the three cohorts, patients were categorised into surgery, radiotherapy and chemotherapy groups according to their treatment records. These groups are not mutually exclusive: if Patient A has both a radiotherapy and chemotherapy treatment record, they appear in both groups. These three treatment groups were then interrogated to count the number of patients in each treatment group individually and in multiple groups indicating multi-modality treatment. This process was repeated for the separate cohorts (see also [Supplementary Figure 2](#)).

Table 1. The contribution that each modality made to the treatment of patients diagnosed between 2009–2013 with their first and only tumour. Data are shown separately for patients who survived less than 5 years and those who survived for 5 years or more.

Modality	All patients (N = 1,029,569)		Patients survived less than 5 years (N = 491,599)		Patient survived at least 5 years (N = 537,970)	
	N	% of patients	N	% of patients	N	% of patients
Surgery	655,322	64%	224,072	46%	431,250	80%
Radiotherapy	358,382	35%	150,450	31%	207,932	39%
Chemotherapy	322,900	31%	168,978	34%	153,922	29%
Surgery and/or Radiotherapy and/or Chemotherapy a	808,413	79%	322,648	66%	485,765	90%

^aAlso shown in Table 2.

RESULTS

For the whole cohort of 1,029,569 patients with ‘any’ survival length, 79% had at least one record of surgery, radiotherapy or chemotherapy. For these patients, 64% received surgery alone or in combination with the other two modalities. Radiotherapy was delivered to 35% alone or in combination, and chemotherapy to 31% alone or in combination (Table 1); 39% of the whole cohort of patients received single modality treatment and 40% received multi-modality (two or three modality) treatment.

The cohort who survived at least 5 years accounted for 52% of the primary cohort, providing an overall estimate of cancer-specific 5-year survival. Among these 537,970 patients, 90% had at least one record of surgery, radiotherapy or chemotherapy (Tables 1 and 2). Some additional patients (totalling 2%) are known to have been managed by active surveillance or hormone therapy; some are known to have received immunotherapy alone, or indeed no treatment; some will also have been treated within formal NHS overseas programmes, such as the Proton Overseas Programme. It is likely that some patients may have received uncommon specialist treatments such as radiofrequency

ablation, cryotherapy or radio-isotope therapy, and a few may have received specialist palliative care. Some may have been treated privately. The dataset does not contain details of these.

More patients who survived 5 years had active treatment with these three modalities than in the whole cohort (90% vs 79%), which will have included patients requiring palliative and supportive care. For these 5 year survivors, surgery was the most common curative treatment modality, with 80% receiving surgery, either alone or in combination with the other modalities. Radiotherapy was delivered to 39% of patients and chemotherapy to 29% (Table 2 & Figure 2); 46% of patients received single modality treatment and 45% received multi-(two or three) modality treatment. Importantly, 13% received all three modalities.

For patients surviving at least 5 years, only 10% received treatment without surgery (Table 2 & Figure 2). Of the patients treated with surgery, over half (53%) also received RT or chemotherapy or both. Slightly more patients received radiotherapy alone compared to chemotherapy alone. However, these figures

Table 2. Number of patients for single and multi-modality treatment who were diagnosed between 2009 and 2013 with their first and only tumour. See also Figure 2.

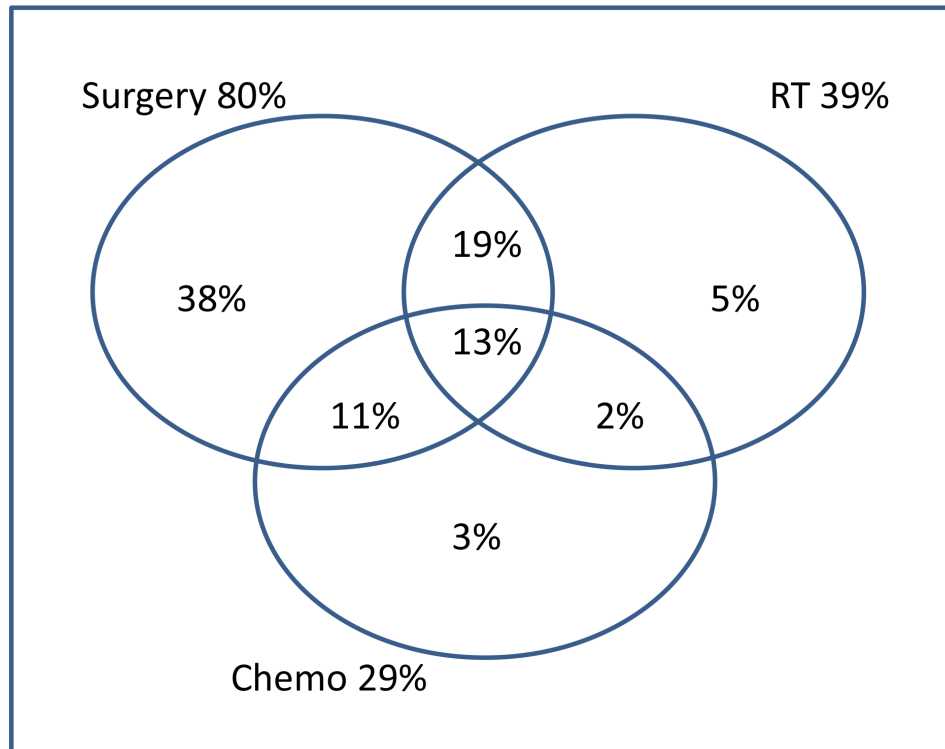
Modality	All patients (N = 1,029,569) ^a		Patients survived less than 5 years (N = 491,599) ^b		Patient survived at least 5 years (N = 537,970) ^c	
	N	% of patients	N	% of patients	N	% of patients
Surgery only	286,903	28%	84,046	17%	202,857	38%
Radiotherapy & Surgery	136,502	13%	36,709	7%	99,793	19%
Radiotherapy & Surgery & Chemotherapy	119,453	12%	51,064	10%	68,389	13%
Surgery & Chemotherapy	112,464	11%	52,253	11%	60,211	11%
Radiotherapy only	62,108	6%	32,915	7%	29,193	5%
Chemotherapy only	50,664	5%	35,899	7%	14,765	3%
Radiotherapy & Chemotherapy	40,319	4%	29,762	6%	10,557	2%
Surgery and/or Radiotherapy and/or Chemotherapy	808,413	79%	322,648	66%	485,765	90%

^a51,458 (5%) have a treatment unknown record without a Surgery, RT or Chemo record

^b39,328 (8%) have a treatment unknown record without a Surgery, RT or Chemo record

^c10,759 (2%) have a treatment unknown record without a Sur, RT or Chemo record

Figure 2. Percentages of patients who survived at least 5 years and who received at least one episode of surgery, radiotherapy or chemotherapy, individually or as part of multi-modality treatment, diagnosed with their first and only tumour from 2009 to 2013 [data from Table 2]. The percentages shown in the individual sectors add up to 90%, allowing for rounding, which is the percentage who received treatment with one or more of these modalities. Note that the total for surgery is 80% [Table 1], rather than 81% reached by summing the individual sector numbers, also due to rounding. If the patient treatments shown here, for the 90% of the 5 year survivors who have a treatment record, are normalised to 100% to address only the three main treatment modalities, these figures increase to 89%, 43 and 32% for surgery, RT and chemotherapy respectively (e.g., 80% x 100/90).



(5% and 3%, respectively) are dramatically less than those for combined treatments for the two modalities (34% had radiotherapy combined with surgery or chemotherapy or both and 26% had chemotherapy combined with surgery or radiotherapy or both). This underlines the increasing multi-modality approach to curative treatment.

The cohort who did not survive 5 years accounted for 48% of patients (491,599). Only 66% of these had at least one record of surgery, radiotherapy or chemotherapy. This suggests a lower usage of these modalities compared to those who survived at least 5 years (Table 1). Surgery was still the most common treatment, with 46% receiving surgery either alone or in combination. Radiotherapy was delivered to 30%. Chemotherapy was the only modality with higher usage compared to the 5 year survivors (34% compared to 29%). More patients received multi-modality (44%) than single modality (31%) treatment.

DISCUSSION

This analysis of the use of radiotherapy, surgery and chemotherapy is based on a 5 year cohort of more than 1 million patients, all treated within NHS England. The primary objective was to provide estimates of the usage, and interconnections, of the three main treatment modalities. This information is critical in planning national resources.

The data previously available from Tubiana⁵ (Figure 1) have been widely used for national strategies but are relatively old and warranted updating. There are no other equivalent, modern, international studies with which to compare our results. Most studies which look at treatment options together with survival are from clinical trials or evaluations of data collected during trials. These studies take into account only highly selected cohorts of patients rather than all 'real world' cancer patients, irrespective of factors such as age, performance status, stage or co-morbidities. This is the first study based on fully traceable data and provides estimates of the contribution of each modality to actual survival. This methodology can be referenced in service documents when developing policy and provides a framework for future updates which can be used internationally. We suggest the exercise should be repeated every 10 years and that efforts are made to increase the completeness of the data captured, including treatment intent.

We chose to combine cancer diagnosis with robust data for survival outcome as a way of providing harder estimates of cure than were available previously.⁵ We chose 5-year survival from initial diagnosis as the survival endpoint, as a balance between long enough follow up while using the most recent possible cohort of treated patients. 'Cure' implies complete and lasting remission. Some patients in complete remission can relapse

beyond 5 years; others may have relapsed before 5 years but still be alive; some may even have received palliative treatment at the outset and still be alive.

Five-year survival can nevertheless provide an effective surrogate for survival for some cancers although by no means all. However, using 5-year survival from initial diagnosis, we have data at a well-defined time-point that is easily interpretable in a cohort managed using the most recent treatments available. Clearly, from analysis of the data items to which we have access, it is impossible to guarantee that a patient was actually cured. No time-frame limitation from diagnosis was placed on treatment events over the 5-year follow-up because this would artificially limit the number of treatments which could have contributed to a patient's survival. By including all treatments we aim to calculate figures that are more relevant to what a health service actually delivers rather than just initial primary treatments. It also allows the inclusion of patients initially managed with active surveillance who require treatment later during follow-up.

Of the 5-year survivors, 90% were treated with surgery, radiotherapy, chemotherapy or both. The proportion of patients receiving surgery or radiotherapy (either alone or in combination) is greater in the cohort who survived 5 years compared to the cohort who did not (80% vs 64% for surgery, 39% versus 35% for RT) (Tables 1 and 2); chemotherapy had a slightly lower usage in patients who survived 5 years (29% vs 34%). The percentage of 5-year survivors with surgery as a part of their treatment is high (80%). This figure includes some patients whose surgery is likely to have been biopsy only. However, histological diagnosis is crucial in almost all tumours. In some cases, such as intra-cranial disease, biopsy is a significant surgical undertaking. Patient-friendly access to timely surgical and operating theatre resources is an essential part of comprehensive cancer care. These figures indicate the central role of surgery in cancer cures but also emphasise the crucial curative roles played by both radiotherapy and chemotherapy. The fact that radiotherapy contributes to 5-year survival in almost 40% of patients, is a critical conclusion which must be addressed in policy development.

Although slightly more patients surviving 5 years received RT alone than chemotherapy alone (5% and 3%), both modalities were used much more in combination (34% and 26%, respectively) (Table 2 & Figure 2), including 45% in some combination and 13% for trimodality treatment, that is more than 1 in 8 patients. These figures are likely to still be increasing and underline the multi-modality approach to curative treatment and therefore the importance of adequate provision of services in all three modalities.

When comparing the cohort who survived 5 years to the cohort that did not, the use of surgery alone was strikingly higher, 38% rather than 17%. This is likely a reflection of a smaller role for surgery in the palliative setting. Also notable were the higher use of surgery with RT and with both RT and chemotherapy (19% vs 7% and 13% vs 10%, respectively).

In the cohort that did not survive 5 years, the use of chemotherapy alone was more than double (7% vs 3%), RT alone slightly higher (7% vs 5%), and bi-modality treatment with RT and chemotherapy was treble (6% vs 2%), compared to the 5-year survivors. Multi-modality treatments were used in 34% of patients and single-modality in 31%.

10% of patients who survived 5 years did not have a record of surgery, radiotherapy or chemotherapy. This does not mean they received no active management: some (2%) are known to have been managed by active surveillance and/or hormone therapy. There are also some 'Treatment Unknown' records, but only 2% in this cohort. Some are known to have received immunotherapy, and some had no treatment; some may have received specialist treatments such as radiofrequency ablation, cryotherapy or radioisotope therapy. A few patients may have received non-specialist palliative care and still survived for more than 5 years. Some may also have received private treatment, whose data are not collected in this data set, or treatment abroad under formal NHS overseas programmes, such as the Proton Overseas Programme which started in 2008. These NHS programmes do have treatment and follow-up data returned, collected and analysed although this is not within the RTDS at present^{12,15}; although important, such programmes include only small numbers of patients. Thus, there are some treatments whose details are not collected and therefore cannot be quantified.

The finding of 52% 5-year survival must be compared carefully with outcomes from other sources. Our figures give the raw cancer-specific survival rates of the cohort in our study. Often, survival rates are age-standardised for comparison and include adjustments for background mortality (net survival). For our cohort, we did exclude patients who died within 5 years of diagnosis with an underlying cause of death that was not cancer-related, but life tables were not used to estimate net-survival. The closest comparison to our raw survival figures is a population-based study which predicted the 5-year age-standardised net-survival of adults in England to be 54.3% for 2010–2011¹⁶ although they looked only at ages 15–99. National bodies in England, such as the Office for National Statistics and NCRAS, only publish survival statistics broken down by cancer site. Outcomes had been steadily improving year on year so it is likely that the raw survival rates of patients diagnosed today could be a little better than in our cohort diagnosed as early as 2009. These improvements may be driven by early diagnosis schemes, multi-disciplinary decision-making, more sophisticated technology such as image-guided intensity-modulated RT, and multi-modality treatment. A few patients in our cohort may have benefited from newer medical treatments, such as immunotherapy.

Although the objectives are similar, our results are not directly comparable to the well-cited figures from Tubiana.⁵ Firstly, Tubiana estimated the percentage of patients *predominantly* cured by each modality; he did not take into account multi-modality treatment, which has progressed dramatically since 1992, although he recognised the start of this progression, even stating that his figures were tentative due to this. It is likely that the increase in chemotherapy use, from Tubiana's 11% to 29%

here is the result of our counting adjuvant treatment, which may not have been the predominant curative modality for Tubiana, but which nevertheless contributes to cure. Moreover, there is now greater use of adjuvant chemotherapy than at the time of Tubiana's estimates. Developments in surgical techniques may now allow more surgery than in the era of Tubiana's data but it is hard to be definitive about this. The distinction between biopsy and resection is also not clear in our data which may be important and our 80% figure, double Tubiana's, is likely to include some patients who had biopsy only. Secondly, Tubiana was able to provide only estimated "cures" in his figures, whereas we have used hard 5-year survival outcome data. His figures were based on results published in the preceding decade⁶ using 1980s data from the SEER programme, which at the time covered only 10% of the US population. In short, the estimate that 40% of cancer patients are cured by RT is based on old and relatively incomplete data. Despite these shortcomings, these estimates have influenced, and still influence, policy [e.g. 7–10].

Information which demonstrates the central role of any of the key treatment modalities is vital for future planning. We report here figures for the actual usage of the three main treatment modalities, along with individual patient outcomes. However, actual usage does not necessarily equate to optimal usage, which is considered to be around 50%.^{17,18} Using data from 2012, collected within the span of our data collection, as part of the HERO project (Health Economics in Radiation Oncology), Borrás et al¹⁷ showed significant discrepancies between optimal and actual RT usage. Of 24 European countries, the UK was in the lower half of optimal/actual usage: the overall UK figure for RT utilisation was 35.5%, compared to estimated optimal usage in the range 53.0–54.4%. This figure of actual usage closely matches our figure for RT use of 35% overall (Table 1).

Another estimate of the overall usage of the three main modalities has been published comparatively recently based on data from 2013 to 2016 in England.¹⁹ However, the estimates of the use of both surgery (45%) and RT (27%) are considerably lower than ours (64% and 35%) (Table 1). Even overall usage of chemotherapy was slightly lower at 28% (cf. 31%). No details of methodology were given and there are no associated outcome data. The RT estimate is also out of line with the ESTRO HERO project data noted above.¹⁷

The UK Government recently announced that NHS England is to have a single all-embracing strategy for all major conditions, including cancer. Without a dedicated plan, and after more than a decade of declining funding for cancer, services are likely to fragment and inequalities widen, leading directly to lost lives.^{20,21} Within this framework, it is highly likely that a specialist and often poorly understood service, such as RT, which has been under-resourced in the past,^{1,11} may not receive appropriate resourcing. Thus, quantifying the role of RT, which is used to treat more than 100,000 patients in the UK each year, as well as the two other major treatment modalities, is critical in approaching future resource planning, with patient outcomes as the key consideration. Cancer data play a crucial role in health service planning and research, especially when treatments

prescribed and received are combined with patient outcomes. We suggest that efforts are made to increase the completeness of the data captured, including treatment intent, and that the exercise should be repeated every 10 years.

Limitations of the study

We excluded ICD-10 code C44 patients (a mixed group of non-melanoma skin cancers) although some will have been managed by surgery or radiotherapy. This category is large and accounts for most of the difference in numbers between the known overall cancer incidence (circa 320,000–340,000 cases per annum²²) and the approximate 200,000 cases per annum (1,029,569 in 5 years) in our cohort. This will have led to some underestimate of numbers treated, often cured, by surgery and RT, individually or together, but allowed a clearer picture of treatment of more malignant tumours.

Missing or incomplete data is an issue for this type of study. While NCRAS collect and link data from multiple sources within the NHS, from hospital provider level up to national datasets, the datasets used to create the patient, tumour and treatment tables, are not entirely complete. Before 2016, the RTDS database was maintained outside of NCRAS who therefore cannot comment on historical completeness. However, the numbers of 'Treatment Unknown' records is modest: in the overall cohort, 5% have a record without a Surgery, RT or Chemo entry (8% for those surviving less than 5 years and only 2% for those surviving 5 years or more) (Table 2). Information is available for a further 2% but less common treatment modalities are not recorded fully and therefore cannot be quantified.

Previously, including in our collection period, collection of SACT data was not mandated. Indeed, this information was mandated only from 2014.¹⁴ This means our calculated chemotherapy numbers are likely to be underestimates, although we cannot say by exactly how much. However, we included the SACT data because of the relevance, especially of combination treatment. We defined chemotherapy as cytotoxic treatment and excluded newer targeted agents because data for these are incomplete. However, usage was still relative low during our collection period. Despite these reservations, the data used here are much more complete and with a broader coverage than Tubiana's.⁵

CONCLUSIONS

The proportion of patients receiving multi-modality treatment (45%) emphasises the importance of coordination in providing integrated multidisciplinary care. The results that 80% of 5-year survivors received surgery and 29% chemotherapy are important. The finding that radiotherapy was delivered to almost 40% of patients who survived 5 years is a critical message.

Data sharing

The data used in this study were obtained through a specific data request to Public Health England. The service is now part of NHS-Digital. Patient-level data can be requested via the National Data Registration service. <https://www.ndrs.nhs.uk/dataaccess/>

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REFERENCES

- Bentzen SM, Heeren G, Cottier B, Slotman B, Glimelius B, Lievens Y, et al. Towards evidence-based guidelines for radiotherapy infrastructure and staffing needs in Europe: the ESTRO QUARTS project. *Radiother Oncol* 2005; **75**: 355–65. <https://doi.org/10.1016/j.radonc.2004.12.007>
- International Agency for Research on Cancer (IARC). 2011. GLOBOCAN 2008. Available from: <http://globocan.iarc.fr/factsheets/cancers/all.asp> (accessed 14 Apr 2023)
- Overgaard J. Radiotherapy: gazing at the crystal ball of European radiotherapy. *Nat Rev Clin Oncol* 2015; **12**: 5–6. <https://doi.org/10.1038/nrclinonc.2014.205>
- Scaife JE, Barnett GC, Noble DJ, Jena R, Thomas SJ, West CML, et al. Exploiting biological and physical determinants of radiotherapy toxicity to individualize treatment. *Br J Radiol* 2015; **88**: 20150172. <https://doi.org/10.1259/bjr.20150172>
- Tubiana M. The role of local treatment in the cure of cancer. *Eur J Cancer* 1992; **28A**: 2061–69. [https://doi.org/10.1016/0959-8049\(92\)90256-2](https://doi.org/10.1016/0959-8049(92)90256-2)
- DeVita VT. Progress in cancer management. *Cancer* 1983; **51**: 2401–9. [https://doi.org/10.1002/1097-0142\(19830615\)51:12<2401::AID-CNCR2820511302>3.0.CO;2-7](https://doi.org/10.1002/1097-0142(19830615)51:12<2401::AID-CNCR2820511302>3.0.CO;2-7)
- International Atomic Energy Agency (IAEA). *Radiotherapy In Cancer Care: Facing the Global Challenge*. 2017. Available from: https://www-pub.iaea.org/MTCD/Publications/PDF/P1638_web.pdf (accessed 14 Apr 2023)
- NHS England Service Specification - Adult External Beam Radiotherapy Services Delivered as Part of a Radiotherapy Network 2019. Available from: <https://www.england.nhs.uk/wp-content/uploads/2019/01/External-Beam-Radiotherapy-Services-Delivered-as-Part-of-a-Radiotherapy-Network-Adults.pdf> (accessed 14 Apr 2023)
- Australian. *Radiation Oncology Targeting Cancer: What is Radiation Oncology – Benefits and Effectiveness* 2020. Available from: <https://www.targetingcancer.com.au/about-radiation-oncology/benefits-and-effectiveness/> (accessed 14 Apr 2023)
- Scottish government. *National Radiotherapy Plan 2022*. Available from: <https://www.gov.scot/publications/national-radiotherapy-plan-scotland/> (accessed 14 Apr 2023)
- Burnet NG, Benson RJ, Williams MV, Peacock JH. Improving cancer outcomes through radiotherapy: lack of UK radiotherapy resources prejudices cancer outcomes. *BMJ* 2000; **320**: 198–99. <https://doi.org/10.1136/bmj.320.7229.198>
- Hwang E, Burnet NG, Crellin AM, Ahern V, Thwaites DI, Gaito S, et al. A novel model and infrastructure for clinical outcomes data collection and their systematic evaluation for UK patients receiving proton beam therapy. *Clin Oncol (R Coll Radiol)* 2022; **34**: 11–18. <https://doi.org/10.1016/j.clon.2021.09.010>
- Henson KE, Ellis-Brookes L, Coupland VH, Payne E, Vernon S, Rous B, et al. Data resource profile: National cancer registration Dataset in England. *Int J Epidemiol* 2020; **49**: 16–16h. <https://doi.org/10.1093/ije/dyz076>
- Bright CJ, Lawton S, Benson S, Bomb M, Dodwell D, Henson KE, et al. Corrigendum to: data resource profile: the systemic anti-cancer therapy (SACT) Dataset. *Int J Epidemiol* 2020; **49**(1): 354. <https://doi.org/10.1093/ije/dyz249>
- Burnet NG, Mackay RI, Smith E, Chadwick AL, Whitfield GA, Thomson DJ, et al. Proton beam therapy: perspectives on the national health service England clinical service and research programme. *Br J Radiol* 2020; **93**: 20190873. <https://doi.org/10.1259/bjr.20190873>
- Quaresma M, Coleman MP, Rachet B. 40-year trends in an index of survival for all cancers combined and survival adjusted for age and sex for each cancer in England and Wales, 1971–2011: a population-based study. *Lancet* 2015; **385**: 1206–18. [https://doi.org/10.1016/S0140-6736\(14\)61396-9](https://doi.org/10.1016/S0140-6736(14)61396-9)
- Borras JM, Lievens Y, Dunscombe P, Coffey M, Malicki J, Corral J, et al. The optimal utilization proportion of external beam radiotherapy in European countries: an ESTRO-HERO analysis. *Radiother Oncol* 2015; **116**: 38–44. <https://doi.org/10.1016/j.radonc.2015.04.018>
- Lievens Y, Borras JM, Grau C. Provision and use of radiotherapy in Europe. *Mol Oncol* 2020; **14**: 1461–69. <https://doi.org/10.1002/1878-0261.12690>
- Public Health England. *Chemotherapy, Radiotherapy and Surgical Tumour Resections in England*. 2020. Available from: <https://www.gov.uk/government/statistics/chemotherapy-radiotherapy-and-surgical-tumour-resections-in-england/chemotherapy-radiotherapy-and-surgical-tumour-resections-in-england> (accessed 24 Jul 2023)
- Sullivan R, Aggarwal A. Proposal to scrap England's long term plan for cancer. *BMJ* 2023; **380**: 326. <https://doi.org/10.1136/bmj.p326>
- Kings Fund 2011 Available from: <http://www.kingsfund.org.uk/sites/files/kf/How-to-improve-cancer-survival-Explaining-England-poor-rates-Kings-Fund-June-2011.pdf> (accessed 14 Apr 2023)
- Cancer Research UK Cancer Statistics Available from: <https://www.cancerresearchuk.org/health-professional/cancer-statistics/survival> (accessed 14 Apr 2023)