

Radiotherapy Board

Intensity Modulated Radiotherapy (IMRT) in the UK: Current access and predictions of future access rates

July 2015

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1. Foreword

We are grateful to Dr Staffurth and the team for their review of clinical practice and for recommendations for the implementation of IMRT. The Royal College of Radiologists, Society and College of Radiographers and the Institute of Physics and Engineering in Medicine^a regard it as essential that, for the whole of the UK, we achieve cancer survival rates equivalent to the best in Western Europe. Improving the quality of radiotherapy is a key component of increasing survival rates along with initiatives to achieve earlier diagnosis. We expect an increasing demand for radiotherapy as the population ages. Highest quality of technical radiotherapy with respect to planning and delivery will maximise cancer survival, minimise late effects and achieve the optimum therapeutic ratio.

The target of 24% of patients treated by inverse-planned IMRT provided a starting point for the UK which, until recently, was significantly behind most other Western European countries with respect to IMRT implementation. For most departments the 24% target reflects the majority of patients with head and neck, and prostate, cancers being treated with IMRT. However, as discussed in this document, there are many other patient groups for whom IMRT would provide clinical benefit.

IMRT represents a new paradigm in planning and delivery. Looking at comparisons with international experience, it is inevitable that IMRT will take over from 3-dimensional conformal radiotherapy as the standard paradigm for radiotherapy planning and delivery which, together with a range of advanced radiotherapy technologies, will represent a new era in technical radiotherapy. This report's conclusions on future usage of IMRT is consistent with previous UK-based estimates that approximately 50% of radically treated patients would benefit from IMRT. This is a global estimate of future usage derived from all English centres and should not be used as a target.

The Royal College of Radiologists, Society and College of Radiographers and the Institute of Physics and Engineering in Medicine have considerable experience of working together and will work enthusiastically with health administration bodies and commissioners throughout the UK to establish IMRT or other advanced radiotherapy modalities as the new standard for the majority of patients treated by radical radiotherapy.

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^a These three professional bodies form the core membership of the Radiotherapy Board. The role of the Radiotherapy Board is to provide guidance, oversight and support for the continuing development of high-quality radiotherapy services for cancer patients in the UK.

2. Glossary of terms

Class solution is the term used in radiotherapy planning for complex techniques such as IMRT. The treatment planning systems are semi-automated based on previous patients' treatment plans to efficiently produce optimal treatment plans for each new patient.

Episode of radiotherapy is the term that describes a course of radiation given during the entire pre-planned period of care as covered in the original treatment intent. Such episodes may be delivered in one attendance or multiple attendances over many weeks (eg. multiple phases of treatment, treatment to multiple sites given concurrently or consecutively or split courses of radiotherapy).

External Beam Radiotherapy Treatment (EBRT) is the most common form of radiotherapy in current use. Treatment is delivered using a machine that generates an external source of radiation that is aimed at/delivered to a particular part of the body. The term 'radiotherapy' in this document refers to this type of treatment.

Fraction of radiotherapy is the term for the dose of radiotherapy delivered at each visit to the treatment machine. Radiotherapy is often divided into a number of small doses called fractions, which are usually given each day Monday to Friday over a number of weeks.

Hypo-fractionated Radiotherapy is the term for a course of radiotherapy where a smaller number of fractions delivers a higher dose of radiation at each fraction than during conventional courses of radiotherapy.

Image Guided Radiotherapy (IGRT) is the use of images taken to ensure that radiotherapy is delivered precisely as planned and allow adjustments to the treatment if necessary. Before, and sometimes during, a course of radiotherapy, images are acquired to ensure the treatment accurately targets the area requiring treatment. This may involve taking x-ray images or moving the machine to get an image similar to a Computed Tomography (CT) scan. The images are then compared to those taken during the radiotherapy planning process.

Intensity Modulated Radiotherapy (IMRT) shapes the radiotherapy beams and allows different doses of radiotherapy to be given to different parts of the treatment area. This limits the dose of radiotherapy received by healthy tissue, particularly healthy tissue that is more easily damaged by radiotherapy. As a result, immediate and long-term side effects are reduced.

Quality Assurance (QA) is the term used in radiotherapy to describe all the checks and procedures that ensure that the delivery of radiation as a therapeutic intervention is safe and consistent.

Planning target volume (PTV) is a geometric concept, used for treatment planning, and it is defined to select the most appropriate treatment technique, beam arrangements and beam sizes to ensure that the prescribed dose is delivered to the tumour.

Radiotherapy Trials Quality Assurance (RTTQA) is the term used to describe the QA processes used within clinical trials involving radiotherapy. In the UK, the RTTQA group is closely aligned with the various National Cancer Research Institute (NCRI) Clinical Studies Groups and the Clinical and Translational Radiotherapy Research Working Group (CTRad). It has supported the uptake of new radiotherapy technologies in the UK.

Stereotactic Ablative Body Radiotherapy (SABR) is the delivery of curative doses of radiotherapy using advanced IGRT and extremely short fractionation schedules.

Volumetric modulated arc therapy (VMAT) is a form of inverse-planned IMRT in which the radiotherapy is delivered continuously as the treatment machine rotates around the patient. It is generally associated with a shorter delivery time and a more conformal dose distribution for the same level of target coverage.

3. Executive Summary

- 3.1** The rising incidence of cancer, the ageing population and the drive towards earlier diagnosis will continue the increase in patients being treated with radical radiotherapy.
- 3.2** The increased complexity of radiotherapy increases the chance of cure, reduces the risk of side effects and opens up a curative option to patients not previously considered for radical therapy. Costs include increased patient preparation, outlining, planning and delivery times.
- 3.3** IMRT is one of these technologies and offers clinical benefit for multiple tumours, predominantly due to increased conformality of the high dose volume to the PTV and/or reduced dose inhomogeneity.
- 3.4** The predominant clinical benefit is reduced toxicity, which has been proven in multiple studies and randomized controlled trials for multiple clinical scenarios. Further confirmatory trials are not required.
- 3.5** Improved tumour control is expected if PTV coverage is improved or if safe dose escalation becomes feasible, but this has not been definitely established in clinical trials.
- 3.6** Centres should aim to implement IMRT for all tumour sites that local clinical teams feel would gain clinical benefit. However, there are other developments in radiotherapy occurring at the same time that may offer equal or higher levels of clinical benefit for a given tumour site. For example, some tumour sites will benefit more from IGRT than IMRT and local teams may prefer to implement IGRT first.
- 3.7** The UK has been relatively slow to implement IMRT, but initiatives over the past five years have partially addressed this. English access rates for inverse-planned IMRT now exceed the initial 2009 target (24% accessing inverse-planned IMRT), with 35% of all radical episodes in England treated with IMRT in March 2014.
- 3.8** There is still a wide variation in access rate by centre, with four centres not achieving this 24% target by February 2014 and five centres exceeding 40%.
- 3.9** The majority of patients being treated have prostate or head and neck (H&N) cancer, with 88% and 78% respectively of the national population being treated with IMRT; there is relatively consistent access to IMRT between centres for these tumour sites.

- 3.10** A few centres have low access for H&N cancer which is unacceptable and patients should be referred to other centres. The most immediate priority is that no locally advanced H&N cancer patients should be irradiated in the UK without being offered IMRT.
- 3.11** Prostate and H&N cancer have the highest level of clinical data, accruing over many years, supporting the use of IMRT. They have also been the subject of multiple UK-based clinical trials supported by the RTTQA group and were the tumour sites selected by most centres undergoing National Cancer Action Team (NCAT)-funded IMRT training and support.
- 3.12** There is greater variation in use of IMRT for the other major cancer types and in all cases centres range from treating 0% to 100% of their patients with IMRT.
- 3.13** This is likely to change rapidly as IMRT becomes more routine and national trials, with their associated RTTQA programs, in other tumour sites are developed. Current examples include INPACT (penile cancer), SCOPE2 (oesophageal cancer), SCALOP2 (pancreatic cancer) and INTERLACE (cervical cancer).
- 3.14** The additional cost of treating an individual patient with IMRT will vary between different clinical scenarios and with the experience of the treating team. Generally, as experience increases, unit cost will decrease as educational levels improve, class solutions are developed, VMAT is introduced and per patient QA is reduced. As IMRT becomes routine, lower banded staff may do more of the planning and QA tasks. However, this will be balanced by the high costs associated with the implementation of IMRT for new clinical scenarios.
- 3.15** IMRT enables other developments such as safe hypofractionation, radical treatment of patients who previously could only be treated palliatively, and safe and efficient subvolume boosting based on functional imaging.
- 3.16** We estimate that centres should be planning for approximately 50% of their total radical episodes to be delivered with inverse-planned IMRT, with more detailed modelling suggesting this figure to be 51.8% of the total radically irradiated population across the UK. Centres need to ensure that their staffing levels, hardware and software licenses reflect this.
- 3.17** These figures are based on national radiotherapy data and this will vary between centres based on their demographics and referral patterns. There is no upper limit of IMRT usage to which centres should be restricted as higher levels of IMRT usage may be departmentally advantageous.

3.18 Increasing IMRT activity towards these values is expected to continue across UK centres over the next 5 years. Each centre should review this report and, if necessary, develop a local implementation plan with their commissioners.

4. Introduction

4.1 Background

4.1.1 In 2007, the National Radiotherapy Advisory Group (NRAG) published its report 'Radiotherapy: developing a world-class service for England'.¹ The Radiotherapy Development Board (RDB), with a UK-wide remit, and the National Radiotherapy Implementation Group (NRIG), with an England-only remit, were set up to address the implementation of the NRAG report's recommendations. Both the RDB and NRIG had IMRT working groups, which published five papers in *Clinical Oncology* addressing the underlying clinical evidence, QA, education and training, and current access to IMRT.²⁻⁶

4.1.2 NRIG produced a commissioner's advice document in 2009, which recommended that 33% of all radical radiotherapy treatments be delivered using an IMRT technique, 24% of which should be delivered using inverse-planned IMRT.⁷ These figures were derived by estimating the percentage of all radical fractions delivered to breast, prostate, gynaecological, head and neck, CNS and 'other' cancers and the proportion of these patients in these broad groups who would benefit from IMRT (Table 1).

Table 1: Estimate of percentage of radically-treated patients likely to benefit from IMRT and consequent proportion of all fractions as IMRT in 2010.²

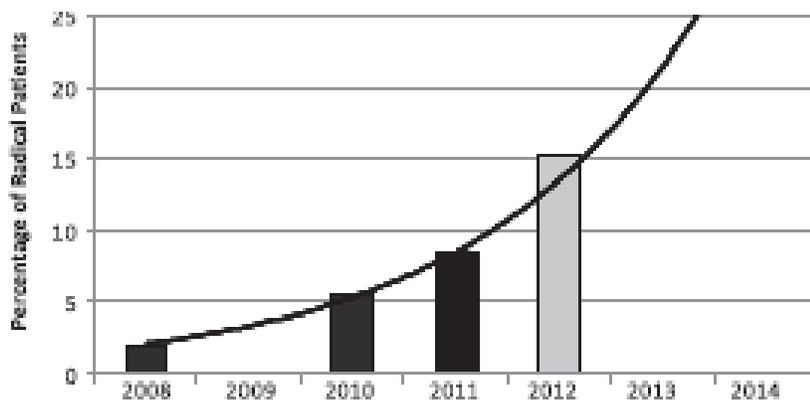
Tumour site	% of all RT fractions	% pts who benefit	% all fractions as IMRT	
			Forward Planned	Inverse Planned
Breast	30%	30%	9%	-
Prostate	16%	80%		13%
Gynaecological	5%	20%		1%
H + N	8%	80%		6%
CNS	3%	60%		2%
Other sites	10%	20%		2%
		Total	9%	24%
		Grand Total	33%	

4.1.3 Following the 2009 NRIG report, the NCAT developed an IMRT clinical support programme to expedite the implementation and uptake of IMRT in England. The Prime Minister's Cancer Radiotherapy Innovation Fund then injected £23 million into English radiotherapy centres in 2012-13 with the express aim of ensuring that all radiotherapy centres in England would meet the 24% inverse-planned IMRT target by April 2013, or as soon as possible afterwards.⁸

4.1.4 Within Scotland, the Radiotherapy Programme Board, which reports to the Scottish Cancer Task Force, lobbied for increased availability of IMRT, leading to the National Procurement Programme ensuring IMRT-capable linacs are purchased. Within Wales, the Welsh Scientific Advisory Committee (WSAC) and its Clinical Oncology Sub-Committee (COSC) produced a Professional Advice Document in 2011 that led to nationally funded business cases.⁹ Within Northern Ireland, which has a single treatment centre, IMRT has been implemented via the internal management of its radiotherapy department.

4.1.5 Overall, these documents and other initiatives appeared to have had a positive impact on access to IMRT in the UK. Mayles et al re-surveyed the UK centres in January 2012 and reported that the percentage of radically irradiated patients treated with inverse-planned IMRT increased from 5.6% in 2010 to 15.3% in 2012 (Figure 1).¹⁰ Furthermore, the percentage of radically irradiated patients treated with VMAT increased from 0.6% in 2010 to 6.0% in 2012.

Figure 1: Growth of inverse-planned IMRT in UK radiotherapy centres up to January 2012.¹⁰



4.2 Aims of this report

4.2.1 The aims of this report are to critically review the current access to inverse-planned IMRT in the UK and to predict future usage of IMRT. We are able to use National Clinical Analysis and Specialised Applications Team-Radiotherapy Dataset (NATCANSAT-RTDS) data from the 50 English centres, broken down by tumour site, but at the time of writing the devolved nations were not submitting to the NATCANSAT-RTDS.

4.2.2 We are aware that the devolved nations are monitoring their access to IMRT,¹¹ but as the precise definitions of both numerators and denominators are different, we decided not to report this data. We also report access rates for the centres that contribute the seven highest total radical practices.

4.2.3 We will use this data, IMRT access rates in Ontario¹² and expert opinion on current literature and expected changes in use of IMRT to advise centres on the likely access to inverse-planned IMRT to allow them to plan their services appropriately.

4.3 Key issues considered in generation of this report

4.3.1 Implementation of IMRT occurs in three main phases in each centre: initial implementation, expansion and routine practice. Initial implementation requires significant levels of investment to upgrade software and hardware, and provide multi-professional education and training, which includes an exhaustive review of all aspects of the radiotherapy process. This phase usually revolves around one or two tumour sites. The expansion phase also requires significant investment as IMRT is applied to an increasing number of patients and tumour sites. This phase requires increased staff numbers and a further expansion in software and hardware. However, as IMRT moves into the routine phase some departmental efficiencies may materialise. This is at least partially offset by the use of IMRT to treat patients not previously treated with curative intent (ie some lung cancer patients) or to deliver more complex treatments than could previously be considered (ie dose escalated pelvic nodal radiotherapy).¹³

4.3.2 There is overwhelming data from many years' experience with new radiotherapy technology that the volume of normal tissues irradiated to different levels is related to the risk of developing critical late toxicity.¹⁴ IMRT has been shown in multiple modelling studies in multiple clinical scenarios to provide improved dosimetry, generally, in terms of lower volumes of critical normal tissues treated to high doses. There are many non-randomised reports of improved toxicity outcomes with IMRT compared to 3-dimensional conformal radiotherapy (3D-CRT) and no consistent evidence of worse tumour control. Several randomised trials in multiple clinical scenarios have proven that IMRT can reduce toxicity to the level predicted by modelling studies.¹⁵⁻²⁰ There is a lack of equipoise in the community regarding the role of IMRT and it is unethical to limit IMRT usage to the indications proven by the trials. We recommend that centres aim to develop their services such that IMRT is used whenever it offers a superior dosimetric solution such that the clinical outcome for the patient would be better whether due to reduced toxicity, improved quality of life or improved tumour control.

4.3.3 It should be remembered that for some tumour sites other radiotherapy developments, such as IGRT, will offer more benefits than IMRT and these should be prioritised above IMRT. In other situations, IGRT should be implemented before IMRT to ensure the highly conformal dose distribution is delivered accurately. IMRT may also be an enabler for optimal use of other developing technologies such as functional imaging defined sub-volume boosts.

- 4.3.4** Many centres have moved partially or completely to VMAT, which offers quicker delivery times and reduced monitor units. Developments in VMAT planning such as class solutions may make VMAT planning quicker even than 3D-CRT planning. However, as VMAT usage increases, more planning licenses will be required. On the other hand, as the IMRT/ VMAT experience builds in a centre, QA processes may be moved from per-patient to programmatic. Combined with the improved planning solutions, it may be departmentally efficient to treat 100% of patients with a particular tumour with IMRT, even if not all patients will definitely benefit clinically or dosimetrically.
- 4.3.5** The 2009 inverse-planned IMRT target of 24% did not include any site-specific targets, although the figure was derived from an estimate of the proportion of patients with different tumour sites likely to benefit from IMRT. Bearing in mind the complexity of introducing IMRT to each tumour site and the potential efficiency of routine use of IMRT for a tumour site, centres may have 'exceeded' the 2009 tumour-site specific estimates appropriately - ie by treating 100% of prostate cancer patients with IMRT/VMAT as opposed to the 80% target.
- 4.3.6** Differences in IMRT access rates between centres are likely to reflect real differences in departmental IMRT capability and capacity. However, they might also reflect local clinical prioritisation or interpretation of available data and/or different patient populations based on local demographics or regional sub-specialisation.
- 4.3.7** IMRT is a complex treatment and rigorous QA is required to ensure patient safety. The relatively slow uptake in the UK may reflect some of the well-publicised issues abroad.²¹ There is a recognised need for a multi-professional approach to QA including external and internal peer review of outlining and planning and dosimetry audits.²² Initial results show that this can be achieved at a provincial level in Ontario²³ and has been achieved at a national level in the UK.²⁴ A further dosimetry audit in the UK has just been completed and the results are being submitted for publication (personal communication with Dr Catharine Clark, National Physics Laboratory, June 2015). In the UK, the NCRI RTTQA group has had a major role in the implementation of IMRT in new clinical scenarios and has supported the NCAT IMRT training programme.

5. Current access to IMRT in England

5.1 Methods

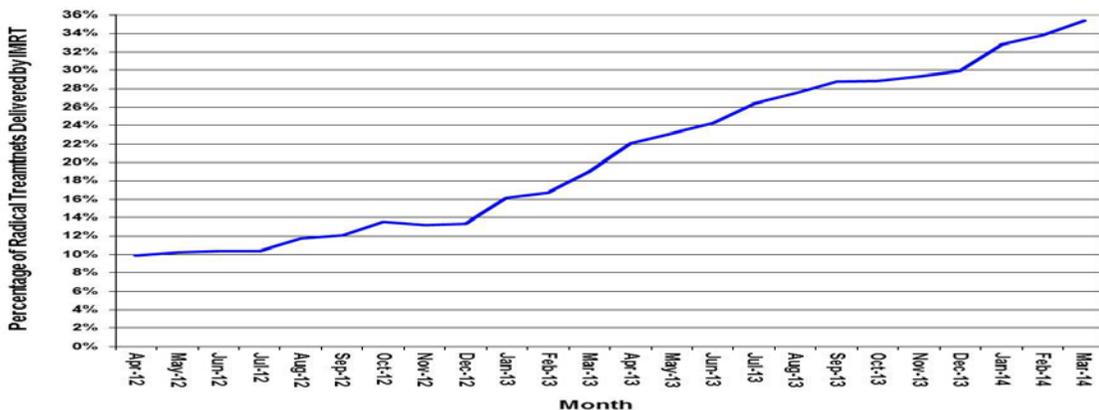
5.1.1 We have been given access to the NATCANSAT-RTDS database, which is populated with curated data from each of the 50 English radiotherapy centres. The centres from the devolved nations are currently working to submit their data. This data is being prepared for publication by the IMRT Working Group in *Clinical Oncology*.²⁵

5.1.2 Patient numbers for all completed treatments coded as a radical “simple intent” on the NATCANSAT-RTDS database were collected. Prior to April 2014 the coding of a radical “simple intent” denoted treatments that had 15 or more attendances. If a patient had two phases of treatment, these were recorded as a single treatment - ie an ‘episode’. Forward planned breast IMRT was not considered as an IMRT-type treatment but any inverse-planned breast treatment or a forward planned breast IMRT plan with patient specific QA were included in the IMRT numbers. Any treatment delivered using a VMAT was coded as being delivered by IMRT.

5.2 All diagnoses

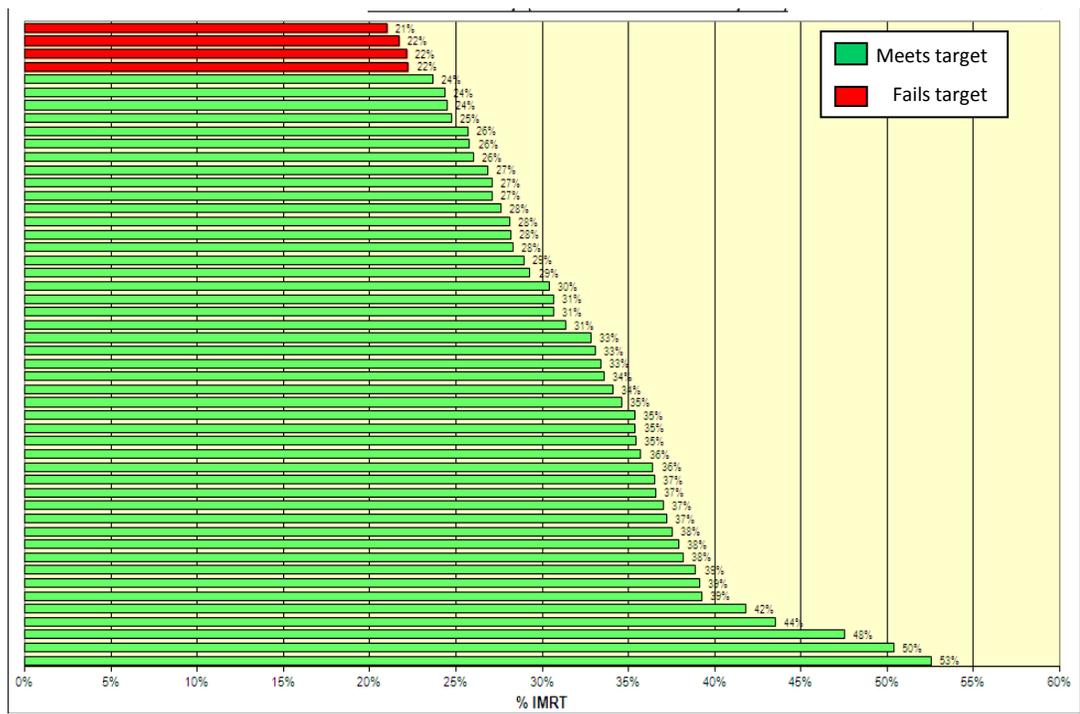
5.2.1 The proportion of all radical treatments delivered with inversed-planned IMRT for all 50 English centres over the period 1st April 2012 to 28th February 2014 is presented in Figure 2. There is an ongoing rapid expansion in IMRT delivery. The 24% target was reached in national (English) terms in May 2013, and has increased to 35% by March 2014. For all further analyses we have used a 3-month period 1st December 2013 to 28th February 2014.

Figure 2: Percentage of radical episodes delivered with inverse-planned IMRT in England up to March 2014.



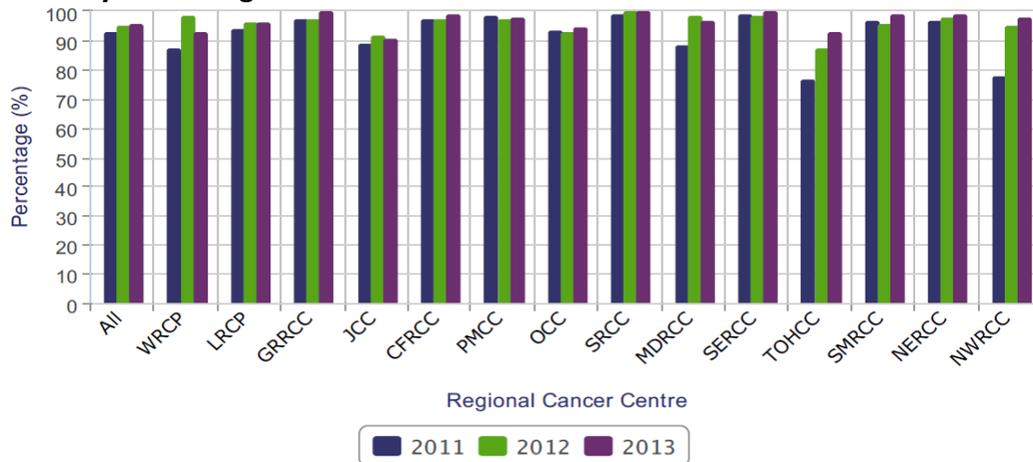
5.2.2 Figure 3 shows the percentage of radical episodes delivered with inverse-planned IMRT by each of the 50 English centres in this 3-month period. Four of the centres had not reached the 24% target, five exceeded 40% and one had treated 53% of their patients with IMRT. The seven high-volume centres treated 24%, 30%, 33%, 33%, 36%, 38% and 39% of their patients with IMRT.

Figure 3: Percentage of radical episodes delivered with inverse-planned IMRT using 3 month data (1st December 2013 to 28th February 2014) by all 50 English centres.



5.2.3 To provide some comparison, Figure 4 shows the percentage of all radical courses of radiation (for head and neck, prostate, breast, CNS combined) delivered with IMRT in 2011, 2012 and 2013 by the 14 regional cancer centres in Ontario.¹² This is the only publicly available data on population access to IMRT that we are aware of.

Figure 4: Percentage of all radical courses of radiation (for head and neck, prostate, breast, CNS combined) delivered with IMRT in 2011, 2012 and 2013 by the 14 regional cancer centres in Ontario.



5.2.4 This cannot be compared directly to the data in Figure 3 as the denominators are different (all patients having radical radiotherapy versus all patients having radical radiotherapy for head and neck, prostate, breast, CNS tumours). However, in 2013 more than 90% of all head and neck, breast and prostate cancer patients combined who received radiation as part of their care were treated using IMRT across Ontario.

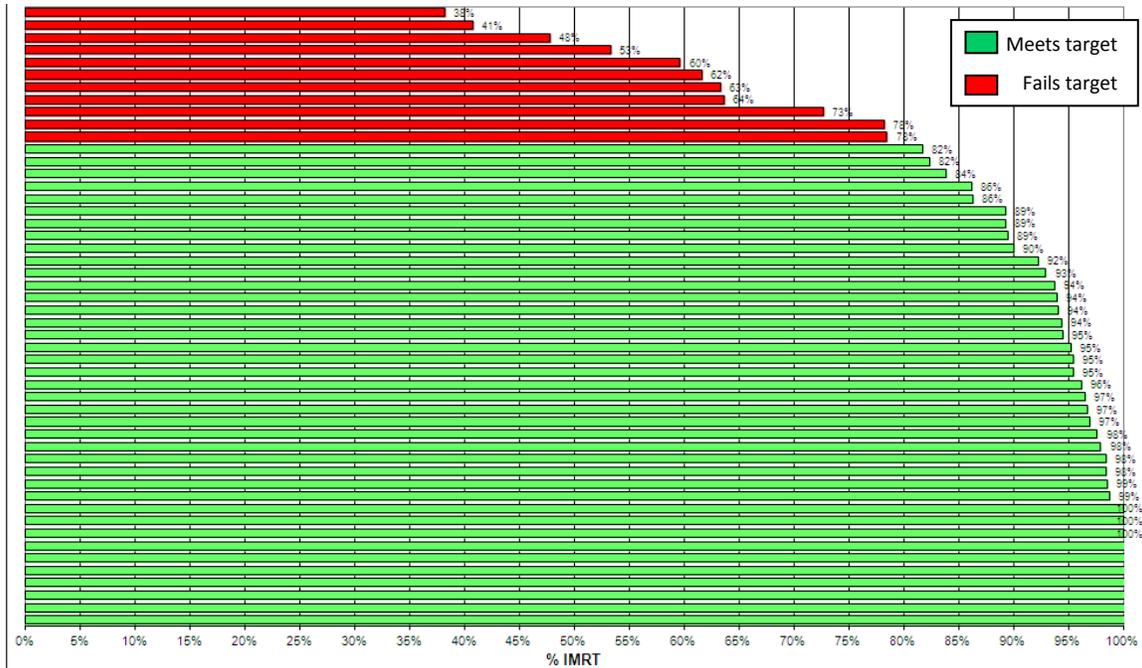
5.2.5 The variation in IMRT utilization has decreased since 2011 as a result of noticeable increase in utilization in two of the centres particularly The Ottawa Hospital (TOHCC) and Northwestern (NWRCC). This has been achieved during a period of increasing cancer incidence. Figure 2 shows that England is still in a period of rapid increase in IMRT usage.

5.3 Prostate cancer

2009 NRIG estimate = 80%

5.3.1 Figure 5 shows the percentage of radical episodes delivered with inverse-planned IMRT for prostate cancer patients by each of the 50 English centres in this three month period. Eleven centres had not reached the 80% 'target' but ten achieved 100%. The seven high volume centres treated 95%, 99%, 99%, 100%, 100%, 100% and 100% of their prostate patients with IMRT. Overall 88% (2992 of 3402) of all radical prostate cancer patient episodes were treated with IMRT. 21.8% of all radical episodes in England were prostate cancer patients (3742 prostate cancer; 17156 total episodes) and prostate cancer IMRT contributed 55.3% of all the IMRT episodes (3062 prostate cancer IMRT; 5537 total IMRT episodes).

Figure 5: Percentage of prostate cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



5.3.2 The large number of centres treating over 90% of their prostate cancer patients with IMRT shows that this is highly achievable and is likely to be providing some efficiencies of workflow. UK centres should expect IMRT access rates to approach 100% when their access to IMRT is unrestricted.

5.4 Head and neck cancer

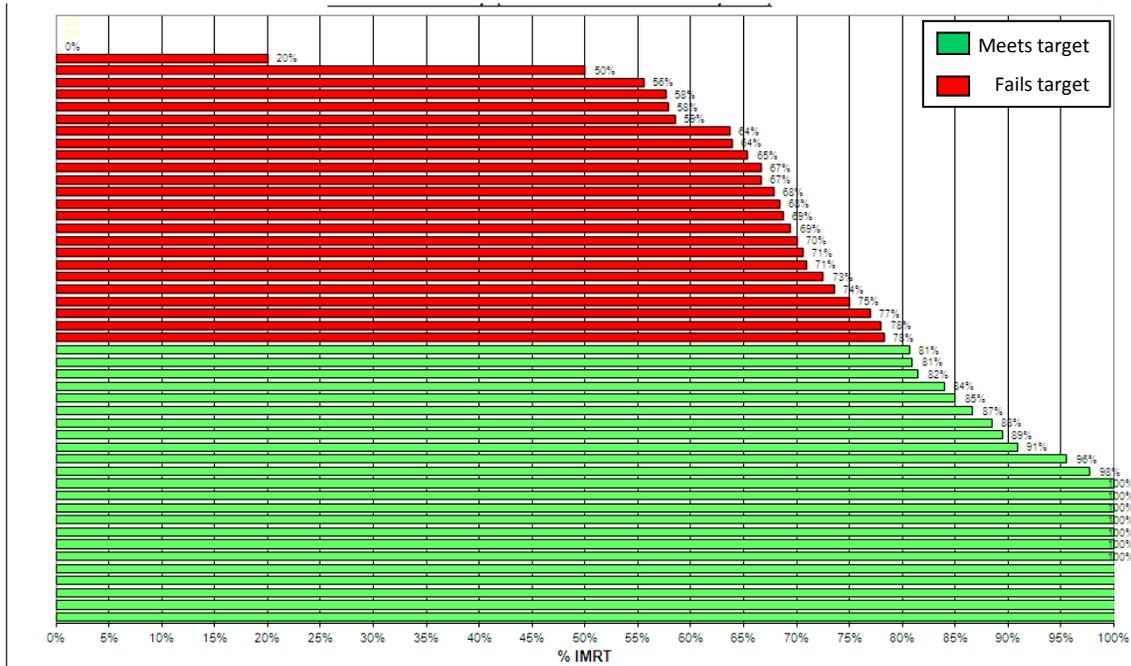
2009 NRIG estimate = 80%

5.4.1 IMRT significantly reduces late toxicity following head and neck (HandN) radiotherapy, as established by a UK phase III randomised controlled trial (RCT).¹⁷ It also allows treatment of complex tumour volumes close to critical structures – eg. paranasal sinus tumours that could not be treated to radical dose without IMRT. Ongoing studies are investigating whether dose escalation using IMRT can improve local control rates for HandN cancers.

5.4.2 Figure 6 shows the percentage of radical episodes delivered with inverse-planned IMRT for head and neck cancer patients by each of the 50 English centres in this 3-month period. Twenty-four of the centres had not reached the 80% ‘target’ with one only treating 20% of its head and neck patients with IMRT. Another centre has treated none of its head and neck patients with IMRT; it has since

been stopped from treating any head and neck patients with radical radiotherapy and they are referred to another centre.

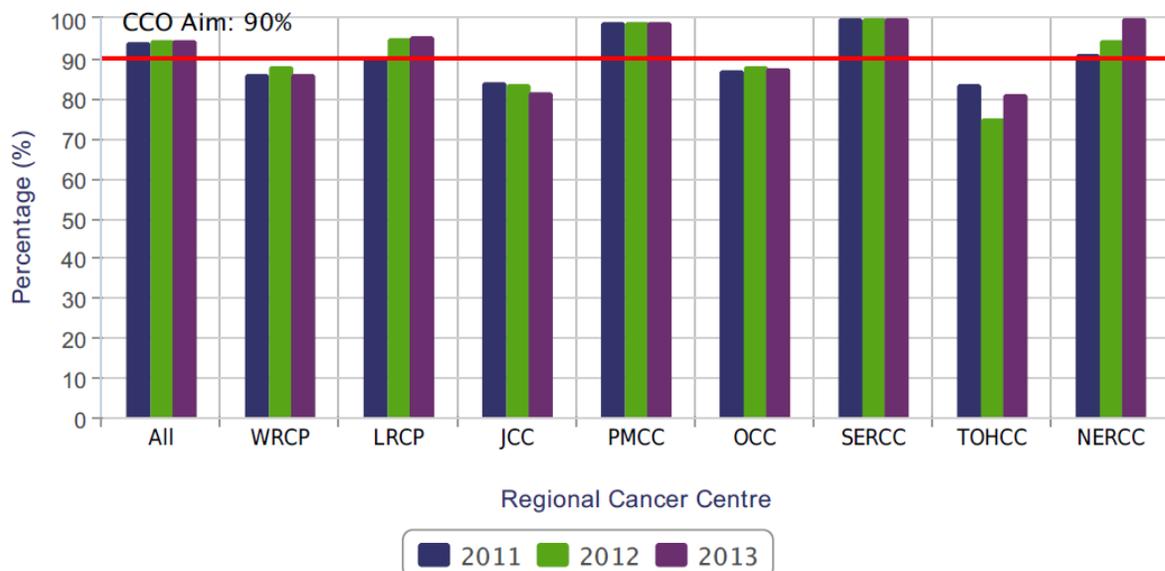
Figure 6: Percentage of head and neck cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres



5.4.3 Twelve centres treated all of their patients with IMRT, including one of the high volume centres. The other six high volume centres treated 78%, 82%, 84%, 88%, 96% and 98% of their head and neck cancer patients with IMRT. Overall, 78% (1117 of 1429) of all radical head and neck cancer patient episodes were treated with IMRT. Furthermore, 8.3% of all radical episodes in England were head and neck cancer patients (1429 HandN cancer; 17156 total episodes) and HandN IMRT contributed 20.2% of all the IMRT episodes (1117 HandN cancer IMRT; 5537 total IMRT episodes).

5.4.4 Figure 7 shows the percentage of all radical courses of radiation for head and neck delivered with IMRT in 2011, 2012 and 2013 by the nine regional cancer centres in Ontario that treat HandN cancer (of 14).¹² Fewer centres treat head and neck cancers as the newer centres treat a limited number of disease sites.

Figure 7: Percentage of all radical courses of radiation for head and neck delivered with IMRT in 2011, 2012 and 2013 by the eight regional cancer centres in Ontario.



5.4.5 They had set an aim of 90% of HandN cancer patients to receive IMRT after recommending IMRT for cases where xerostomia, blindness or osteonecrosis is to be minimised or avoided and for nasopharyngeal, nasal and paranasal sinus tumours to maximise tumour control.²⁶ This aim is not being met by half of the eight centres with The Ottawa Hospital (81%) and Juravinski Cancer Centre (82%) having the lowest use of IMRT in 2013. The overall HandN IMRT percentage usage has been relatively stable over these past three years and suggests that UK centres should expect IMRT access rates to be between 90% and 95% when their access to IMRT is unrestricted.

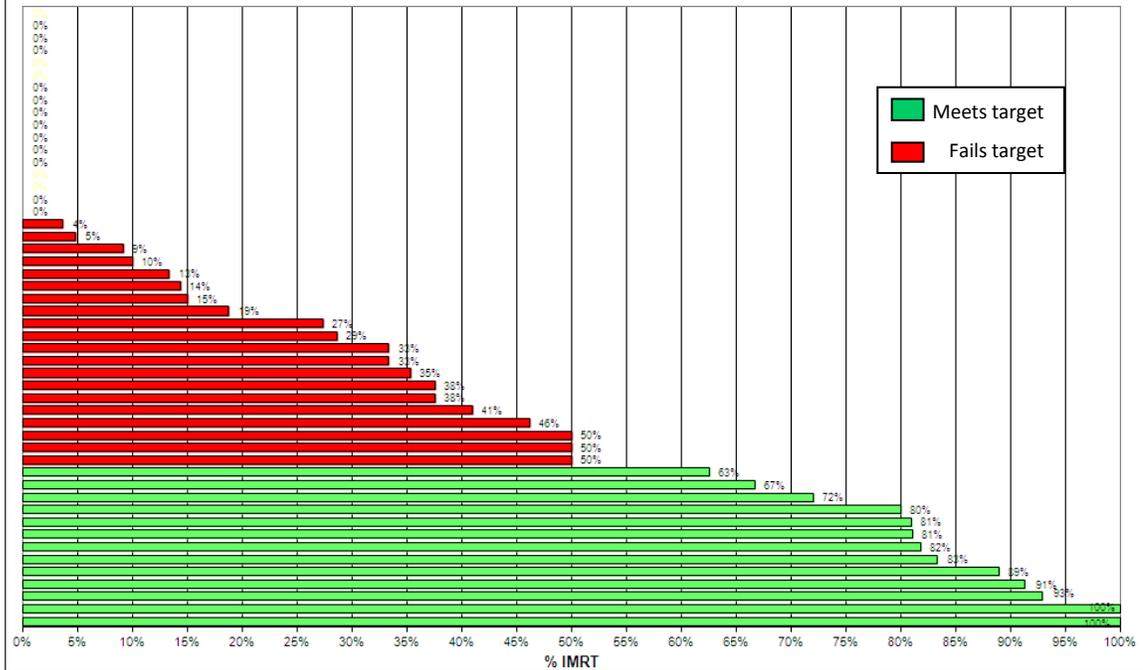
5.5 CNS tumours

2009 NRIG estimate = 60%

5.5.1 Figure 8 shows the percentage of radical episodes delivered with inverse-planned IMRT for CNS cancer patients by each of the 50 English centres in this 3-month period. Only 13 centres had reached the 60% 'target', yet two treated 100% of their CNS patients with IMRT, including one of the high volume centres.

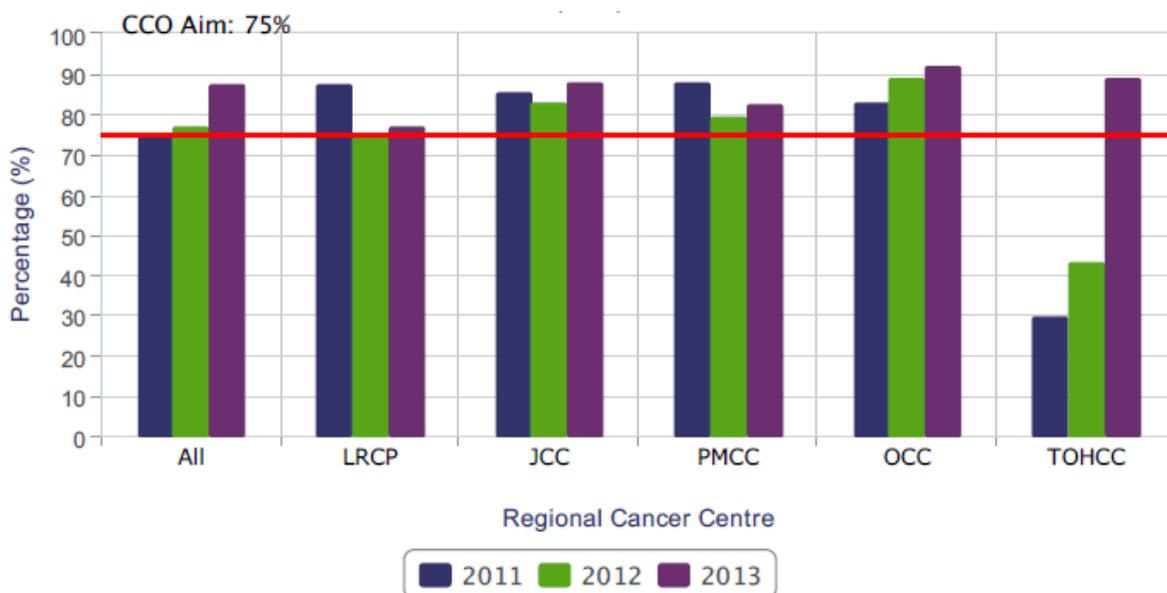
5.5.2 Twelve centres did not treat any of their CNS tumour patients with IMRT, also including one of the high volume centres. The other five high volume centres treated 4%, 5%, 41%, 72% and 91% of their CNS tumour patients with IMRT. Overall, 39% (239 of 620) of all radical CNS cancer patient episodes were treated with IMRT.

Figure 8: Percentage of CNS cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



5.5.3 Within Ontario, the IMRT target for cancers of the central nervous system is 75% since evidence does not support the use of IMRT for all patients, with the decision based on the stage, location and type of cancer. Figure 9 shows the percentage of all radical courses of radiation for CNS cancers delivered with IMRT in 2011, 2012 and 2013 by the five regional cancer centres in Ontario treating CNS tumours.

Figure 9: Percentage of all radical courses of radiation for CNS tumours delivered with IMRT in 2011, 2012 and 2013 by the six treating regional cancer centres in Ontario.



5.5.4 Fewer centres treat central nervous system cancers since these are treated exclusively in larger centres with robust surgical programs.¹² All centres reached the target of 75% by 2013 with a marked increase in access at The Ottawa Hospital over a 2-year period from 30% in 2011 to 90% in 2013.

5.5.5 The overall IMRT percentage usage has increased from 75% to 88% over this 3-year period. Access to IMRT for patients with CNS tumours in England varies greatly between centres but in general lags a long way behind access in Ontario. When centres do adopt IMRT for CNS tumours, access rates of 80% were achieved in 10 English centres, which suggests that centres should plan for IMRT access rates of over 75% when their IMRT access is unrestricted.

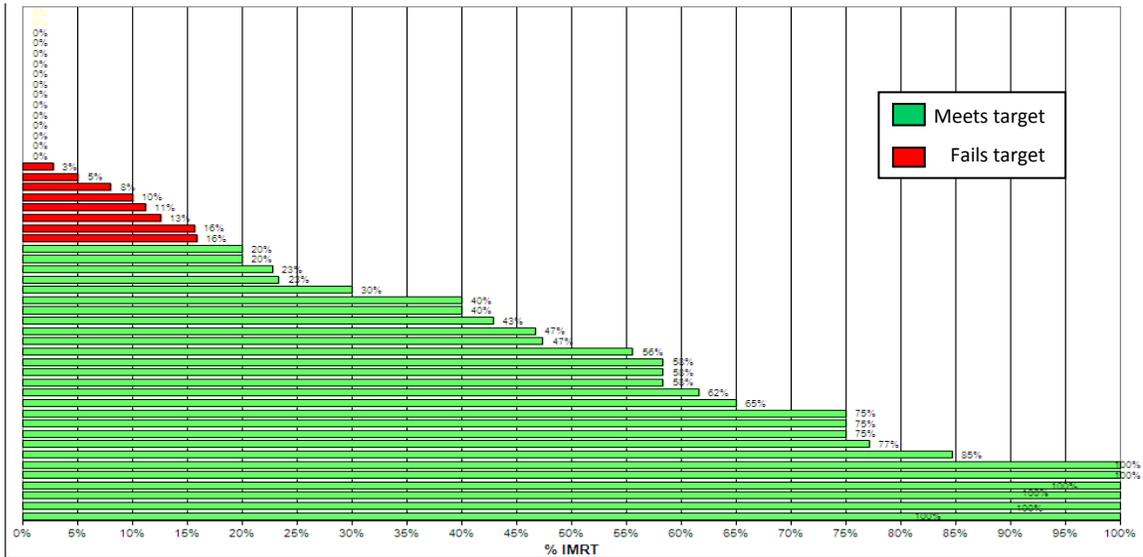
5.6 Gynaecological cancers

2009 NRIG estimate = 20%

5.6.1 Figure 10 shows the percentage of radical episodes delivered with inverse-planned IMRT for gynaecological cancer patients by each of the 50 English centres in this 3-month period. Twenty-seven of the centres had reached the 20% 'target' and six treated 100% of their gynaecological patients with IMRT, including one of the high volume centres. Thirteen centres did not treat any of their gynaecological cancer patients with IMRT, also including one of the high volume centres. The other five high volume centres treated 16%, 16%, 23%, 73%

and 77% of their gynaecological patients with IMRT. Overall 33% (233 of 708) of all radical gynaecological cancer patient episodes were treated with IMRT.

Figure 10: Percentage of gynaecological cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres



5.6.2 There are no figures provided for access to IMRT for gynaecological cancer patients in Ontario, although IMRT has been recommended if reduction in acute and chronic toxicities is the main outcome of interest.²⁷ There are concerns regarding internal organ motion during IMRT particularly in the setting of primary cervical cancer; this is one of the clinical scenarios when IGRT should be implemented before IMRT. Access to IMRT for patients with gynaecological cancer in England varies greatly between centres. When centres do adopt it, access rates of 75% were achieved in 12 English centres and between 50% and 75% in another six centres. This suggests that centres should plan for IMRT access rates of 75% when their IMRT access is unrestricted.

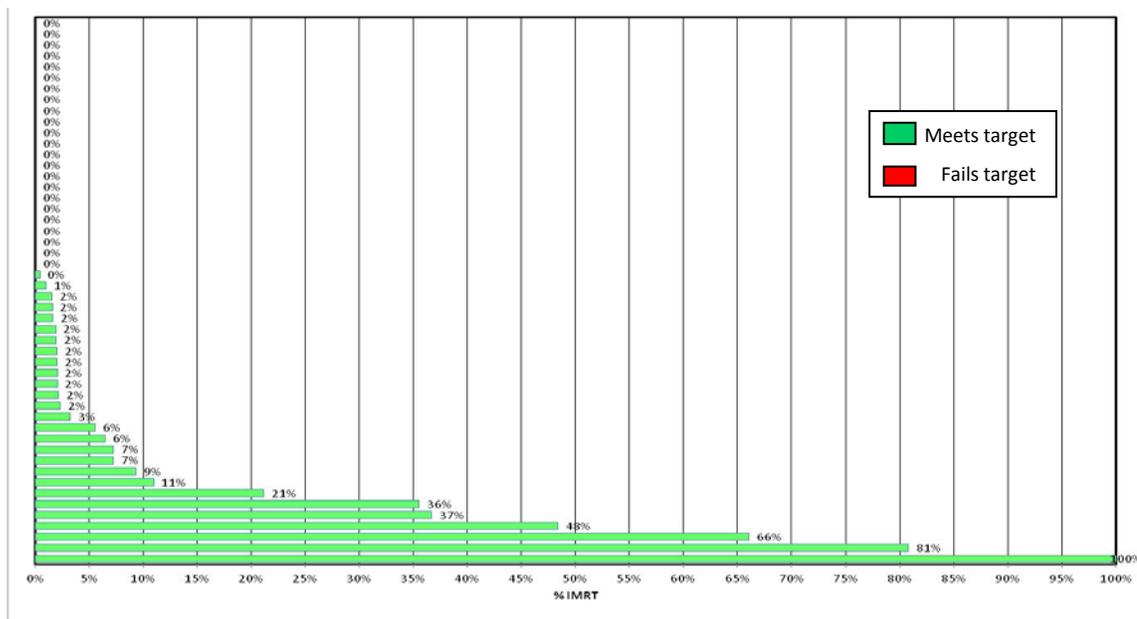
5.7 Breast cancer

2009 NRIG estimate = 0%

5.7.1 The 2009 NRIG IMRT commissioner’s advice document estimated that 30% of breast cancer patients would require IMRT, but that this would be delivered solely with forward-planned techniques functioning as tissue compensators to reduce the dose inhomogeneity from conventional tangential fields, which are known to contribute to poor late cosmetic outcome. Figure 11 shows the percentage of radical episodes delivered with inverse-planned IMRT (or forward

planned IMRT with patient-specific quality assurance) for breast cancer patients by each of the 50 English centres in this 3-month period. The use of IMRT is highly variable, with 23 centres not treating any patients in this time period. Overall 10% (689 of 7244) of all radical breast cancer patient episodes were treated with IMRT.

Figure 11: Percentage of breast cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



5.7.2 Predicting the usage of IMRT for breast cancer is currently highly complicated. The 2009 NCRG document included an estimate that 30% of breast cancer patients would require forward-planned IMRT purely to correct for the dose inhomogeneity from tangential fields. Data from the Cambridge Breast cancer trial (n=1142) have shown that this is an underestimate as approximately 70% of patients had dose distributions outside ICRU 50 recommendations with two tangential fields only.²⁸ Furthermore the distinction between forward-planned and inverse-planned IMRT is blurring. Centres should expect these techniques to become standard practice, as extreme hypofractionation and subvolume boosting enter clinical practice. The recent major UK-based clinical trials have been exploring the safety and efficacy of hypofractionation in the era of tissue compensation (FAST and FAST FORWARD) and subvolume boosting (IMPORT LOW and HIGH).

5.7.3 Recent evidence has shown the equivalence of axillary radiotherapy to dissection in sentinel node positive patients,²⁹ and this may well become the treatment of choice as most patients will also be having adjuvant breast radiotherapy. Two

large randomised controlled trials of internal mammary nodal radiotherapy, reported in abstract only so far, have reported survival advantages.^{30, 31} they are yet to be fully published.

5.7.4 There has also been conclusive evidence of the long-term cardiac effects of tangential breast radiotherapy, related to the volume of breast tissue irradiated to critical doses.³² This will lead to routine use of deep inspiration breath holding techniques to minimise cardiac irradiation during standard tangential radiotherapy/IMRT. The integration with axillary and internal mammary nodal radiotherapy is more complex. We recommend that centres should plan for 70% of their patients to require inhomogeneity correction: although this can be delivered with forward-planned IMRT, some centres will prefer to use inverse-planned IMRT. In addition, approximately 20% of their more complex breast cancer patients will currently require inverse-planned IMRT. As the complexity of breast radiotherapy increases, the number of patients likely to benefit from inverse-planned IMRT will increase, perhaps, towards 40%.

5.8 Other sites

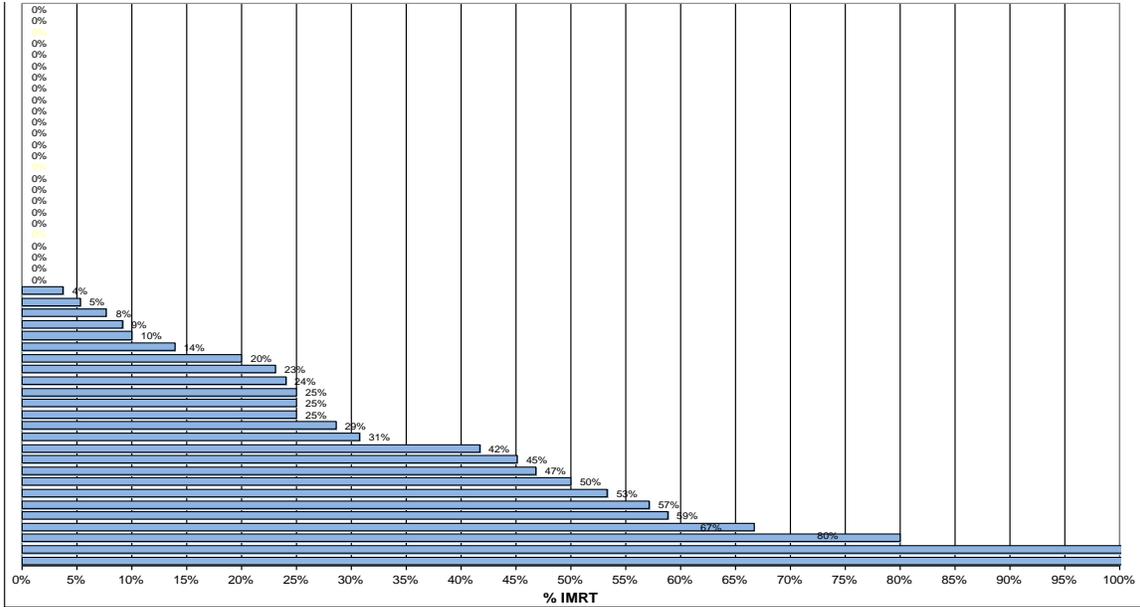
2009 NRIC estimate = 20%

5.8.1 The 2009 NRIC IMRT commissioner's advice document estimated that 20% of other cancer patients would require IMRT. There was no breakdown of which tumour subsites this would involve. We have performed an analysis of the RTDS dataset to investigate the variation in usage of IMRT for the following tumour sites: lung, upper gastrointestinal, lower gastrointestinal (and rectum), urology (in addition to the prostate cancer analysis), musculoskeletal and lymphoma. In each case we have assumed that the target is 20%.

5.9 Lung cancer

5.9.1 Twenty-five English centres are treating lung cancer patients with IMRT; 19 treating >20%, 11 >40% and two 100% of their patients (Figure 12). Overall, 25% (211 of 838) of all radical lung cancer patient episodes were treated with IMRT. There is a high level of evidence showing the relationship between lung V20Gy and severe toxicity, which is used to exclude some patients from radical therapy with 3D-CRT. There is concern within the community that harm can be caused to lung through the low-dose bath effect, especially if patients have co-existing lung disease and there remains equipoise regarding the clinical benefit of IMRT.^{33,34}

Figure 12: Percentage of lung cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



5.9.2 There is a large inter-patient variability in volumes of normal tissue irradiated and this has led to the concept of individualised dose delivery based on isotoxic dosing which is being explored in early phase clinical trials in the UK, including one involving IMRT. There is also evidence that some currently palliatively-irradiated patients can be treated with radical intent with IMRT and that centres adopting this approach will increase the proportion of patients being irradiated radically by approximately 15% (Personal communication: Prof Corinne Faivre-Finn, University of Manchester, January 2015).

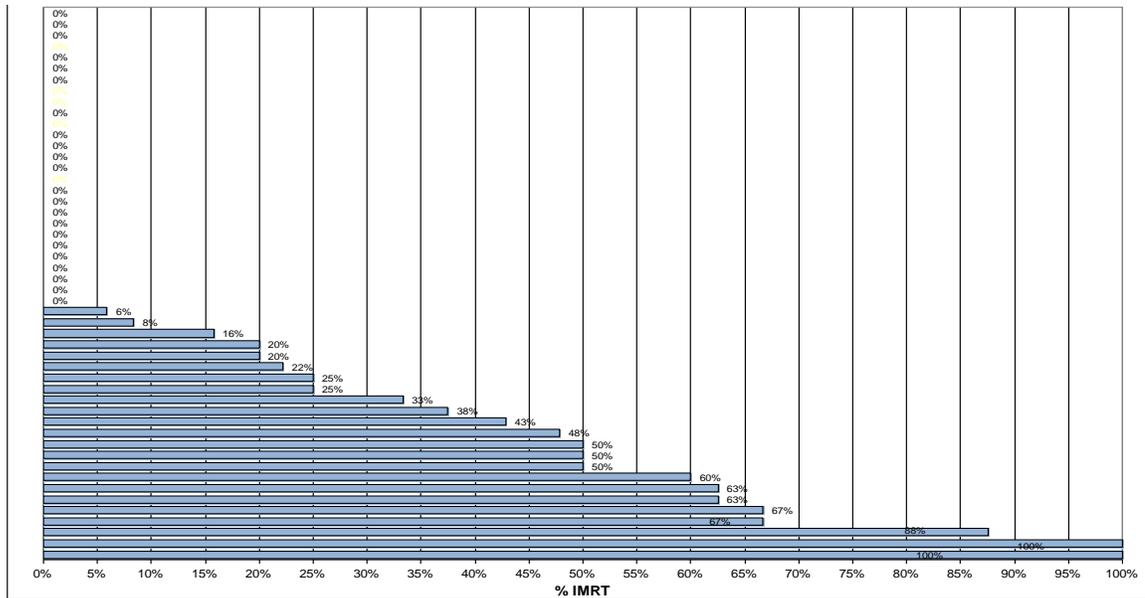
5.9.3 IMRT planning of patients with thoracic tumours is more complicated as collapsed cone algorithms (or equivalent) are required. Respiratory motion management is an important enabling technology that should be addressed before IMRT as it can benefit the majority of lung cancer patients and is required for SABR. It should be noted that this data does not include SABR patients. It is reasonable for centres to plan for at least 40% of their radical non-SABR lung patients to benefit from IMRT. However, compared to the other tumour sites, this rate may show more centre-to-centre variation owing to different patient demographics (performance status, stage at diagnosis and rates of coexisting respiratory disease).

5.10 Upper gastrointestinal cancers

5.10.1 Twenty-three English centres are treating upper gastrointestinal cancer patients with IMRT; 23 treating >20%, 13 >40% and two 100% of their patients (Figure 13). Overall 23% (82 of 357) of all radical upper gastrointestinal cancer patient episodes were treated with IMRT. As with lung cancer, there is strong evidence showing the relationship between lung V20Gy and severe toxicity, although with current radiation doses, this rarely restricts delivery of a radical dose. Cervical oesophageal tumours have a similar relationship with the spinal cord as hypopharyngeal tumours and should be treated with IMRT.

5.10.2 The next multi-centre UK trials in radical chemoradiation for both oesophageal and pancreatic cancers (SCOPE2 and SCALOP2 respectively) are exploring dose escalation and mandate the use of IMRT for it. It is reasonable for centres to plan for at least 40% (up to 60%) of their radical upper gastrointestinal cancer patients to benefit from IMRT. As with lung cancer, IMRT may allow the safe radical treatment of patients previously not considered for radical radiotherapy – ie. patients with stomach cancer.

Figure 13: Percentage of upper gastrointestinal cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



5.11 Lower gastrointestinal cancers

5.11.1 Thirty English centres are treating lower gastrointestinal cancer patients with IMRT. Eighteen are treating rectal cancer patients, of which 12 are treating

>20%, 10 >40% and four 100% of their patients, meaning that 15% (102 of 682) of the total English rectal cancer radical patient episodes were treated with IMRT. Twenty five centres are treating anal cancer patients (assuming all lower gastrointestinal but non-rectal cancer patients are anal cancers), of which 21 are treating >20%, 18 >40% and six 100% of their patients. This means that 36% (92 of 256) of the total English anal cancer radical patient episodes were treated with IMRT.

5.11.2 There is evidence that IMRT reduces acute toxicity from anal cancer chemoradiation and much work has been done by the Anorectal Sub-Group of the NCRI Clinical Studies Group to develop IMRT guidance for future UK clinical trials, which are currently being reviewed for funding.^{35,36} It is reasonable for centres to plan for at least 20% (and up to 50%) of their radical rectal and 100% of their anal cancer patients to benefit from IMRT.

Figure 14: Percentage of a) lower gastrointestinal cancer; b) rectal cancer and c) lower gastrointestinal non-rectal cancer (ie anal cancer) radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.

Figure 14a: all lower gastrointestinal cancer

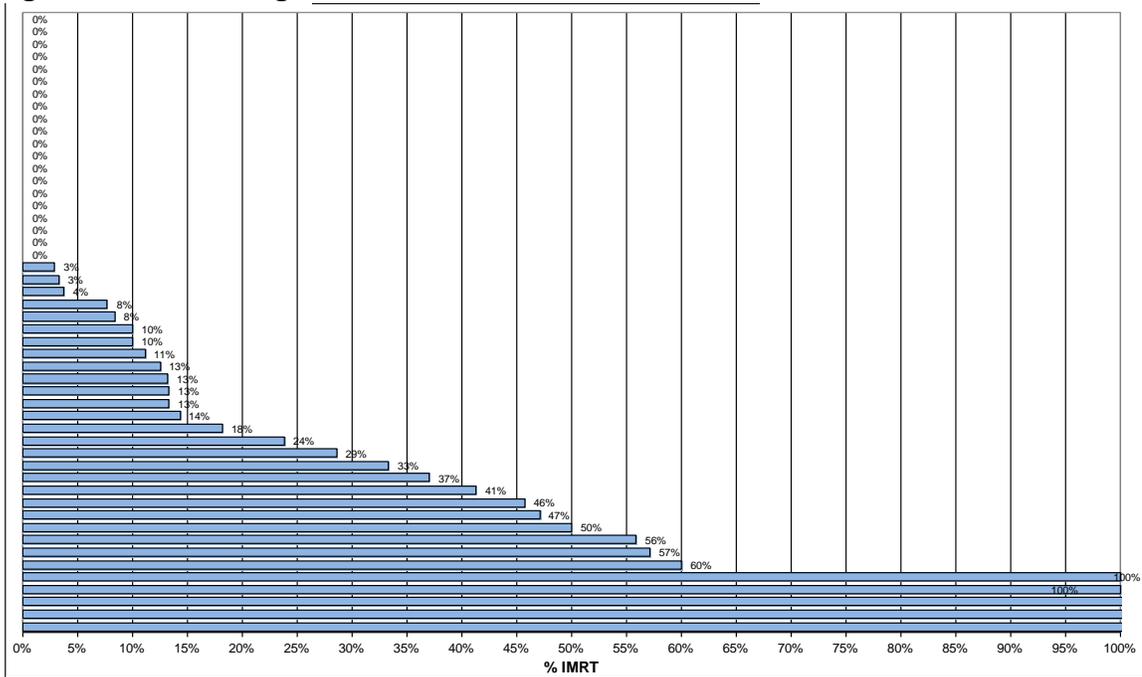


Figure 14b: rectal cancer

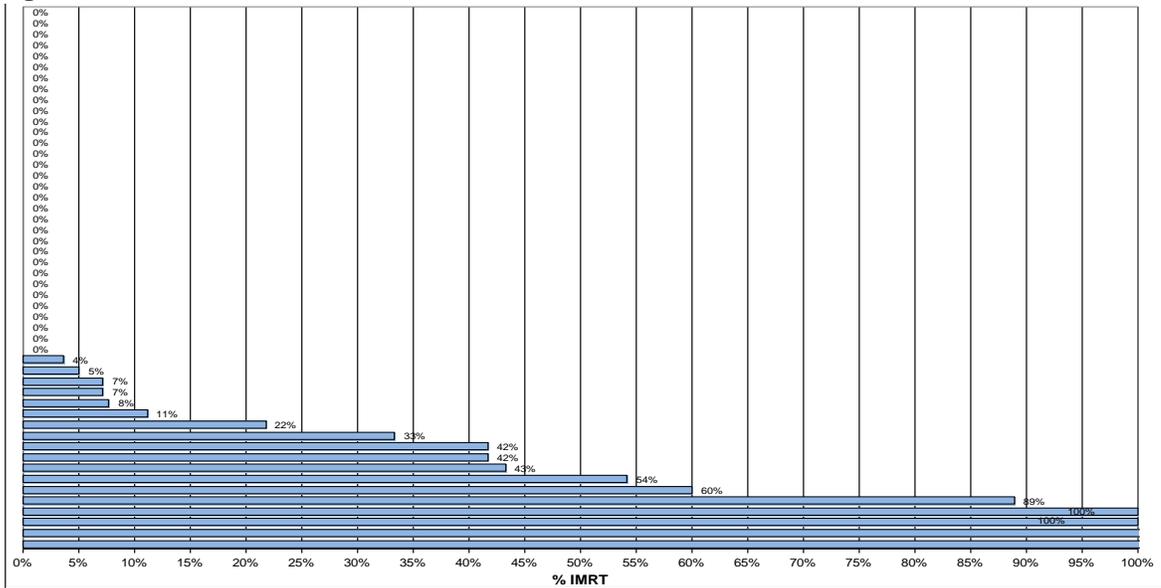
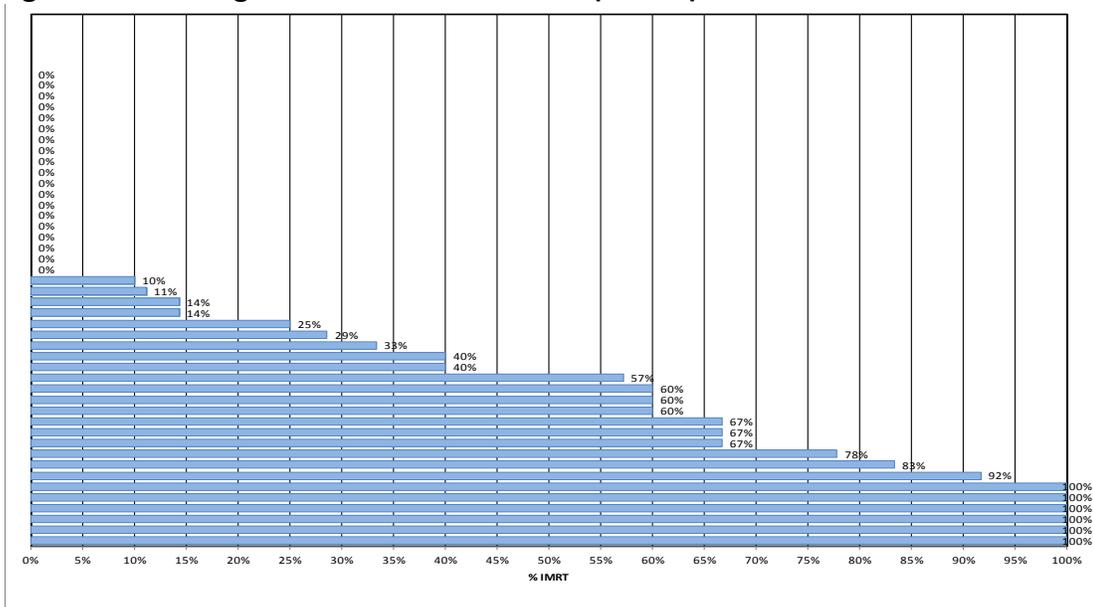


Figure 14c: lower gastrointestinal non-rectal (ie anal) cancer

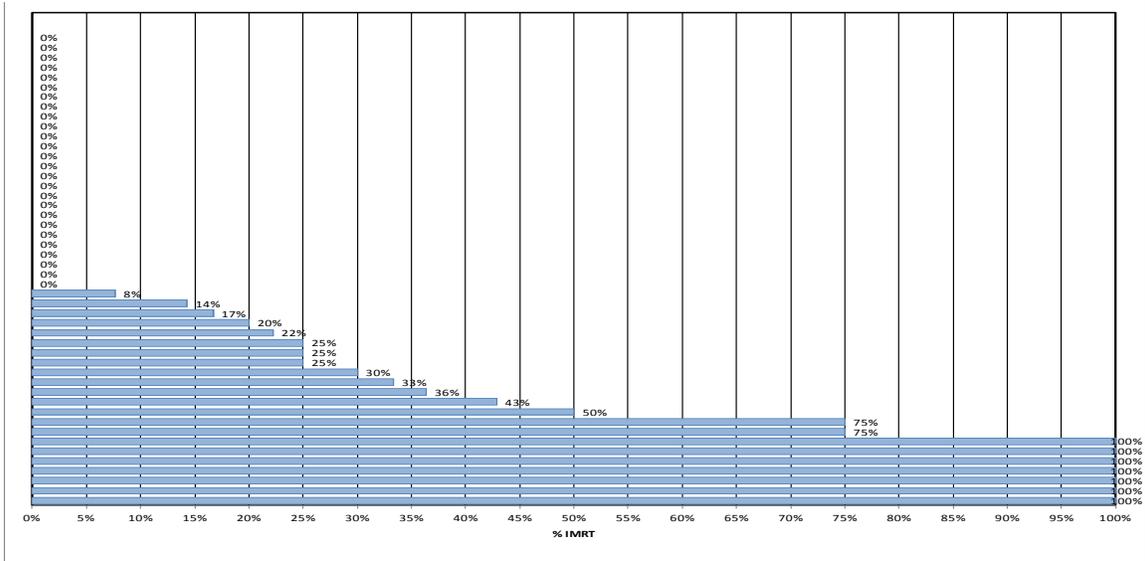


5.12 Urological cancers (not including prostate cancer)

5.12.1 Twenty-two English centres are treating non-prostate urological cancer patients with IMRT; 19 treating >20%, 11 >40% and seven 100% of their patients (Figure 15). Across England therefore, 21% (70 of 341) of all these episodes were treated with IMRT. The main tumour is bladder cancer and current clinical trials are investigating the role of image-guidance techniques such as plan of the day to address the internal organ motion of the bladder itself (HYBRID, RAIDER). INPACT is a penile cancer trial in which all patients will be treated with IMRT. An IMRT/

VMAT solution may be departmentally efficient for the multiple plans needed in plan of the day treatments. It is reasonable for centres to plan for at least 40% of their radical non-prostate urological cancer patients to be treated with IMRT.

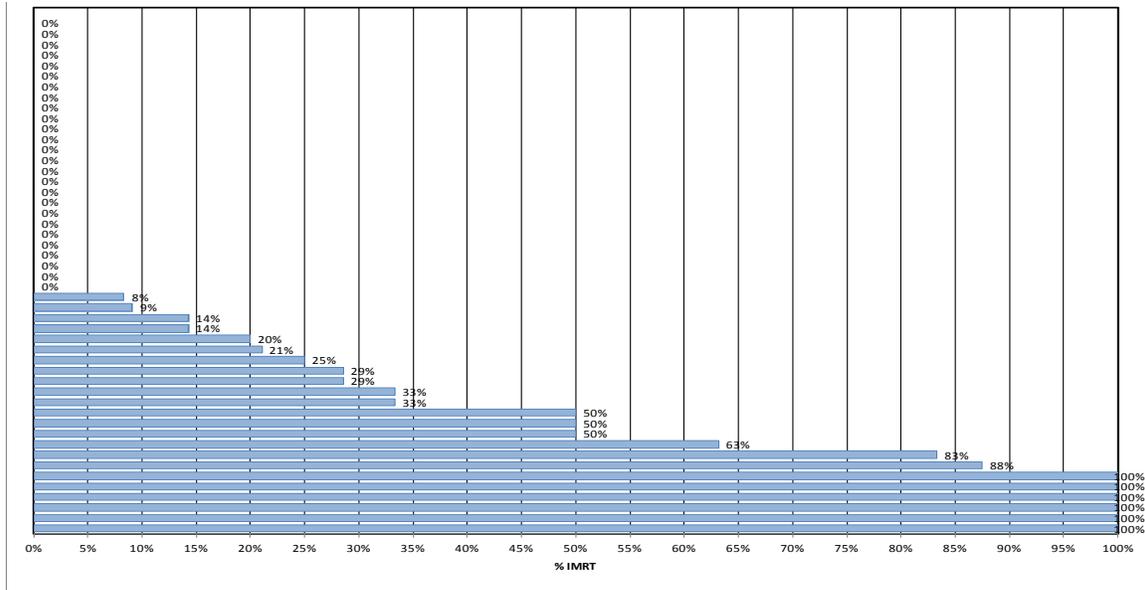
Figure 15: Percentage of non-prostate urological cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



5.13 Musculoskeletal cancers

5.13.1 Twenty-three English centres are treating musculoskeletal cancer patients with IMRT; 19 treating >20%, 12 >40% and six 100% of their patients (Figure 16). Across England therefore, 32% (63 of 194) of all these episodes were treated with IMRT. Musculoskeletal tumours are very diverse in their extent and anatomical position. There is often a very close relationship between critical organs and the tumour and/or large dose inhomogeneities. It is reasonable for centres to plan for at least 60% (up to 100%) of these patients to be treated with IMRT and referral to specialised centres for radical radiotherapy should also be considered.

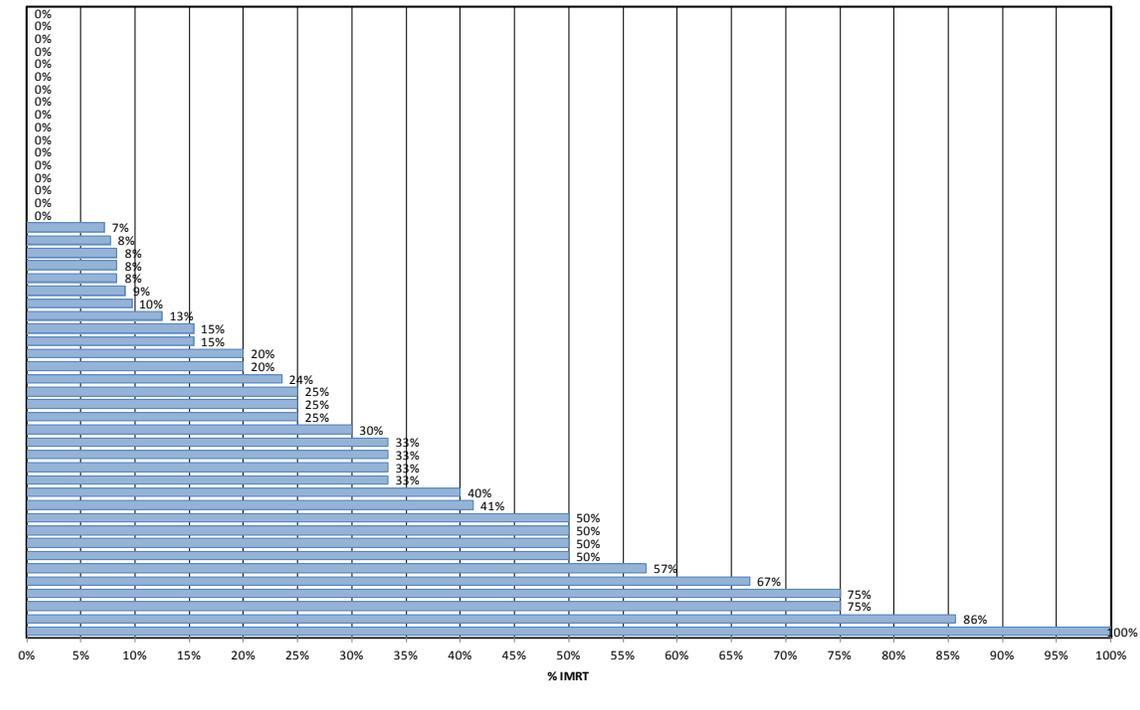
Figure 16: Percentage of musculoskeletal cancer radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres



5.14 Lymphoma

5.14.1 Thirty-three English centres are treating lymphoma patients with IMRT; 23 treating >20%, 12 >40% and one 100% of their patients (Figure 17). Across England therefore, 20% (79 of 401) of all these episodes were treated with IMRT. Lymphomas are generally treated with lower doses than other cancers, but patients are often very young and therefore at particular risk of very long term late effects including radiation-induced second malignancy. As the volume of normal tissue irradiated with low dose generally increases with IMRT or VMAT, the benefit of IMRT is not as clear as for other tumour types. It is agreed that IMRT should be used for parotid sparing and thus it is reasonable for centres to plan for 30 % of their patients to be treated with IMRT.

Figure 17: Percentage of lymphoma radical episodes delivered with inverse-planned IMRT between 1st December 2013 and 28th February 2014 (3 months) by all 50 English centres.



- 6. Summary of current IMRT usage and predicted future usage in the UK**
- 6.1** IMRT offers improved radiotherapy dosimetry compared to 3D-CRT in a large number of clinical scenarios. This has been shown in multiple clinical studies to reduce the volume of normal tissue irradiated to critical levels, reduce dose inhomogeneity and potentially allow safe dose escalation. Multiple single-arm and comparative non-randomised studies have supported this modelling work, and, crucially, so have the few randomised controlled trials in Head and Neck and breast cancer. Implementation of IMRT requires additional resources for hardware, software, training and staff. As numbers and experience increase, planning becomes class-based, QA becomes programmatic and delivery becomes VMAT: IMRT can become a departmentally efficient and routine solution in many clinical scenarios.
- 6.2** The UK has been slow to adopt IMRT compared to other healthcare systems in the developed world. Initiatives in the last decade have, however, systematically addressed the considerable hurdles faced by radiotherapy departments. This report shows that IMRT access in England is rapidly increasing and this is also the case in the other devolved nations (Personal communication: Prof Anthony Chalmers, Glasgow University; Dr John Staffurth, Cardiff University; and Dr Gerry Hanna, Queen's University Belfast, all January 2015).
- 6.3** It is clear that access to IMRT varies considerably between clinical sites, as one would expect, but access still varies enormously between different cancer centres. The two tumour sites with the largest volume of supporting data – head and neck cancer, and prostate cancer – show the highest access to IMRT across England and the lowest variation between centres. However it is completely unacceptable that any patient with locally advanced head and neck cancer should be treated without IMRT. Patients should be referred to another centre in preference to a local non-IMRT treatment. It should be noted that there have been multiple UK-based multi-centre clinical trials, supported by the NCRI's RTTQA group,³⁷ in these two tumour sites. They were also the tumour site generally selected by centres in the NCAT-funded IMRT training program (Personal communication: Ms Elizabeth Miles, National Cancer Research Institute Radiotherapy Trials Quality Assurance Group, February 2015); this may explain the widespread and relatively uniform uptake of IMRT.
- 6.4** Access to IMRT for the other tumour sites varies widely between centres. This may reflect different levels of clinical demand for IMRT, but is more likely to represent ongoing limited resources. It is to be expected that, as more national trials allow or require IMRT, with the associated RTTQA support, IMRT access rates will increase and become less variable. This will benefit both patients within and outwith the trial themselves. Centres need to plan appropriately for this continued rapid rise in IMRT as it will continue to impact on staffing levels,

hardware, software and local QA requirements. Although we recognise that the additional resources for IMRT become relatively less on a per-patient basis such that the IMRT tariff may need to be revisited, few centres will be at this level yet except for a few clinical indications. Radiotherapy is becoming more complicated other than just IMRT, with increasing image guided radiotherapy, adaptive radiotherapy and use of functional imaging to guide sub-volume boosts. Thus IMRT may continue to evolve even if the numbers appear to be static.

6.5 In attempting to predict future access rates for IMRT there are many variables. In every tumour type, at least one England centre has treated all of their patients in this 3-month period with IMRT and two centres have treated over 50% of their entire population of radical patients with IMRT. This data is already over six months out of date. We believe that IMRT should be available in every centre for every patient that the clinician believes would benefit from IMRT. In addition, there may be departmental efficiencies to be achieved by treating patients with a consistent semi-automated IMRT technique even if there is no obvious dosimetric advantage, and this should be encouraged as long as there is no clinical detriment to the patient. We would recommend that centres plan their services expecting their IMRT access rates to AT LEAST approximate to the values in Table 2.

6.6 The derivation of the estimates in Table 2 are a combination of assessing the trend for increased access to IMRT in the UK; a site-by-site review of current UK access to IMRT; comparison with data from one international group; specialist opinion of unmet IMRT usage for clinical benefit and the potential for IMRT/VMAT to offer departmental efficiencies. These should not be taken as new national IMRT targets. Additionally, it is clear that each radiotherapy centre will have a different individual caseload, further weakening the 51.8% as a national target. Some centres will appropriately treat a lower proportion of their radical cases with IMRT and some will exceed this figure. Such centres should absolutely not be penalised for exceeding the 51.8% figure or be restricted to this value.

Table 2: Estimate of future access rates to inverse-planned IMRT that centres should use to plan their services.

Tumour site	Number of patients (total England 3 months)	Current access number (%)	Future predictions (%)	Future predictions (Number)
Prostate cancer	3402	2992 (88%)	100%	3402
Non-prostate urological cancers	341	70 (21%)	40%	136
H&N cancer	1429	1117 (78%)	95%	1358
CNS cancer	620	239 (39%)	75%	465
Gynaecological cancers	708	233 (33%)	75%	709
Lung cancer	838	211 (25%)	40%	335
Rectal cancer	682	102 (15%)	20%	136
Anal cancer	256	92 (36%)	100%	256
Upper GI cancer	357	82 (23%)	40%	143
Breast cancer ^	7242	689 (10%)	20%	1449
Musculoskeletal cancers	194	63 (32%)	60%	116
Lymphoma	401	79 (20%)	30%	120
Other *	685	253 (37%)	40%	274
Total	17156	6226 (36.3%)	-	8899 (51.8%)

^This relates to inverse-planned IMRT for breast cancer

*'Other' comprises cancers coded as 'other', 'unknown', 'endocrine', 'skin', 'haematology' (not lymphoma)

7. Implementation

- 7.1** The Radiotherapy Board aimed for this report to address current and future usage, but not to tackle implementation of findings or recommendations. However, the authors feel that some points that have emerged during the writing of this report are worth noting. It is strongly recommended that this report is widely distributed within each devolved nation at least to the leads of each department and ideally to national/regional groups that oversee/commission radiotherapy services.
- 7.2** This report has highlighted that there is currently a variation in access to IMRT between centres and between tumour sites. The level of variation is relatively low in prostate and head and neck cancer but remains exceptionally high for all other tumour sites - ie the proportion of patients irradiated with IMRT in different centres varies between 0% and 100% for every other tumour site. This level of variation may exist currently because once a centre decides to adopt IMRT/ VMAT for a given site, the proportion of patients treated with IMRT rises rapidly for a variety of reasons including departmental efficiency.
- 7.3** We expect the level of inter-departmental variation will fall over the next five years as the centres treating a high proportion of their patients with IMRT reach a plateau and as the number of clinical trials allowing/mandating IMRT and the increasing use of SABR in different tumour sites increases the uptake of IMRT.
- 7.4** Furthermore, we believe that a UK-wide strategy to reduce the variation in access to IMRT for tumour sites with very wide variation in IMRT usage not supported by ongoing trial(s) needs to be developed, following the successful example of the NCRI's Anorectal Sub-Group's development of national outlining and planning documents for anal cancer prior to a clinical trial being funded.^{35,36}
- 7.5** Specific feedback to and support of sites with low overall IMRT usage and low usage in specific sites should be addressed by national/regional groups and the devolved nations should continue to work towards submitting data to NATCANSAT to allow UK-wide review of access to IMRT. NATCANSAT should consider reviewing its definitions to include inverse-planned IMRT only and to consider how to include radical SABR into their figures.
- 7.6** We recommend that all centres develop a five year implementation plan based on local patterns of care and priorities, including other radiotherapy developments, expecting their IMRT usage to be at least 50% of all radical cases within this time frame. Leading centres should expect to achieve this within three years.

- 7.7** We recommend that the use of IMRT for all patients with locally advanced head and neck cancer be implemented immediately – either by local use of IMRT or referral to another centre - and that all centres aim to implement IMRT for parotid sparing for lymphoma patients and for anal cancer within the next 12 months.
- 7.8** The long term view of many of the authors is that IMRT will be used for virtually all radical cases and for many palliative cases within the next 10 years.

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NB: some full text links require log in and/or purchase of articles in order to view.

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