

Radiotherapy Equipment Needs and Workforce Implications 2006 - 2016

Cancer Services Co-ordinating Group

**Radiotherapy & Chemotherapy Advisory Group
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Acknowledgements

The CSCG Radiotherapy and Chemotherapy Advisory Group*

The Clinical Oncology Sub Committee (COSC) of the Welsh Scientific Advisory Committee#

Dr M Adams*#, Chair Radiotherapy and Chemotherapy Advisory CSCG Sub Group; Medical Director, Consultant Clinical Oncologist, Velindre NHS Trust.

Dr S Al-Ismail* South West Wales Cancer Network Lead Clinician, Consultant Haematologist, Swansea NHS Trust.

Ms. N Bowl#, Radiotherapy Services Manager, North Wales Cancer Treatment Centre.

Mr. P Brown*#, Assistant Director, Department of Radiography, Wales College of Medicine, Cardiff University.

Dr A Champion*# Clinical Director and Consultant Oncologist, North Wales Cancer Treatment Centre.

Ms. S Evans*, Chief Pharmacist, Velindre NHS Trust.

Mr. D Heron*, Director, North Wales Cancer Network.

Professor R Leonard*#, Clinical Director of Cancer Services and Consultant Medical Oncologist, Swansea NHS Trust.

Ms. C Lloyd*, Director Radiotherapy Modernisation, NLIAH

Professor M Mason#, Professor of Oncology, Wales College of Medicine, Cardiff University.

Mr. H Morgan*, Director, South East Wales Cancer Network.

Ms. M Noonan# Superintendent Radiographer, Swansea NHS Trust.

Ms. P Pimm*# Radiotherapy Services Manager, Department of Clinical Oncology & Radiotherapy, Velindre NHS Trust.

Dr S Ryde*#, Consultant Clinical Scientist, Department of Medical Physics & Clinical Engineering, Swansea NHS Trust.

Dr J Steward, Director, Welsh Cancer Intelligence and Surveillance Unit

Assembly Government Adviser: Dr O Crawley,

CSCG Adviser: Dr J Hanson

Editors

Dr M Adams

Dr J Hanson

Ms. P Pimm

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CONTENTS

Acknowledgements	1
List of Tables	4
Executive Summary	5
Introduction.....	8
Background.....	8
Aim of Report	8
Importance of Radiotherapy in Cancer Treatment.....	9
Factors Influencing Future Demand for Radiotherapy	11
Increased population changes – ageing and population size	11
Increased cancer incidence	11
Increased cancer referrals	12
Increased complexity of treatment.....	13
Access to radiotherapy in relation to cancer incidence.....	15
Radiotherapy Provision and Linear Accelerator Productivity	17
Radiotherapy provision in Europe	17
Radiotherapy provision in Wales and UK	18
Radiotherapy Provision Models.....	20
Estimation of Future Capacity	23
Estimation of Future Capacity	23
Scottish Model	23
Linear accelerator productivity	24
<i>Number of fractions per hour</i>	25
<i>Number of hours used per day</i>	26
<i>Number of days used per year</i>	26
<i>Utilisation</i>	27
<i>Overall number of radiotherapy fractions per linear accelerator per year</i>	27
Recommendation 1	28
Gap Analysis and service models for meet the estimated demand for radiotherapy	29
Recommendation 2	31
Recommendation 3	31
Replacement Programme for linear accelerators	32
Implications for commissioning new and replacement linear accelerators	32
Recommendation 4	33
Increased requirements for associated equipment	33
<i>CT Simulators</i>	33
Recommendation 5	33

<i>Treatment Planning Systems</i>	33
Recommendation 6	34
<i>Equipment Site Issues</i>	34
Recommendation 7	34
Workforce issues including training	36
Clinical oncologist provision required for Wales	36
Radiotherapy radiographer provision	37
<i>Role of Therapeutic Radiographers</i>	37
<i>Current Radiographer Staffing</i>	37
<i>Radiographer staffing levels and the impact upon waiting lists</i>	38
<i>Future Provision of Radiographer Staffing</i>	40
Recommendation 8	41
<i>Future Training Issues</i>	41
Radiotherapy physics provision	43
<i>Role of Radiotherapy Physics</i>	43
<i>Current Physics staffing levels</i>	43
<i>Training issues for Scientists, Engineers and Dosimetrists</i>	47
Recommendation 9	48
<i>Research and development</i>	49
Service Modernisation	49
Recommendation 10	51
References	52
Appendices	56
Appendix 1	56
Service Standards for Radiotherapy Centres	56
1.1 <i>Waiting Times for Radiotherapy - National Cancer Standards and RCR</i>	56
<i>Audits of Compliance with Waiting Times for Radiotherapy</i>	57
1.2 <i>Core Standards for satellite centres</i>	60
1.3 <i>Standards for radiotherapy services required in the National Cancer Standards</i> ...	62
Appendix 2 – Radiotherapy Equipment	64
Appendix 3 – Radiotherapy workload	67
Appendix 4 – Roles and Responsibilities of Medical Physicists and Clinical Technologists ..	69
Appendix 5 – Access to Radiotherapy Centres	71
Appendix 6 - Models for projecting linear accelerator requirements	79

List of Tables

Table 1 - Increasing Cancer Incidence 2003 - 2015.....	12
Table 2 - Non Surgical Cancer Referral Increases Across Wales 2002 - 2004.....	13
Table 3 - Increasing radiotherapy workload across Wales 2001 - 2005	15
Table 4 - Access to radiotherapy in Wales in 2002 and 2003.....	16
Table 5 - Linear accelerator provision throughout Europe	18
Table 6 - Provision of linear accelerators in the UK.....	19
Table 7 - Cumulative % population in relation to distance travelled in kilometres.....	20
Table 8 - Summary of radiotherapy provision models.....	22
Table 9 - Current linear accelerator workload for Welsh Cancer Centres 2005	25
Table 10 - Impact of changing the working day on radiotherapy capacity.....	31
Table 11 - Capacity, based on service model A, of each cancer centre.....	35
Table 12 - Clinical Oncology provision required for Wales	36
Table 13 - Current Radiographer Staffing.....	37
Table 14 - Radiotherapy Physics Staffing at December 2005.....	44
Table 15 - Total Radiotherapy Physics Staffing for additional accelerators based on Service Model A, plus patient factors and other supporting equipment, facilities and tasks at December 2015	45

Executive Summary

1. Wales has an ageing population and consequently cancer will continue to be an increasing problem. Projections for the period 2003 - 2015 confirm that there will be a significant increase in the incidence of common cancers over the next 10 years. It is anticipated that the overall incidence of prostate, breast and colorectal cancer will increase by 28.5% during this period. These common cancers represent approximately 50% of the overall cancer incidence (**see paragraph 17**)
2. Radiotherapy is the use of high-energy X-rays to treat disease and is usually fractionated which allows large doses of radiation to be given whilst sparing normal tissues and limiting side effects. It remains a key component of curative and palliative cancer management and its use is increasing internationally. It accounts for treatment in 53% of cancer patients in developed countries. The demand for radiotherapy has been and will be exacerbated by the increasing complexity of treatment. (**see paragraph 5**)
3. With current equipment and manpower resources, most patients in Wales are not receiving their radiotherapy according to the Welsh National Cancer Standards which endorse the Royal College of Radiologists (RCR) Standards. Audit data show the RCR waiting times for radiotherapy in Wales to be longer than elsewhere in the UK which suggest the current linear accelerator and workforce provision in the Welsh Cancer Centres to be inadequate. (**see paragraph 10**)
4. Currently Wales has 3.7 linear accelerators per million population, significantly less than the average provision in England or Scotland which stands at 4.7 and 4.98 linear accelerators per million respectively. (**see paragraph 38**)
5. Published reports in Scotland and across the developed world, have unanimously concluded that the projected need for radiotherapy has been significantly under-estimated as they have not fully accounted for the increase in cancer incidence and the rapid developments in clinical practice (**see paragraph 34**)

6. In order to provide adequate provision of radiotherapy in Wales, it is recommended that Wales should aim to provide 58,000 fractions of radiotherapy per million population by 2016. This figure is supported by the minimum projections from recently data published for developed countries and the projected cancer incidence in Wales (**see paragraph 33**).
7. To achieve the above recommendation, between 6 to 10 new additional linear accelerators will be needed by 2016, depending on the service model adopted, with each providing at least 8,000 fractions per year by 2016. It is also estimated that 11 replacement linear accelerators will be needed over this time scale. As a first step all radiotherapy centres in Wales should have 5 linear accelerators per million population and be providing at least 8,000 fractions per linear accelerator per year. Extending the working day to an average of 9 hours has the potential to increase capacity to a mean of 9,388 fractions per linear accelerator per year. The number of radiotherapy fractions per linear accelerator per year should be monitored annually (**see paragraph 67, 71**).
8. The extra radiotherapy equipment and the potential for extended working hours will require increased staffing of clinical and medical oncologists, radiographers, clinical scientists, dosimetrists and engineers. (**see paragraph 81**).
9. To ensure optimum use of equipment and appropriate staffing levels an ongoing review of working patterns in each radiotherapy centre, including extending the working day beyond the conventional 8 hours per day 5 days per week, is recommended. A review of working patterns and staffing levels, needed to provide a core service, should commence in 2006 (**see paragraphs 0, 72, 81**).
10. The Royal College of Radiologists (RCR) is currently undertaking a review of the evidence base for fractionation (**see paragraph 0**). The CSCG Radiotherapy and Chemotherapy Advisory Group plan to audit the fractionation protocols in use in the three Radiotherapy Centres against best practice. The increase in demand estimated in this report should be reviewed following completion of this work.

11. This report has considered the radiotherapy equipment needs based on existing technology. However, radiotherapy technology is developing very rapidly, and to develop a world-class service, techniques based on image guided radiotherapy will need to be incorporated in the service. This will also benefit from an early review.

12. The ability to implement these recommendations will depend upon an effective regional commissioning strategy which ensures adequate revenue funding to support both the capital development and modernisation in working practice.

Introduction

Background

1. The Cancer Service Co-ordinating Group initially submitted a strategic plan for Cancer Services to the Assembly Government in 2002. This plan included a 12 year plan for Radiotherapy services drawn up by the Welsh Scientific Advisory Committee's Clinical Oncology Sub Group (COSC). In 2005, the CSCG commissioned COSC to review and update the 2002 plan. In 2006, the CSCG convened a Radiotherapy/Chemotherapy Advisory Group to further support this work and provide on-going national advice to inform strategic developments in line with the Assembly Government's strategy Designed for Life⁴².

Aim of Report

2. Designed for Life provides a plan for creating world-class healthcare and social services in Wales by 2015. The first phase of implementation of the strategy, ending in 2009, includes the requirement that cancer services must comply with the 2005 National Cancer Standards. Access to and timely delivery of radiotherapy is key to clinical management. A report of Wales' radiotherapy equipment and specialist manpower is required to determine the steps that need to be taken to ensure the Cancer Standards for radiotherapy are met.
3. This report examines the provision of radiotherapy in Wales in comparison to other developed countries; assesses the importance of this treatment for cancer patients and the reasons for the increasing demand. Recommendations are made for future radiotherapy equipment provision and the associated manpower implications.

Importance of Radiotherapy in Cancer Treatment

4. Radiotherapy is a key component of 40% of curative (radical) cancer treatment when used alone or combined with other modalities¹⁻³. This compares to 50% for surgery and only 11 % for chemotherapy. In addition, radiotherapy is a highly effective option for palliative treatment in advanced or recurrent cancer e.g. relief of pain from bone metastases¹⁴. Linear accelerators are used to deliver external megavoltage radiotherapy which is largely devoted to curative treatment (70-80%)^a.
5. In the 1980s, it was frequently predicted that the proportion of patients requiring radiotherapy would decrease as a result of potential treatment developments particularly with drugs. However, these expectations have not been realised and the need for radiotherapy internationally has steadily increased. In addition it has increasingly been integrated into combined treatment with surgery and chemotherapy. New developments in imaging have also led to technically more complex radiotherapy that is less likely to cause major side effects. Consequently, in developed countries the number of patients who require radiotherapy has significantly increased. The proportion of patients who receive radiotherapy as part of their treatment has risen in some countries from about 43 % in the early 1990's to 53 % in recent years⁸⁻¹⁰.
6. It is important to deliver radiotherapy in a timely fashion otherwise cancers may progress and the prognosis deteriorate. Delayed radiotherapy for palliative treatment will result in prolongation of suffering e.g. pain from bone metastases with consequent deterioration in quality of life.
7. There is now increasing clinical evidence which indicates delayed radiotherapy treatment results in reduced prospects for cure²¹⁻²⁹. A delay of 30-60 days can result in reduced local cure rate for head and neck, cervical, breast and prostate

^a Brachytherapy is an important component in the treatment of some cancers especially gynaecological cancer. It is currently the subject of RCR and NICE guideline review which is anticipated in 2006 and is consequently outside the scope of this report

cancer particularly for faster growing tumours ²¹. Waiting times which allow tumour volumes to increase, may result in an average tumour control loss of 16-19% for oropharyngeal tumours ²⁹.

8. A delay greater than 40 days was significantly associated with reduced tumour control at the primary site and in neck failure, and poorer survival in patients with head and neck cancer treated with radical radiotherapy ²⁷. Hansen reported a month delay from the onset of symptoms to start of radiotherapy was equivalent to a 4.5% decrease in recurrence-free survival ²⁶. Similarly a delay between surgery and radiotherapy of 50 days causes inferior local control rates²⁴.
9. The importance of access to radiotherapy is reflected in the RCR recommendations of best practice and maximum waiting times. Compliance to these recommendations is required in the 2005 National Cancer Standards along with the generic waiting times to start of definitive treatment (see Appendix 1)
10. All Welsh Cancer Centres have participated in UK RCR audits undertaken in 1998, 2003 and 2005 18, 19. In 1998 32% of patients were waiting longer than the RCR 28 day standard for radical radiotherapy in UK Cancer Centres (see Appendix 1 Table A1.1). There is no basis at present to set a threshold of delay below which there is no risk. However the longer the radiotherapy is delayed the poorer the prognosis ²¹.
11. By 2003 waiting times had deteriorated with 75% waiting longer than 28 days for radical radiotherapy. The results of the 2005 audit showed that this alarming situation has continued with only 26% of radical and 57% of palliative patients being seen within 28 and 14 days respectively.
12. Increased capacity both in terms of staff and equipment is considered central to achieving the waiting times standards and therefore better outcome for patients.

Factors Influencing Future Demand for Radiotherapy

Increased population changes – ageing and population size

13. The Welsh population is projected to increase to 3 million by 2009 from the current 2.95 million and to increase further to 3.08 million by 2015. The population will continue to age with an extra 150,940 people over 60 year in Wales by 2015 compared to 2003 with an age distribution which continues to have a higher retirement group than the rest of UK. Clearly, these population changes will further contribute to cancer incidence and the demand on radiotherapy services over the next 10-15 years.
14. Wales, like the rest of the UK, has an ageing population and as cancer incidence increases with age, cancer is becoming an increasing problem, affecting one in three of the population². It is reasonable to assume that more elderly patients are likely to receive radical radiotherapy as recent data confirms that chronological age is not a major factor related to the level of side effects experienced by elderly patients receiving radical radiotherapy¹⁶.
15. In addition an increasing number of patients in Wales and throughout Europe are surviving longer with advanced disease as a result of new treatments. These patients are not cured but will remain on follow up for prolonged periods until they sadly succumb to the disease. They will frequently require further radiotherapy to palliate symptoms.

Increased cancer incidence

16. The incidence of three of the most common cancers (breast, prostate and large bowel cancers) has increased significantly in the UK. These cancers are all heavy users of radiotherapy. For example the incidence of prostate cancer has risen by 48%¹⁵. The increased incidence of breast cancer in the UK from approximately 34,000 to 40,000 during 1993 to 2000, would suggest the need for 11 new linear accelerators across the U.K to provide the required radiotherapy just for this one

type of cancer ¹⁷. Similarly the incidence of prostate cancer has also significantly increased the demand for radiotherapy.

17. Table 1 indicates the estimated incidence for common cancers in Wales over the next 12 years 2003 to 2015. There are likely to be major increases in the incidence of prostate, breast and colorectal cancer with an overall anticipated increase in incidence of 28.5% by 2015. These common cancers represent approximately 50% of overall cancer incidence.

Table 1 – Increasing Cancer Incidence 2003 - 2015

Site	2003	2015	Increase	% Increase
Prostate	2,023	3,012	989	41.0
Breast	2,388	3,144	726	25.3
Colorectal	2,029	2,716	687	28.2
Total	16,376	21,990	5,594	28.5

Source: Wales Cancer Intelligence and Surveillance Unit (WCISU)

18. These cancers are increasingly being diagnosed in the early, curable stages due to improved screening and health education ¹⁵. In these earlier stages they are more likely to benefit from radical radiotherapy. These treatments require large numbers of fractions per course i.e. 20-30, whereas palliative radiotherapy requires fewer fractions ¹⁻⁹. Thus, increasing rates of early diagnosis can contribute to increasing radiotherapy demand and results in an overall increase in fractions and exposures per course.

Increased cancer referrals

19. Increased referrals for all cancers have been noted in the UK with increased use of evidence based practice following the Calman Hine report (1995) in the UK and the Cameron report (1996) in Wales. In the 1990's many cancers would have been

treated with surgery alone. With clinical trial evidence introduced into clinical practice, there has been an increasing role for radiotherapy e.g. cancer of rectum. Although most radiotherapy for lung cancer remains palliative, recent evidence now supports the use of hyperfractionation treatment for some lung cancers, which is inevitably associated with an increased number of fractions⁴³.

20. In Wales, increasing cancer referrals continue to be observed in all 3 Cancer Centres and at present there is no indication that the increased referral rate is slowing (Table 2). This has inevitably led to further demand on radiotherapy services.

Table 2 – Non Surgical Cancer Referral Increases Across Wales 2002 - 2004

Radiotherapy Centre	2002	2004	% Change
Velindre	4956	5876	+ 19%
Swansea	2844	3250	+14%
N Wales*	1880*	1969*	+5%

* These figures exclude medical oncology in N .Wales

Increased complexity of treatment

21. Increasing complexity is becoming a feature of modern radiotherapy treatment. The development of new imaging techniques and computerised planning makes it possible to direct radiation more accurately to the tumour volume whilst sparing normal tissues and reducing the risk of radiation damage e.g. Intensity Modulated Radiotherapy (IMRT).

22. These techniques require more fractions and exposures and increasing treatment time on linear accelerators, therefore reducing the throughput of patients. They also

provide the opportunity to increase the radiation dose to improve cure rates e.g. for treatment of prostate cancer. From 1992-1997, the UK has observed an 18% increase in the number of radiotherapy exposures as a result of complexity and this trend has continued.

23. A range of factors may influence the patient throughput on a linear accelerator ⁴⁸. The introduction of multileaf collimators (MLCs) and auto-sequencing, in the last 10 years, have tended to increase the throughput of patients. Linear accelerators greater than 10 years old may not have these facilities. Average fraction time, in minutes, has been found to vary between 11.9 - 13.4 minutes (new versus old linear accelerators); 12.1 - 13 minutes for presence or absence of MLCs; and 11 - 13.1 minutes for presence or absence of auto-sequencing, for the same case mix.
24. These data would suggest a maximum throughput of 4.5 to 5 fractions per hour depending on linear accelerator age. However, in recent years, there has been a demand for increased quality assurance. Verification of the treatment plan using electronic portal imaging devices (EPIDs) can increase fraction time by 1.51 to 2.75 minutes per field, which will tend to negate the increased efficiency associated with MLCs and auto-sequencing.
25. In Wales, the complexity of administering radiotherapy can be measured by the number of radiotherapy fractions and exposures; these have been increasing since the 1990's. This is associated with a higher proportion being treated curatively, fewer palliatively and the use of increasingly more sophisticated treatment plans to spare normal tissues.
26. This trend is evident in all Welsh Cancer Centres with a 9.26% increase in radiotherapy fractions and a 19.5% in radiotherapy exposures from 2001/02 – 2004/05 (Table 3). Further detail is provided in Appendix 3.

Table 3 - Increasing radiotherapy workload^b across Wales 2001 - 2005

Radiotherapy Centre	Fractions		Exposures	
	2001-2	2004-5	2001-2	2004-5
South East	42,661	47,360	105,641	132,571
South West	24,475	24,372	54,864	60,688
North	16,406	19,109	45,770	53,219
All Wales	83,142	90,841	206,275	246,478

Source: COSC

27. Recently published work from the RCR has described current radiotherapy practice in the UK and concluded that, whilst this has become more uniform over the last 15 years, significant variations in practice remain⁴⁴. Clinical guidance requiring increases or decreases in fractionation protocols for the common cancers will impact on workload and this needs to be kept under review. The START trial, which is expected to report within the next 2 years, is investigating fractionation patterns in breast cancer and may lead to a reduction in work load. However, on-going trials involving colorectal cancer and prostate cancer may offset these gains if increased fractions are indicated for these cancers.

Access to radiotherapy in relation to cancer incidence

28. The total number of new cancer patients in the UK receiving radiotherapy as part of their treatment increased significantly in the 1990's. The number of patients receiving radiotherapy increased from 52,737 in 1992 to 57,269 in 1997 with an increase of 8.6 % in exposures over the same time period. The proportion of patients who receive radiotherapy as part of their treatment has risen internationally from 43% in the early 1990's to more recent figures of 53% in Australia in 2003.

^b Includes linear accelerators, brachytherapy, superficial and orthovoltage.

29. The access rate to radiotherapy for different years can be defined as the percentage of patients who receive radiotherapy as part of their first line treatment for cancer (see Table 4).

30. It has been estimated from the Radiotherapy Equipment Survey (RES) and supported by the RCR that delayed radiotherapy (for relapse) can be applied to 16% of patients treated with radiotherapy in the UK. This re-treatment rate is calculated on the basis of prescriptions, and fractions making up those prescriptions, where the same patient has a previous prescription within the last three calendar years. For this report a 14% re-treatment rate was recommended (personal communication M. Williams). Therefore the factor 1.14 has been used to separate first radiotherapy courses from the total number of radiotherapy courses in Wales.

Access rate to radiotherapy is calculated using the following formula:-

$$\text{Access} = \frac{\text{Total no. of RT courses/year}}{1.14 \times \text{Total number of cancers in Wales/year}}$$

Table 4 Access to radiotherapy in Wales in 2002 and 2003

	2002	2003
Total cancer incidence	15,479	16,376
Number of radiotherapy courses	6,546	6,453
Access to Radiotherapy	37.1%	34.6%

31. The range of 34.6% to 37.1% for access to radiotherapy in Wales is low in comparison with other developed countries where the access figure has exceeded 50% ^{8, 13}. Further work is needed in order to validate these data however it suggest that there may be under-referral for radiotherapy treatment in Wales.

Radiotherapy Provision and Linear Accelerator Productivity

Radiotherapy provision in Europe

32. The World Health Organisation Global Review 1999¹ of radiotherapy services for developed countries recommended a minimum provision of 5 linear accelerators per million population.

33. Between 2003 – 2005, a series of reports from the UK, Scotland, Netherlands, Australia, and Canada have unanimously concluded that, to meet current standards and avoid waiting times, the number of linear accelerators/million population needs to be significantly increased to a minimum of 6.5 linear accelerators per million population (Table 8)^{7-9, 12, 13}. Having assessed the cancer incidence in the relevant country, the likely developments in clinical practice and achievable linear accelerator throughput, the reports have all come to a remarkably similar minimum figure of 54-58,000 radiotherapy fractions/million population being needed by 2010-2015. The number of linear accelerators required per million population will depend on productivity and current practice shows this to be approximately 8,000 fractions per linear accelerator per year (Table 8). Increased productivity has been achieved through service modernisation and forms the basis of the recently published Scottish Report⁴⁵. A report projecting the radiotherapy demands and capacity for England is in preparation.

34. The provision of radiotherapy equipment throughout Europe shows that the UK has, for many years, lagged behind in terms of access to radiotherapy facilities (Table 5).

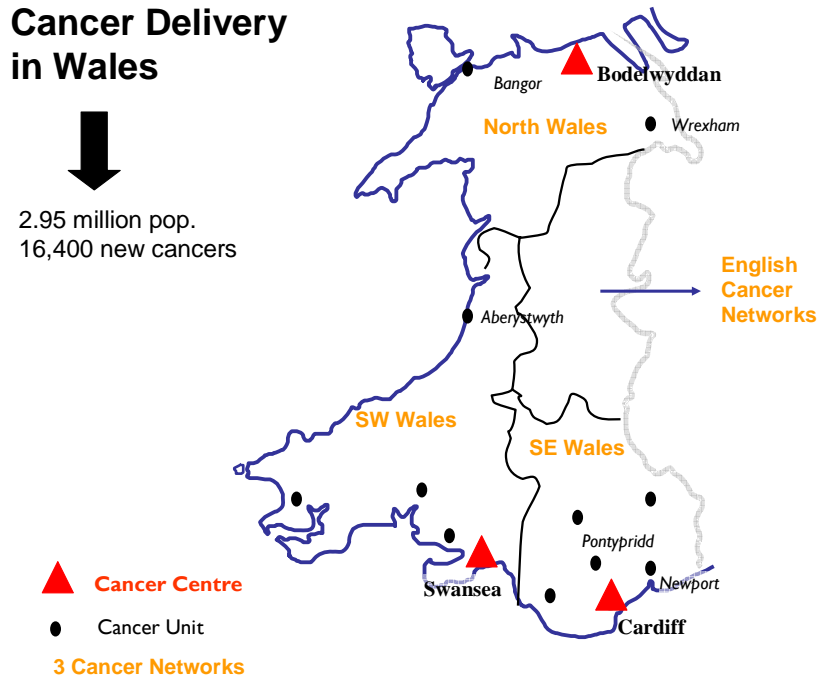
Table 5 Linear accelerator provision throughout Europe

Country ⁷	Number of linear accelerators/ million population in 2000
France	6.12
The Netherlands	4.65
Germany	4.60
Italy	4.31
England	3.37
Scotland	4.97
Wales	3.10

Radiotherapy provision in Wales and UK

35. Radiotherapy in Wales is provided by 3 Radiotherapy Cancer Centres; this was endorsed by the Cameron Report in 1996. Their locations are illustrated (Figure 1 and Appendix 5).

Figure 1 – Radiotherapy provision in Wales



36. The population served and the linear accelerator provision in each Cancer Centre is detailed in Table 6.

Table 6 Provision of linear accelerators in the UK

	S.E. Wales	S.W. Wales	N. Wales	Wales	England	Scotland
Population Served (millions)	1.46*	0.75*	0.73*	2.95	48.7	5.1
Total linear accelerators	5	3	3	11	229	25
Linear accelerators/million population (+2007)	3.5	4.0	4.3	3.7	(4.7 ⁺)	(4.98 ⁺)

*Population figures based on patient referrals for radiotherapy commissioned from Dr Brian Cottier for the CSCG using the same methodology as for England http://cancernw.org.uk/downloads/catchpop_comm30.12.2002_v1.0.exe.

⁺ The number of linear accelerators by 2007.

37. Currently funding is being considered to support a national programme to increase radiotherapy capacity in Wales.

38. Wales will therefore require further significant investment to reach the targets for 2007 in England and Scotland prior to expanding further to meet the 2015 target capacity.

39. Travel times for some patients in South West Wales and North Wales is greater than in South East Wales reflecting the rural character of these regions (Table 7 Appendix 5). Excessive travel times may affect uptake of radiotherapy treatment.

Table 7 Cumulative % population in relation to distance travelled in kilometres

% cumulative population	Distance Travelled (Km)		
	S.E. Wales	S.W. Wales	N. Wales
80%	28	75	51
90%	34	88	65
Maximum distance travelled	110	112	107

40. In England, following Government funding for the National Cancer Plan in 2002, the number of linear accelerators will increase to 4.7 linear accelerators per million population by 2007. In Scotland additional funding will result in 4.98 linear accelerators per million population by 2007/08. The Assembly Government in Wales provided funding to support 2 linear accelerators^c as the first step of the CSCG 2002 strategic plan.

Radiotherapy Provision Models

41. As described earlier, the demand for radiotherapy has been determined by increased cancer incidence, increasing indications in clinical practice and rapid treatment developments which have led to increased complexity. These factors have proved difficult to accurately predict.

42. In 2002 the RCR recommended 4 linear accelerators per million population rising by 5% per year to take account of increasing cancer incidence and complexity⁴. This gave a predicted requirement of 5 linear accelerators per million population by 2006 and 5.5 linear accelerators per million population by 2010.

43. Radiotherapy provision in Scotland will have reached 4.98 linear accelerators per million population by 2007. Redesign of the working day, with a limited further

^c 1 new and 1 replacement linear accelerator in North Wales Cancer Treatment Centre and Velindre Cancer Centres respectively

expansion to approximately 5.6 linear accelerators per million population is suggested^{12, 45}.

44. Welsh data of current cancer incidence, provision and productivity are presented and compared with data from Scotland, England and the Netherlands in Table 8.
45. There has been a strongly held view in the UK and abroad that cancer services, such as radiotherapy facilities should be based at cancer centres. However, there is now good evidence from parts of the world with dispersed populations that distance from a radiotherapy facility may influence the uptake of radiotherapy by patients⁴⁶. There are moves in some developed countries e.g. Sweden to move away from a completely centralised model. Expansion of radiotherapy facilities may provide an opportunity for improving access to radiotherapy with linked 'satellite' units. In addition building constraints may lead to the provision of devolved services. However, such devolved satellite centres should follow core standards recommended for all radiotherapy treatment as defined by RCR
46. Devolved services imply radiotherapy units or satellites with links to cancer centres. The RCR define a linked unit as one which cannot provide its agreed level of service without the professional support of another radiotherapy facility. These links might include the provision of specialist clinical, radiographic and physics services, particularly for the planning and delivery of treatment. A unit independent by the above criteria would still need essential clinical links for multidisciplinary working. A hospital radiotherapy department making referrals elsewhere for specialist radiotherapy services would not constitute a linked relationship.
47. This RCR report reviews the complex range of issues which must be addressed by clinicians and managers to ensure that the quality and timeliness of treatment and the care of patients is not compromised in any way by the introduction of a devolved radiotherapy service. The risks and benefits of various models for the

delivery of treatment are assessed. Core standards are recommended for all radiotherapy treatment and are summarised in Appendix 1.2.

Table 8 Summary of radiotherapy provision models

	Scotland 2005¹³	England 2003⁴⁷	Netherlands 2003^{10**}	Wales 2005[†]
Cancer incidence /million	5,000	5,000	4,730	5,017
Fractions/ linear accelerator	7,646	7,258	8,000	7,666
Fractions/ million	56,300- 69,500	56,250	58,000	30,161
Courses/ million	2,700	3,653	3,621	2,236
Linear accelerator/ million	7.4-9.1	7.7	7.2	3.7

[†] Current radiotherapy provision based on figures provided by WCISU and the three Welsh Radiotherapy Cancer Centres

^{**} This paper described the underestimate provided by previous models and proposed a new model based on complexity.

48. The methodology forming the rationale for the projections and recommendations in the recent UK reports differs and is described below. The overall recommendations, in terms of radiotherapy fractions/million, are very similar for all countries with similar cancer incidence (see Table 8).

Estimation of Future Capacity

Estimation of Future Capacity

49. Data from the European Union funded project ESTRO QUARTS has been used to plan future requirements ⁷. This study identified the crude incidence of 23 reference cancers and then used the appropriate radiation rate (ARR) from the Australian CCORE work to calculate the number of linear accelerators required ⁸. The total number of linear accelerators required was calculated assuming 8,000 fractions a linear accelerator per year and using the following formula:

Total fractions required = ARR x Incidence x Fractions /treatment

Total linear accelerators required =
$$\frac{\text{Total Fractions}}{\text{Fractions/linear accelerator}}$$

50. This model, which considered the case mix to be found in different European countries, was used to provide recommendations using the GLOBOCAN 2000 cancer incidence figures appropriate to the UK. The findings are consistent with a provision of 58,000 fractions of radiotherapy per million population for the UK as shown in other models (Table 8).

Scottish Model

51. This report commissioned by the Scottish Executive also built on the work of the Australian group led by Delaney et al (2003)^{45, 8}. It anticipated that demand for radiotherapy would increase substantially over the next 10-15 years due to a combination of demographic and clinical factors. Large increases were predicted in the number of oesophageal, prostate and colorectal cancers, with a fall in only lung, cervix and stomach cancers. Cancer incidence was expected to be approximately 6,300 per million by 2015 and up to 48% would require radiotherapy.

52. The future clinical demand and the basis for capacity planning was achieved by modelling stage and incidence with likely patterns of treatment using best evidence guidelines and clinical expectations of future practice.
53. The report recommends 56,300- 69,500 fractions of radiotherapy per million population to meet the expected demand with machines working to 90% capacity. In addition, having achieved 4.98 linear accelerators per million population by 2007 the report makes very specific measures for service design with either a small linear accelerator expansion (3 to 4 additional linear accelerators, equating to 5.6 linear accelerators per million population) or increase in working hours to a 6 day week providing for increasing service capacity.
54. The Scottish model is underpinned by increasing capacity through service redesign. The following steps are identified.
- Expand to 5.6 linear accelerators per million population
 - Consider increasing the core clinical service to a 10 hour day, 5 day week;
 - Reduce the days lost as a result of closure for public holidays and routine maintenance to achieve 257 clinical days per annum; Wales currently works for 244 clinical days per annum.
 - Optimise the capacity of all linear accelerators in Scotland and redistribute workloads;
 - Review workforce shift patterns, working practices, skill mix, new roles and additional staff requirements to meet the new core service model;
 - Identify funding required to increase the number of medical physicists in training from four to six per year for therapy physics and providing pump-priming funding for advanced practitioners and/or consultant therapy radiographers in at least the larger centres to enhance recruitment and retention.

Linear accelerator productivity

55. Current linear accelerator productivity in the Welsh Radiotherapy Centres is summarised in Table 9.

Table 9 Current linear accelerator workload for Welsh Cancer Centres 2005

	SE. Wales	S.W. Wales	N. Wales	All Wales average
No fractions/hour	4.65	4.06	4.16	4.29
Hours/day used	8	8	6.3*	7.4
Number of days used/year	244	244	244	244
Utilisation	125%	100	70%	98.3%
Overall Exposures/linear accelerator/yr	25,973	19,982	17,407	22,003
Overall fractions/linear accelerator/yr	9,084	7,919	6,096*	7,666

Source: COSC

* N Wales has 1 linear accelerator working 50% of each working day due to therapeutic radiographer shortage.

56. In order to deliver timely radiotherapy, the calculation of the efficiency of patient throughput on the linear accelerators is an important consideration to calculate radiotherapy provision. These factors will vary with the age of the linear accelerators, the availability of radiographers and working patterns. The key factors are:-

Number of fractions per hour

57. The number of fractions per hour varies from 3.9 to 4.55 as evidenced by the RCR⁴. The variability is due to adequacy of staffing, complexity of radiotherapy set up, infirmity of the patients and the number of clinical interruptions or machine breakdowns.

58. In Wales, the mean number of fractions/hr/linear accelerator is currently 4.3 (Table 9).

Number of hours used per day

59. The Scottish report has suggested a redesign of working patterns including extending the working day beyond conventional 8 hours per day 5 days a week. Problems have been encountered when this has been attempted in the past, and adequate staffing levels are required to make this service model sustainable. In addition, longer working days will inevitably result in a loss of flexibility when breakdowns occur. Three reports have examined the potential economic savings from extended working and concluded that there are minimal savings to be made when the extra costs of staff overtime and the consequent shortening of linear accelerator lifetime are taken into consideration³⁰⁻³².

60. In Wales there have been problems of recruiting and training radiographers particularly in North Wales where one linear accelerator is working at 50% capacity because of staff shortages. Extending the working day or commissioning new linear accelerators is only an option if further radiographers can be trained and recruited. Further, the radiotherapy physics group in the North Wales Radiotherapy Cancer Centre are currently experiencing staff shortages which would need to be addressed before extended day support of the clinical service was possible.

Number of days used per year

61. In Wales, currently all linear accelerators are working 244 days for routine radiotherapy, with on-call days to provide emergency treatment e.g. cord compression on weekends. Continuous Hyperfractionated Accelerated Radiotherapy (CHART) fractions for the radical treatment of lung cancer are also covered at weekends and in the evenings.

62. The Scottish Report suggests reducing the days lost, as a result of closure for public holidays and routine maintenance, to achieve 257 clinical days per annum. For Welsh radiotherapy centres to adopt a 257 days model for routine radiotherapy would again require further staff.

Utilisation

63. The RES (Radiotherapy Episode Survey) and the Cancer Services Collaborative Improvement Programme for Radiotherapy have shown that there is potential to maximise the productivity of linear accelerators by more uniform use throughout the working day.
64. The Scottish report recommends 90% utilisation of funded clinical hours. Utilisation of 85-90% ensures allowance for unscheduled machine down-time, research and development needs and to ensure waiting times are not built into the system.
65. In the South Wales Radiotherapy Centres utilisation suggests that there is not sufficient allowance to compensate for servicing, down-time, research and development and no flexibility to cope with surges of referrals which can cause transient increases in waiting times. In North Wales the utilisation of 70% is a further consequence of staff shortages.

Overall number of radiotherapy fractions per linear accelerator per year

66. An overall figure of 8000 fractions/linear accelerator/year can be considered as a bench-marking standard for an 8 hour working day. This standard is currently greatly exceeded in the South East Wales Radiotherapy Centre, suggesting over use of these machines (Table 9). In the South West Wales Radiotherapy Centre the number is similar to the bench-marking standard. In North Wales, this will depend on funding to recruit and retain adequate staff.
67. It is recommended that as a first step Wales should adopt the following productivity recommendations in all three Radiotherapy Cancer Centres. This is considered the core service model.

Recommendation 1

- **Number of fractions/hour = 4.5 fractions – this may reduce due to complexity**
- **Hours used/day = 8hrs per day**
- **Number of days used/year = 244 days**
- **Linear accelerator utilisation = 90%**
- **Overall number of radiotherapy fractions/linear accelerator/year = at least 8,000 as first implementation step**

Gap Analysis and service models for meet the estimated demand for radiotherapy

68. In order to meet the rising cancer incidence in Wales and provide adequate provision of radiotherapy, it is recommended that Wales should aim to provide 58,000 fractions of radiotherapy per million by 2016.
69. This figure is in keeping with the minimum projections from recently available data from developed countries and the projected cancer incidence in Wales. Demand for radiotherapy should be monitored on an ongoing basis to validate radiotherapy projections based on cancer incidence and likely patterns of treatment, using best evidence guidelines.
70. To calculate the extra linear accelerators needed to provide 58,000 fractions per million population the following estimates have been made of the deficit between the current service provision and that predicted to be required by 2016. Based on the need for 58,000 fractions per million population, Wales will require 174,000 fractions by 2016. Currently 87,566 fractions are provided (Appendix 3) giving a deficit of 86,434 fractions.
71. Various options have been considered as to how to meet this demand and are summarised in Table 10 with additional detail in Appendix 6. Calculations are based on,
- a population for Wales of 3 million and has not taken into account any population increases year on year ;
 - the benchmark of 8,000 fractions per linear accelerator per year ;
 - the assumption that Wales has the workforce, land and training capacity to accommodate the additional linear accelerators as detailed above. Full details of these potentially limiting factors can be found in the report
 - each centre in Wales is working to full-capacity and is therefore justified in increasing the number of linear accelerators which they have ;

- all centres have a spare bunker, thus meaning that there is no loss of linear accelerator productivity during the replacement programme.
 - Linear accelerators for Models B and C may need to be replaced earlier because of increased usage
- a) Model A - Optimising the current core clinical service model for every linear accelerator in Wales would achieve a full 8 hour clinical day and would result in an immediate increase in productivity in N. Wales if the staffing is available.
- b) Model B - demonstrates a 10 hour clinical day. Working a 10 hour day on all linear accelerators would inevitably result in the loss of flexibility in radiotherapy departments in the event of breakdowns. Increased productivity is probable if adequate staff are funded and recruited to work shifts and extend the clinical day. The impact would be on radiographers, medical staff, physicists, technologists, engineers, pharmacy, radiology, haematology and supporting services.
- c) Model C - demonstrates half the linear accelerators working a 10 hour day and the other half an 8 hour day, averaged to 9 hours per day.

Table 10 Impact of changing the working day on radiotherapy capacity

Service Model	Total additional linear accelerators	Additional linear accelerators per year								
		2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Model A – optimised 8 hour day	10	4	1	1	1	1	1	1		
Model B – 10 hour day	6	4		1		1				
Model C – Mix of A & B giving 9 hour day	8	4	1	1	1	1				
Replacement linear accelerators Model A		1		3	2			1	3	1

72. The extension of the working day in Models B and C does not envisage staff working beyond contracted hours. If extended working beyond 5pm or at weekends is adopted other core services will need to be provided such as nursing, medical, portering etc.

Recommendation 2

To achieve 58,000 fractions per million population Wales should plan for an extra 6 to 10 new and 11 replacement linear accelerators by 2016 depending on the service model adopted.

Recommendation 3

The establishment of staff will need to be regularly reviewed as innovative ways of working are adopted, the number of patients' change, new equipment, technology and clinical protocols are introduced, and in the light of national published guidance.

Replacement Programme for linear accelerators

73. The timetable outlined in Table 10 shows a possible template for the purchase of new and replacement linear accelerators. However, before new linear accelerators are considered, each radiotherapy centre should demonstrate that their current linear accelerators are working efficiently (see paragraph 67). Each new linear accelerator will require support for maintenance and regular upgrading of software as necessary to enable clinical utilisation of newer treatment technologies.
74. The Swansea Radiotherapy Cancer Centre is fortunate in having a new decant bunker so that capacity can be readily increased. There is also a fifth bunker containing an aging accelerator the design of which is such that with refurbishment of key components it could have its clinical life extended by possibly 3-4 years at perhaps a tenth of the cost of a new machine.

Implications for commissioning new and replacement linear accelerators

75. Procurement, acceptance testing and commissioning of new linear accelerators is a complex and lengthy process and requires, in particular, extensive Radiotherapy Physics resources. Considerable thought would be required in determining the timetable of any replacement and new installation because of these demands on Radiotherapy Physics Services. The ideal timetable spreads the installation and commissioning over a longer period of time; if this is not possible then either extra human resource would be required, or a reduction in other work done during the period of commissioning. Given that the SE and N Wales Centres are due for replacements within four years it is a matter of urgency to commence a phased replacement in order that not all have machines reaching the end of their life at the same time, with the obvious potential consequences of downtime and waiting time.
76. In addition to the constraints of staff availability, the installation and commissioning of replacement accelerators would also need to be reconciled with any additional new accelerators due to availability of equipment required for

commissioning. In order to operate with maximal efficiency it might be necessary to obtain (by purchase or lease) additional equipment, such as at least one extra plotting tank with detectors and acquisition system.

Recommendation 4

The installation programme for major equipment, particularly linear accelerators, should be phased over a suitable time period at each treatment centre.

Increased requirements for associated equipment

CT Simulators

77. The introduction of additional linear accelerators will also require the installation of additional equipment to undertake treatment planning. Every department now has access to a treatment simulator, and SE Wales has also a CT-simulator. As departments expand, additional treatment simulation equipment will be required, in particular at least one CT-simulator for every 5 linear accelerators⁴¹. The base line of the ratio of simulators to linear accelerators should be 1 to 3 but this may vary depending on local circumstances.

Recommendation 5

There should be 1 CT simulator/simulator for every 2 or 3 linear accelerators.

Treatment Planning Systems

78. Replacement and additional units will need to be networked into the existing departmental systems and this cost must be accounted for in the future. It will involve upgrading the pre-existing systems to cope with newer treatment technologies and techniques. At least one additional planning workstation will be required per linear accelerator. There will also be licensing and maintenance costs, and provision should be made to upgrade the software of the planning systems every 3 years.

Recommendation 6

Each new linear accelerator will require a networked treatment planning workstation.

Equipment Site Issues

79. In order to provide a service capable of providing 58,000 radiotherapy fractions and considering service model A which requires the highest number of linear accelerators, the South West Cancer Network will require access to 2 additional linear accelerators, which could be accommodated in existing bunkers. In North Wales the Cancer Network will require access to 2 extra linear accelerators and would require 3 bunkers on the existing Ysbyty Glan Clwyd site. The South East Cancer Network will require access to 6 extra linear accelerators. Velindre could accommodate up to 3 additional new linear accelerators with the need to build 4 spare bunkers on the existing site. Further, linear accelerators could be accommodated on a linked 3 linear accelerator satellite centre serving a suitable population. Table 11 details the maximum capacity (service model A) per Radiotherapy Centre considered. The final capacity at each Centre will depend on the service model adopted.

80. In addition to new linear accelerators, 11 replacement linear accelerators will be required across Wales over the next 10 years. During the building phase it would be prudent to define the footprint for at least one further additional bunker at each Centre to allow for growth in the future. Each extra linear accelerator requires a bunker for radiation protection and the most appropriate location should be determined by the cancer network in the light of local needs.

Recommendation 7

Long-term planning requires that each radiotherapy centre should have at least one decant bunker (depending on the number of machines) to allow for replacement without interruption of the service.

Table 11 Capacity, based on service model A, of each cancer centre

Cancer Network	Total Linear accelerators required	Current Linear accelerators	Current Spare Bunkers	Additional linear accelerators required	Capacity on existing sites
South East	11	5	1	6	9 ^o
South West	5	3	2	2	6 ⁺
North	5	3	0	2	5 [*]

^o Velindre could accommodate up to 9 linear accelerators with 4 extra bunkers on the existing site. Further linear accelerators could be accommodated on a linked satellite centre.

⁺ South West Wales has 2 spare bunkers, which could accommodate 2 new linear accelerators on the existing site, plus potential space to build an extra bunker.

^{*} North Wales would need to build 2 new bunkers on the existing site to accommodate 2 extra linear accelerators

Workforce issues including training

Clinical oncologist provision required for Wales

81. It is inevitable that an increasing number of clinical oncologists will be required with the increasing need for radiotherapy and its growing complexity. Table 12 estimates that 13-23 additional oncologists (clinical and medical) will be required to support the future core service (including chemotherapy) in 2016.
82. The number of clinical oncologists to manage 315 new patients per oncologist per year has not been achieved in any Welsh Centre⁵. Since then, complexity of radiotherapy has increased significantly therefore each oncologist is able to see fewer patients. Taking this into account, a more appropriate workload for each oncologist is 250 new patients per year assuming 10 sessions per week⁴⁵.
83. Two scenarios have been considered based on increases in referrals of 3% (Scenario 1) or 5% (Scenario 2).

Table 12 Clinical Oncology provision required for Wales

Radiotherapy Cancer Centre	Referrals 2004	N^o WTE Oncologists required^d	Scenario 1	N^o WTE Oncologists	Scenario 2	N^o WTE Oncologists
South East	5,876	23.5	7,639	31	8,814	35
South West	3,250	13	4,225	17	4,875	20
North	1,969	8	2,560	10	2,954	12

^d Ref paragraph 80

Radiotherapy radiographer provision

Role of Therapeutic Radiographers

84. The radiotherapy service involves multidisciplinary teams of professional staff, and relies heavily on therapy radiographers. They organise and manage the radiotherapy service including referrals and access, waiting lists, coordinating and delivering the treatment and related care, using a high level of technical expertise and patient care knowledge, and an in-depth knowledge of radiotherapy, oncology and physics.

85. Therapy radiographers are the only discipline who are able to operate all the equipment for clinical use and are accountable for their action via state registration and radiation safety regulations. All therapy radiographers are now educated to degree level with a cancer-related specialist qualification to plan and deliver radiotherapy treatments safely and accurately in compliance with national guidelines and codes of practice.

Current Radiographer Staffing

86. The existing staffing levels as at December 2005 for therapy radiographers, helpers and administration and clerical staff are detailed in Table 13.

Table 13 Current Radiographer Staffing

Cancer Centre	Budgeted Manpower			Current Establishment			Vacancies		
	Rads#	Helpers + Asst prac##	A/C	Rads	Helpers + Asst prac	A/C	Rads	Helpers + Asst prac	A/C
South East	47.07	1.0	4	46.47	1.0	3.0	0.6	0	1
South West	26.5	1.0	1.2	25.7	1.0	1.2	1.0	0	0
North	28.01*	3 + 1 Nurse	3	25.01	4.0 + 1 Nurse	3	2	0	0

#Radiographers

Helpers include assistant practitioners

* includes 1.8 radiographers working in dosimetry

Radiographer staffing levels and the impact upon waiting lists

87. In South East Wales in particular, the lack of linear accelerator capacity has resulted in the generation of waiting lists for patients requiring radiotherapy. The waiting list appears, given the resources available, to be well managed although still exceeding the RCR recommendations¹⁹. This is however, mainly as a result of the good will and dedication of the radiotherapy staff, who are working additional hours under constant and extreme pressure.
88. Radiographers are contracted to work 35 hours/week which will increase to 37.5 hours/week by 2011 under Agenda for Change (AFC), an extra 7% but this will be offset by additional annual leave. New recruits have therefore been working 37.5 hours/week from 2004/05.
89. The '10 hour working day' comprises the normal patient workload, on-call and cover for annual leave. Radiographers cover an on-call system every weekend for emergency treatments e.g. spinal cord compression, superior vena cava obstruction. The radiographers have to 'start up' the treatment units and perform quality assurance checks on the equipment prior to the start of patients' treatments. Finally of the 46 wte radiographers, 9 radiographers have to be on annual leave over the year at any one time resulting in a 20% reduction in staffing levels.
90. These factors have resulted in radiographers working over 1100 hours of overtime in the last year due to the pressure of work and in order to improve the waiting list. For example category 1 patients are treated on Bank Holidays, to ensure there are no gaps in treatment³³.
91. When breakdowns to equipment occur, the radiographers work 12 – 14 hour days on another unit to avoid interruptions to patient treatment.
92. In addition, radiographers provide a CHART service for patients with Ca bronchus out of hours i.e. in the evenings and weekends. This usually takes about 1½ to 2

hours/evening between 9 – 11pm and 2 hours 3 times a day on Saturdays and Sundays. Mould room staff work overtime on Saturdays to keep up with the workload.

93. The same pressures apply to radiographers in all 3 Welsh Centres. The present establishment of radiographers is insufficient to sustain the current level of service to patients. Statutory and mandatory training is not being completed as well as it should be; the work/life balance of radiographers is suffering and continuing professional development (CPD) cannot be properly pursued. This needs to be addressed as registration to the Health Professions Council will be dependent on proof of CPD.
94. In the North Wales Centre, there is a shortage of radiographers resulting in under utilisation of linear accelerators. Recruitment of radiographers has improved in 2005 but the gains have not been fully appreciated yet, due to the high level of maternity and long term sickness in the last year. Consideration of the introduction of recruitment incentives and employment of agency staff has been given, but these options are no longer used due to financial constraints. There is also at present a bottleneck in simulation and planning although work is being done to overcome this. The employment of two extra consultants during 2005 may make a difference.
95. In the Swansea Centre, the opening of the new department has provided temporary additional resources. In order to reduce the waiting list, one of the old linear accelerators is being used to treat palliative patients. In January 2006 this unit will be taken out of service so there is likely to be deterioration in the waiting times for treatment. At the end of 2005 radical patients were starting their radiotherapy within 6 to 8 weeks of attending clinic and palliative patients were receiving their radiotherapy within 14 days.

Future Provision of Radiographer Staffing

96. The Society and College of Radiographers (SOR) have produced a report providing ‘Guidance on Radiographer establishments in Radiotherapy’.³⁶ This guidance proposes that a formula be utilised when calculating the number of staff required to provide the core service to patients, from referral to completion of radiotherapy. The core service includes:

- a) Treatment delivery on linear accelerators, including routine patient support/information;
- b) Simulation and booking/scheduling;
- c) Treatment preparation and calculation;
- d) Management, quality assurance and training functions;
- e) Treatment reception and department administrative support.

97. Radiotherapy capacity and activity planning is linked to linear accelerator hours of service provided each day. Linear accelerator activity is the culmination of the core service activities. The analysis uses the ‘linear accelerator hour’ as the unit of core service, using the overall number of linear accelerator hours planned.

98. The formula used is 1.33 Radiotherapy staff per linear accelerator hour and includes assistant practitioners, helpers and admin and clerical (A&C) staff e.g. receptionists, booking clerks, secretarial support. It does not include mould room staff, radiographers, research radiographers, information and support radiographers or radiographers working in medical physics as dosimetrists.

99. Therefore, considering service model A and 10 additional linear accelerators, the radiotherapy staffing for the core service across Wales will be 106.4 whole time equivalents.

$$\mathbf{10 \text{ linear accelerators} \times 8 \text{ hours per day} \times 1.33 = 106.4 \text{ WTE.}}$$

Recommendation 8

It is recommended that a maximum of 10% of staff should be assistants or helpers or A&C. The number of radiographers required for the proposed additional linear accelerators will vary significantly depending on the service model adopted with the maximum increase relating to Model A with 96 radiographers plus 10 other staff required.

100. There may be further requirements for those staff not included in the core service.
101. It is likely that further national guidance will be published by the RCR and the SOR and the assumptions in this report will need to be reviewed and revised as necessary.

Future Training Issues

102. In order that Wales could employ additional staff over the next 5 years, the university would have to be commissioned to train additional students. When the North Wales Centre became a training establishment, the training numbers increased from eight to fifteen students per annum. The course team feels that the school could take a maximum of 5 additional students per year based on clinical placements, making a total of 20 students per year. This may be adjusted when the new degree validation takes place in 2007
103. The cost to the Welsh Assembly Government per student, in respect of training, is £8,000. Costs for accommodation (£400), travel (£300), student bursaries (£2100 means tested), Professional Body Registration and uniforms (£120) are in addition to the above. This gives an average cost per annum of approximately £11,000, a total cost of £33,000 over a 3 year training period.
104. Should all the 20 students qualify each year and stay in Wales for their first post, more than 2 linear accelerators per year would be staffed i.e. 10 linear accelerators in 5 years. In addition, radiographers who retire or move on would

need to be replaced so there would be a shortfall. However, it is unlikely that 10 additional linear accelerators would be installed in 5 years. It is more realistic to assume that the linear accelerators would be installed over a 10 year period. This would mean that 20 students qualifying in radiotherapy per year could staff the equipment. Some English Centres have offered 'golden hellos' (approx £1,500) to newly qualified radiographers, to attract them to their Radiotherapy departments, with criteria attached on the minimum length of employment.

105. The three Radiotherapy Cancer Centres attract a small number of newly qualified recruits from England. It may be possible for Wales to commission some training places at Higher Education Institutes in England.
106. The university has suggested that in order to increase the intake of students to perhaps 30 per year, decommissioned equipment could be installed within the academic department so allowing more clinical training within the academic environment. The University has suggested a set-up cost of £300,000.
107. The Welsh Assembly Government is encouraging the training of assistant practitioners and is supporting a course to be developed at the University of Cardiff. A course for radiotherapy assistant practitioners is scheduled to start in January 2007. This will require additional support and supervision from radiographers at clinical placements.
108. North Wales has one assistant practitioner due to qualify with a diploma in September 2006; training was via a distance learning course with Hallam University Sheffield. This has been a positive partnership which North Wales would be eager to continue.

Radiotherapy physics provision

Role of Radiotherapy Physics

109. Multidisciplinary teams of professional staff deliver radiotherapy. Medical Physicists and Clinical Technologists (Dosimetrists and Engineers) play an important part in the provision of radiotherapy physics services as a whole, providing essential scientific and technical input. The specialist scientific training and expertise of physics staff means they are uniquely qualified to understand both the physical processes and technology that underpin the entire radiotherapy process.
110. The medical physicists and clinical technologists in radiotherapy are essential members of the multi-professional team responsible for the design and delivery of radiotherapy treatment whose key roles are summarised in Appendix 5.
111. There is considerable depth and breadth to the role of the Radiotherapy Physics Services within Wales. There is an obvious and considerable responsibility in many quality critical areas. Indeed the implementation of new techniques involving advanced equipment, while maintaining patient safety, is of paramount importance, and is fundamentally dependent upon the essential skills of medical physics staff. This is recognised in both EC Directives³⁵ and UK legislation (IRR99 and IR(ME)R)^{36, 37}. Consequently, there is a statutory requirement for Medical Physicists in radiotherapy departments, both as Radiation Protection Advisers and Medical Physics Experts.

Current Physics staffing levels

112. Table 14 summarises the Radiotherapy Physics staff available in each of the three cancer centres. The Guidelines from which the 'Recommended Establishment' is calculated are currently under revision and hence these figures are likely to change in the future.

Table 14 - Radiotherapy Physics Staffing at December 2005

<i>Centre</i>	<i>Recommended Establishment¹</i>			<i>Current Establishment</i>			<i>Vacancies</i>		
	CS ²	Dos. ³	Eng. ⁴	CS	Dos.	Eng.	CS	Dos.	Eng.
SE	13(16)	9(10)	8(9)	13	6	7	0	1	1
SW	8.4(9.5)	6.1	4.1	7.1	5.8	3.5	0.5	0	0
N	8.2	5.1	5.3	6.2	4.6	3.5	1.6	1	0
Total	29.6(33.7)	20.2(21.2)	17.4(18.4)	26.3	16.4	14	2.1	2	1

1. From IPEM Recommendations, 2002³⁸. (N.B. the 'Recommended' figures include the IPEM 'economy of scale' factor – figures in brackets give numbers prior to economy of scale adjustment)

2. Clinical Scientist (including those undertaking Part 2 training)

3. Dosimetrist (treatment planners, staff preparing patient related accessories and undertaking patient immobilisation, QC, *in vivo* dosimetry etc.)

4. Engineers (electronic, mechanical preventative and corrective maintenance)

113. The South East Wales Radiotherapy Cancer Centre is particularly low in terms of linear accelerators per million population. Table 14 merely reflects the staff numbers appropriate for the number of accelerators currently installed. A fully equipped Centre would require a greater number of staff. The number of accelerators given in Table 14 for the South East Centre reflects the need in part to 'catch-up' this equipment shortfall.

114. In North Wales the clinical scientist establishment is under recommended levels and the additional vacancy factor is having a significant impact. The situation is worse than these figures suggest in that recruitment has been of more junior staff and there are only 1.6 WTE in post who qualify as Medical Physics Experts, and 3.6 WTE registered physicists. From April 2006, it is expected that there will be 2.8 WTE clinical scientist vacancies. This is a major concern for the Centre. Attracting experienced clinical scientists to a rural area depends strongly on investment in infrastructure and development opportunities. Neither equipment initiatives or staff retention payments are competitive with our nearest neighbouring North West England Centres and the creation of a new Centre in North West Manchester, which will require staff, has recently been approved. The number of dosimetrist staff includes radiographers supporting this work who

are not members of Medical Physics but are included in the radiotherapy establishment.

115. In South West Wales the situation is somewhat similar in that the current establishment is below the recommended level, and similarly in South East Wales. It is also of note that several of the clinical scientists are novice recruits and are up to a year away from registration and some years away from becoming eligible for Medical Physics Expert status.

Table 15 - Total Radiotherapy Physics Staffing for additional accelerators based on Service Model A, plus patient factors and other supporting equipment, facilities and tasks^e at December 2015

Radiotherapy Cancer Centre Additional linear accelerators		Recommended Establishment		
		Clinical Scientists	Dosimetrists	Engineers
South East	6	12	12	12
South West	2	4	4	2
North	2	4	4	2
	Total	20	20	16

116. From elsewhere in this Report it has been established that the linear accelerator requirements for Wales are likely to increase by between 6 to 10 linear accelerators, which would be distributed as follows according to population: SE Wales 6, SW Wales 2, and N Wales 2. Given this increase in accelerators and concomitant patient services the estimated staffing requirement is given in Table 15.

^e Typically this will include additional major, minor and patient related factors, e.g. advanced treatment planning (3D, brachytherapy, stereotactic, IMRT, image fusion etc.), further equipment (simulators, stereotactic radiotherapy, electronic portal imaging devices, IT and networking facilities, treatment planning work stations), overhead of additional and complex clinical technology with new service development (e.g. IMRT, IGRT, PET-CT and MRI for treatment planning, adaptive therapy), formal post graduate teaching, training of others for professional registration, research and development and PhD supervision, continuous professional development, maintenance of quality assurance systems etc.

117. It is important to appreciate that investment to increase the number of linear accelerators will require a major commitment to other supporting services that naturally accompany an expansion in patient numbers, introducing new technologies, providing more complex treatment planning services and so forth as summarised in the footnote to Table 15. For example, a recent study at the Royal Marsden Hospital London on the impact of introducing IMRT into routine clinical practice suggested an increase in physics time of 4.9 hours per patient in head and neck cancer³⁹. Thus a fully comprehensive and properly supported Radiotherapy Physics Service is estimated from existing Guidelines (currently under review) to require levels of support detailed in Table 15, these staff are in addition to those at December 2005 noted in Table 14.
118. The need to introduce improved treatment options is growing, for example, there is increasing trial evidence of a clinical advantage from dose escalation regimes in, for example, prostate cancer. This approach requires either extra fractions of conformal radiotherapy or more complex IMRT in order to minimize rectal complications etc. Either approach will require extra linear accelerator capacity in order to avoid significant increases in waiting times.
119. Generally speaking, any expansion of, or advances in, conformal radiotherapy and IMRT (involving for example image guidance techniques), the Stereotactic radiotherapy programme (in the SE Cancer Centre), adaptive radiotherapy and so forth, will require extra linear accelerator capacity and human resource for development, implementation and on-going quality assurance.
120. The number of linear accelerators and Radiotherapy Physics staff will be influenced by the length of clinical working day on each accelerator, use at weekends and so forth. This utilisation is important because of the requirement to pursue much of the activities of the Radiotherapy Physics staff, such as quality control, research and development, maintenance etc. outside of these clinical hours. Research and development in particular will be inhibited considerably by a

longer clinical working day. Further, the need for routine out-of-hours working will impact negatively on recruitment and retention as potential and existing staff consider work-life balance.

121. Agenda for Change is anticipated to exert additional pressure on the service. This will include potential pressure on existing posts should Agenda for Change not be fully funded and loss of output arising from longer annual leave.

Training issues for Scientists, Engineers and Dosimetrists

122. An increase in staff numbers is only likely to be met through training and employing novice recruits; the successful opportunities for recruiting experienced and professionally registered staff are low based on experience of the last few years. The most obvious entry to the profession for scientists is through the long established postgraduate Training Scheme for Clinical Scientists, this having worked well in Wales for many years. There remain serious concerns about recruitment of newly (Part 1) qualified Trainees to permanent positions due to funding of new posts: newly qualified staff have been lost from Wales due, in part, to the lack of permanent funding within Trusts and it is these staff who will be crucial in meeting the needs of an expanding service. Note that staff, particularly those newly qualified, need to be employed in advance of the installation of new equipment.

123. The training of Clinical Technologists is not so well established as that for Clinical Scientists, however, an undergraduate degree has recently become available at the University of Wales Swansea, and the SE Centre is developing an internal training programme for clinical technologists in order to develop more broadly based 'dosimetrist' roles. In the SW Centre, advanced Practitioner roles are also being developed.

124. A consequence of a national trend towards regulated professions is the constriction of entry requirements. There is a strong consensus of opinion that

multiple routes of entry to the professions should be maintained. This is now very difficult for Clinical Scientist's due to no bypass route to registration being available. This could also be a difficulty in recruiting Clinical Technologists if the BSc in Clinical Technology becomes the only route of entry. Maintaining independent routes of entry for linear accelerator engineers, other engineers, and possibly dosimetrists is important, and these routes for the moment do exist (e.g. the graduate entry route, with in-service training to follow as applied in the SE and SW Centres).

125. The number of Trainees required will need to be sufficient to meet the anticipated growth of services, the small loss during training and the not inconsequential loss anticipated through retirement over the next 10 years. As an example of this latter point, some 30-40% of the SW Wales Radiotherapy Physics Group is expected to retire by 2015.

126. Past experience has shown that increasing the number of trainees (Part 1 and Part 2 Clinical Scientists and Clinical Technologists) within the Radiotherapy Physics Team places additional, but understandable, demands on the existing staff; additional staff to provide adequate 'training-time' has long been a goal and it is doubtful if an increase in the number of trainees within Wales can be readily accommodated without addressing such needs. This support for trainers is critical if the trainee is to develop and contribute effectively and safely to the Radiotherapy Physics Team, noting that it takes some time for the trainee to contribute at a whole-time-equivalent level.

Recommendation 9

The funding of trainee posts up to state registration level, subject to satisfactory completion of Part 1 training, will provide additional flexibility to treatment centres when addressing the availability, recruitment and retention of a skilled professional workforce and matching to permanent posts.

Research and development

127. It is important to stress that Centres providing a world-class Radiotherapy Physics Service are invariably doing world-class research and development in the field. Therefore the Centres need to ensure that a culture of research and development with the appropriate facilities and opportunities go hand in hand with service improvement. In order to facilitate this, adequate time for Clinical Scientists and Technologists to pursue this type of work must be available. With this in mind, it may be more appropriate to consider staffing allocations without the ‘economies of scale’ factor related to service delivery alluded to in Table 13. There remains considerable work to do within Wales if the latest technological advances and clinical techniques are to be brought into routine clinical service.

Service Modernisation

128. The Radiotherapy Cancer Centres in Wales have been working with Innovations in Care in order to improve the Radiotherapy Service for patients in Wales. Areas that have been examined include:

- Process mapping
- Capacity and demand
- Patient involvement
- Skill mix and new ways of working
- Improving waiting times for patients
- Employing administrative and clerical staff to schedule patients for radiotherapy
- Improving patient information.

129. Improvements in efficiency have already been achieved with relatively few additional resources. All three radiotherapy centres have modernisation programmes underway.

130. The Radiotherapy Team of the Cancer Services Collaborative Improvement Partnership have recently shown how effective modernisation measures have proved ⁴⁰. This group reported that a combination of Sustained Investment, Service Improvement and Staff Involvement (the 3Sis) are needed to achieve waiting time targets for radiotherapy. The team managed to achieve, not only the 62/31 day targets but also the more stringent JCCO targets which apply to all patients receiving radiotherapy.
131. A number of examples of service improvement, with involvement and support of clinical staff and management, have been in place for some time in certain radiotherapy centres in Wales. For example, radiographer review clinics, research radiographers and redefined senior roles within the department. There are also examples of radiographers now routinely carrying out breast planning. In addition radiographer image review, radiographer consent, appointment of booking clerks, patient group directives to allow dispensing of limited supply of medications without physician involvement, have all been instigated. A Macmillan Information and Support Radiographer was employed in 2002. Radiographer led palliative planning has been stalled because of staff shortages.
132. Radiotherapy Physics Services, together with other Oncology services, have been proactive in modernising and redesigning services to meet modern clinical needs and to facilitate improved cost-effectiveness. For example, the planned preventative maintenance of linear accelerators has over recent years been rescheduled to the weekends in order to provide greater clinical utilisation during Monday to Friday; in treatment planning there has been a considerable increase in the use of automation and computation to independently check the calculation of treatment plan dose and to facilitate the transfer of treatment plan prescriptions to simulators and linear accelerators; the skill-mix of staff has evolved with role extension, particularly of Clinical Technologists who undertake some tasks previously the preserve of Clinical Scientists. The modernisation process is still very much on-going. However, whilst these and other initiatives has enabled an

increased throughput of patients, together with enhanced quality assurance, there will remain an additional need for experienced, qualified staff with increasing numbers of linear accelerators and associated equipment and greater numbers of patients presenting for treatment.

133. The Sheffield/Leeds modernisation programme highlighted the central role of commissioning in the process of modernising radiotherapy services. The importance of recruiting additional staff, in particular radiographers, to maximise utilisation of linear accelerators during the current working day or to support the introduction of an extended working day was found to have a significant impact on reducing waiting times.

Recommendation 10

An immediate priority should be the recruitment of radiographers to build up the workforce in order to support service modernisation and in readiness for the commissioning of additional linear accelerators. There is a clear need to retain radiographers being trained in Wales.

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Appendices

Appendix 1

Service Standards for Radiotherapy Centres

1.1 Waiting Times for Radiotherapy - National Cancer Standards and RCR

1. Key waiting time standards for radiotherapy have been defined within the National Cancer Standards (2005) ²⁰. The following generic waiting times standards apply where radiotherapy is the definitive treatment and applies to approximately 30% of patients.
 - a) patients referred urgently with suspected cancer should start definitive treatment within 62 days from the receipt of the referral at the hospital.
 - b) patients diagnosed with cancer but not already included under the urgent suspected cancer category, should start definitive treatment within 31 days of the patients being informed of the diagnosis and agreeing the treatment plan.
2. The 62 and 31 day targets have been incorporated in the Service and Financial Framework for 2005/06 and 06/07 with compliance required by December 2006.
3. The RCR (1993) waiting times as defined by the Joint Council for Clinical Oncology are also endorsed by the National Cancer Standards and are of particular importance where radiotherapy is not the definitive treatment ¹⁷. Waiting times span the time from the decision to treat by the oncologist to the 1st fraction of radiotherapy. The waiting times are categorised as follows
 - a) Urgent (good practice 24 hours and within 48 hours)
 - b) Palliative (good practice within 7 days and within 14 days)
 - c) radical radiotherapy (good practice 2 weeks and within 28 days)

Audits of Compliance with Waiting Times for Radiotherapy

4. All Welsh Cancer Centres have participated in UK RCR audits undertaken in 1998, 2003 and 2005^{18,19}.
5. By 2003 waiting times had deteriorated with 75% waiting longer than 28 days for radical radiotherapy (see Table A1.1).

Table A1.1 %* compliance with waiting times for radiotherapy

Adjuvant Radiotherapy			
	1998	2003	2005
ENGLAND	60%	40%	46%
SCOTLAND	56%	44%	75%
N IRELAND	67%	50%	100%
WALES	80%	25%	0%
Radical Radiotherapy			
ENGLAND	76%	37%	44%
SCOTLAND	60%	30%	54%
N IRELAND	58%	29%	36%
WALES	68%	25%	26%
Palliative Radiotherapy			
ENGLAND	73%	64%	72%
SCOTLAND	81%	53%	60%
N IRELAND	86%	86%	80%
WALES	94%	68%	57%

Source: M.V. Williams (personal communication)

* % within JCCO Targets (Excluding Elective Delays)

6. Following the RCR re-audit of waiting times for Radiotherapy in 2003, the Clinical Oncology Sub Committee decided to repeat the exercise in the 3 Radiotherapy Departments in Wales for a 2 week period between 07/06/04 and 18/06/04. All patients starting Radiotherapy within that period were included in the audit except for BCC's and those patients with an elective delay. Results are presented in Tables A1.2, A1.3 and A1.4. There is a small margin for error given the method of data collection.

Table A1.2 Summary of the patients studied

	North Wales	Swansea	Velindre
No. of Palliative patients	17	22	68
No. of Radical patients	22	24	57
BCC's and elective delay	14	16	14
Total no of patients	53	62	139

Table A1.3 Compliance to waiting times for palliative radiotherapy

RCR good practice is within 7 days with a maximum waiting time within 14 days.

	North Wales	Swansea	Velindre	National Audit 2003
Within 7 days	5 (29%)	10 (45%)	35 (51%)	
Within 14 days	7 (41%)	11 (50%)	38 (56%)	
Outside 14 days	10 (59%)	10 (45%)	30 (44%)	60%
	/	1 unknown	/	
Total number of patients	17	22	68	
Range	0-27 days	0-78 days	0-45 days	

Table A1.4 Compliance to waiting times for radical radiotherapy

RCR good practice within 14 days with a maximum waiting time within 28 days.

	North Wales	Swansea	Velindre	National Audit 2003
Within 14 days	0	0	6 (0.5%)	
Within 28 days	1	3 (12.5%)	19 (33%)	
Outside 28 days	22 (100%)	21 (87.5%)	38 (66%)	72%
Total number of patients	22	24	57	
Range -	34-64 days	17-97 days	1-57 days	

7. The results of the 2005 audit showed that this alarming situation has continued with only 26% and 57% of radical and palliative patients being seen within 28 and 14 days respectively (Table A1.1).

8. A recent audit at the Velindre Cancer Centre revealed the average interval between surgery and radiotherapy in head and neck cancer was 59 days and only 12% were treated within the maximum acceptable interval of 6 weeks (NICE Guidance on Cancer Services: Improving Outcomes in Head and Neck Cancer 2004).

9. North Wales has had some improvements in waiting times with increased use of the third linear accelerator this has been proportionate to the improved recruitment figures of 2005.

1.2 Core Standards for satellite centres

10. The Core Standards for all radiotherapy treatment (see 'Guidance on the Development and Management of Devolved Radiotherapy Services' RCR 2004) which devolved satellite centres would be required to meet are detailed below:

- a) All patients receiving radical radiotherapy must have been through a process of review by a multidisciplinary team before being accepted for radiotherapy treatment. This review can be retrospective in clinical emergencies. All treatment must be supervised by an appropriate member of the multidisciplinary team.
- b) Technical standards must be high and this should include delivery of conformal radiotherapy and intensity modulated radiotherapy as these are more widely implemented and become the standard of care. If appropriate treatment is not available locally then the patient should be referred to a cancer centre.
- c) Convenience of access should not be allowed to compromise quality of care as this would risk impairing long-term outcomes. Sub-specialisation and best practice may therefore require referral of selected patients to a cancer centre with appropriate experts, even if the technological capability for treatment exists in the unit.
- d) Patients at a linked centre should have access to the same level of care and support from all staff groups as they would have received in the cancer centre
- e) There should be continuity of patient care, including detailed review of symptom control and provision of a seamless service that will cope efficiently with any problems that may arise during the implementation of

the treatment plan. Direct access to simulation and treatment planning should be available within units to avoid interruptions in patient treatment.

- f) Responsibility for on treatment review may be delegated to appropriately trained staff: agreed protocols must clearly indicate when referral to the treating oncologist is essential.
- g) A linked unit should aim to acquire a minimum of two multi-modality linear accelerators (preferably with electrons), one simulator (computed tomography or conventional) and a treatment planning system together with appropriate staff. If equipment for full simulation and treatment planning is not purchased, the consequences of this decision for patient management should be worked through in detail at the cancer centre.
- h) If a unit has only one linear accelerator, there should be a clear plan for the management of patients during periods of staff shortage and machine maintenance and breakdown.
- i) The development of written protocols and procedures defining clear lines of accountability and responsibility are essential. Staff must be fully familiar with the treatment techniques that they are to apply and there must be a robust system of clinical governance.
- j) Modern information technology should be exploited to facilitate links between the centre and unit to improve the quality of patient care. Video-conferencing is an essential component of a devolved radiotherapy service: it will improve communication and can facilitate participation in multidisciplinary meetings.

1.3 Standards for radiotherapy services required in the National Cancer Standards

OBJECTIVE: To ensure patients receive radiotherapy which is planned, prescribed, delivered and supervised in a safe and effective manner.

Rationale: As with all other forms of treatment, the results of radiotherapy are likely to be optimum when it is delivered according to a formal written policy specifying dose, fractionation, overall treatment time, planning technique and means of verification plus other appropriate QA measures. This is especially true of radical (curative) therapy, where a uniform approach is necessary to be able to evaluate outcomes. It is also important that policies are in line with those in use elsewhere in the UK and worldwide. Where there is substantial deviation, this should be in the context of a formal clinical trial. Palliative treatments will need to be individualised on a more frequent basis, but the overall approach should conform as closely as possible to a written policy. There are circumstances where evidence exists for the superiority of one form of technology over another. An example is of the use of conformal radiotherapy in some pelvic malignancies, as a means of reducing treatment-related side effects.¹³ Networks need to have a strategy to ensure that patients for whom such technology is optimum are able to access it, even if this means crossing Trust or Network boundaries. The general quality of procedures in the radiotherapy department will be reflected in externally modulated quality schemes as originally specified by Quality Assurance in Radiotherapy (QART).

Standards:

1. Patients receiving radiotherapy should be treated according to an agreed, documented policy or in a formal clinical trial;
2. Radiotherapy centres should jointly agree definitions to monitor major long-term morbidity following radical radiotherapy;
3. Major long-term morbidity rates following radical radiotherapy should be monitored;

4. All radiotherapy centres should have a recognised quality system accredited by an authorised standards institution to a recognized standard;
5. Equipment capable of delivering conformal radiotherapy should be available to each network;
6. Equipment capable of delivering Intensity Modulated Radiotherapy (IMRT) should be available to each Network.

Appendix 2 – Radiotherapy Equipment

The current radiotherapy equipment in use in South East Wales:

NAME	MODEL	YEAR OF INSTALLATION	REPLACE- MENT
Linear accelerator 1	Varian C linear accelerator 2100C	1993	2005/06
Linear accelerator 2	Varian C linear accelerator 600C	1999	2009/10
Linear accelerator 3	Varian C linear accelerator 2100C	1990	2004/05
Linear accelerator 4	Varian C linear accelerator 2100C/D	1999	2009/10
Linear accelerator 5	Varian C linear accelerator 2100C/D	1999	2009/10
CT Sim	Siemens	2005	2012
Simulator 2	Varian Ximatron CDX	1998	2008/09
DXR/SXR	Gulmay D3300	2001	?
Microselectron	Nucletron Microselectron HDR – V2	2004	2014

The current radiotherapy equipment in use in South West Wales:

NAME	MODEL	YEAR OF INSTALLATION	REPLACEMENT
S4855	Pantak Control Panel – DXR Unit	Sept. 92/1993	?
S5054	Gulmay D3300	2002	?
LA1	SL -15 Treatment Unit	1993	2006
Sim1	Simulix – CT	1994	2004/05
Sim2	Simulix Evolution	2005	2015
	Selectron LDR	1984	None
LinA	Elekta Precise accelerator	2004	2014
LinB	Elekta Precise accelerator	2004	2015
LinC	Elekta Precise accelerator	2004	2016

1. A new centre was completed in 2004. Three new Elekta Precise linear accelerators (2 multimode accelerators with electrons, 1 single mode accelerator) have been installed to replace the old treatment units, and 1 new simulator has been installed. There is a 4th decant bunker available. There is also a fifth bunker containing an aging accelerator, however, the accelerator design is such that with refurbishment of key components it could have its' clinical life extended by maybe 3-4 years at about a tenth of the cost of a new machine and have compatibility with the new Precise accelerators. Furthermore, many of the refurbished components would be transferable to the newer Precise accelerators once the accelerator becomes generally no longer serviceable. Whilst not a long-term solution, this accelerator may provide a welcome short-term solution that could be quickly implemented, for example there would be minimal re-commissioning to do.

The current radiotherapy equipment in use in North Wales:

NAME	MODEL	YEAR OF INSTALLATION	REPLACEMENT
Linear Accelerator	Varian	1999	2009
Linear Accelerator	Varian	1999	2009
Linear Accelerator	Varian	2004	2014
Simulator	Varian	1999	2009
Superficial/Orthovoltage Unit	Pantak Limited	2000	?
Treatment Planning System	Varian	1999	?
Treatment Planning System	Varian	2002	?
Treatment Planning System	Varian	2003	?

Appendix 3 – Radiotherapy workload

Radiotherapy Workload in Wales 2000 – 2005:

1. The radiotherapy workload on linear accelerators in Wales between 2000 and 2005 is as follows:

Linear accelerators Only					
	2000/01	2001/02	2002/03	2003/04	2004/05
Courses: (Patients)					
North Wales (newly opened)	893	1279	1397	1355	1402
Swansea	1716	1592	1919	1682	1656
Velindre	3323	3556	3331	3355	3425
TOTAL	5932	6427	6647	6392	6483
Fractions: (Attendances)					
North Wales	9792	15483	17207	16552	18289
Swansea	21722	22219	24548	22379	23757
Velindre	39670	37769	41965	43479	45520
TOTAL	71184	75471	83720	82410	87566
Exposures					
North Wales	27228	44119	48364	47078	52220
Swansea	49697	52064	57694	54611	59946
Velindre	103287	98215	113703	120300	129865
TOTAL	180212	194398	219761	221989	242031

2. The statistics show that, over the years the number of fractions and exposures of Radiotherapy have risen but the number of courses has remained relatively static.
3. The main reason for this is that approximately 70% of the patients are treated with curative intent and techniques have improved over the years with the introduction of more sophisticated equipment. This has allowed higher doses to be given to the tumour

because more of the surrounding normal tissue can be avoided. A number of trials have found that dose escalation has a benefit on outcome. In practice this means that whereas a patient with prostate cancer may have been treated radically with 20 fractions of radiotherapy, those patients would now be treated with 35 – 38 fractions of radiotherapy.

Appendix 4 – Roles and Responsibilities of Medical Physicists and Clinical Technologists

Key Roles and Responsibilities of Medical Physicists in Radiotherapy can be summarised as:

1. Management, development and scientific direction of the radiotherapy physics service
2. Ensuring the accuracy of radiotherapy treatment through scientific supervision of dose calculation procedures and of ongoing quality control of both equipment and treatment
3. Design and implementation of new and innovative treatments
4. Leadership of research and development, especially in the technological basis of radiotherapy
5. Providing advice on appropriate treatment techniques
6. Ensuring radiation safety
7. Management of computer systems and software design and development
8. Equipment management and procurement of radiotherapy equipment
9. Teaching and training of staff (including junior Medical Physicists, Radiation Technicians, junior doctors, radiographers, etc.).

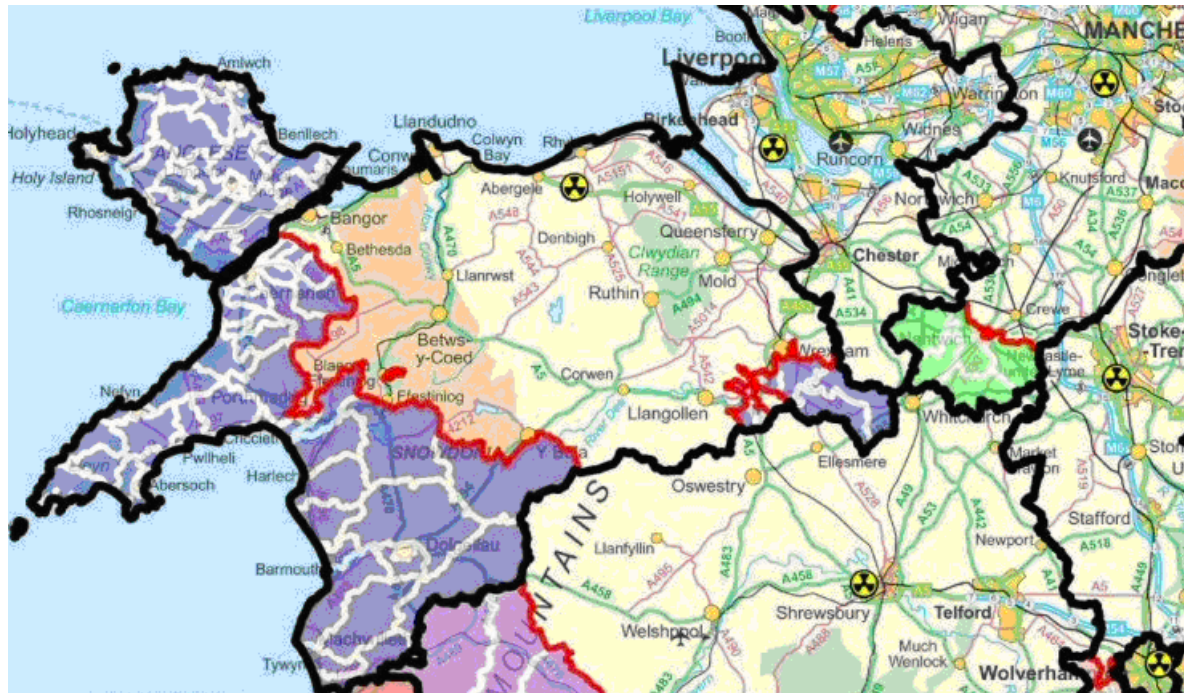
The key roles and responsibilities of Clinical Technologists in radiotherapy can be summarised as:

1. Management and service development
2. Equipment procurement
3. Training of other staff (including junior Radiation Technicians, Medical Physicists, junior doctors, radiographers, nurses)
4. External beam treatment planning including treatment verification
5. Brachytherapy treatment planning (including preparation of radioactive sources, assisting in theatre)
6. Preventive and corrective maintenance of radiotherapy equipment
7. Manufacture of treatment aids
8. Mould room work

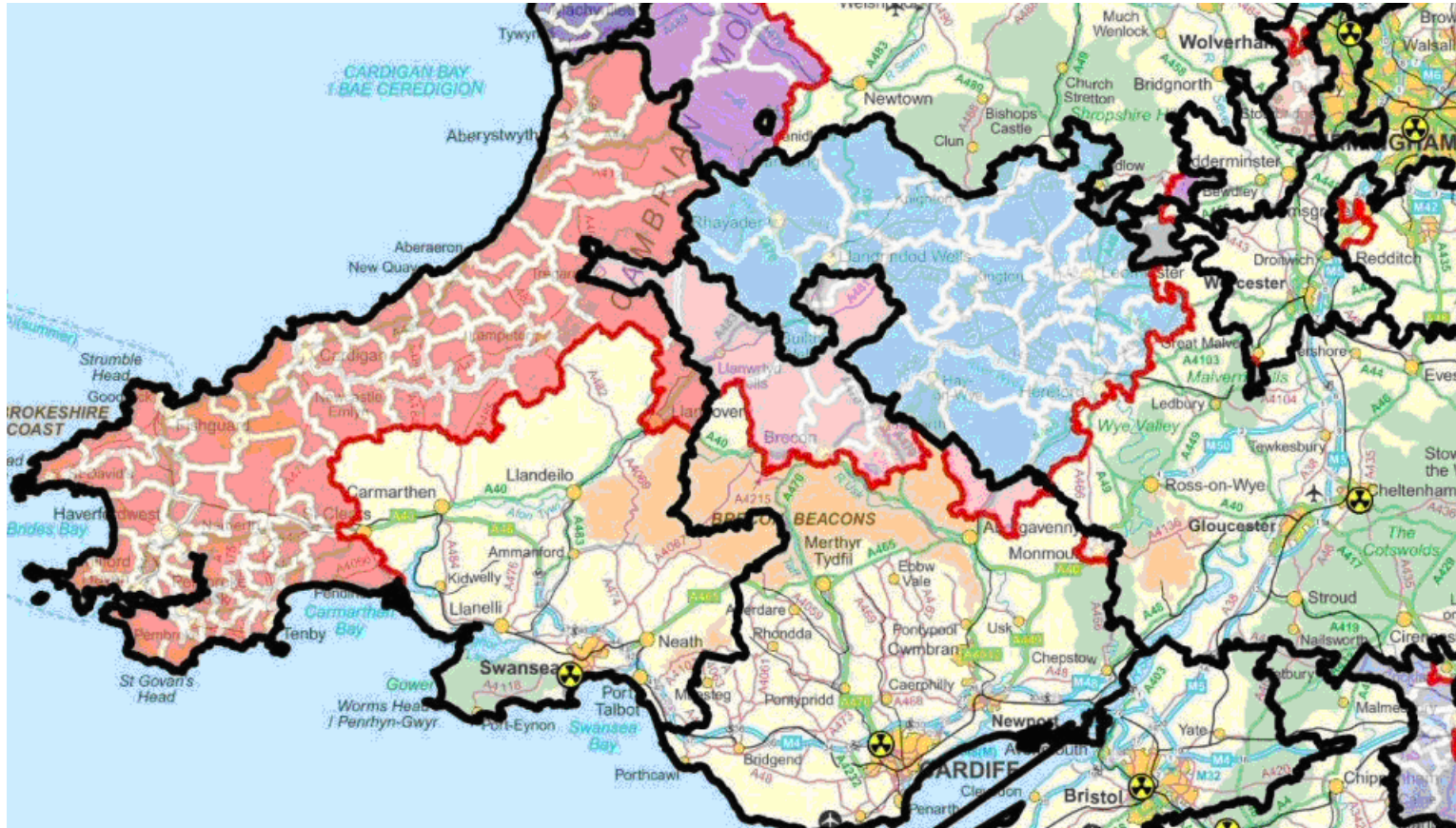
9. Research and development
10. Quality control and assurance
11. Safety testing
12. Management of computer systems and software development.

Appendix 5 – Access to Radiotherapy Centres

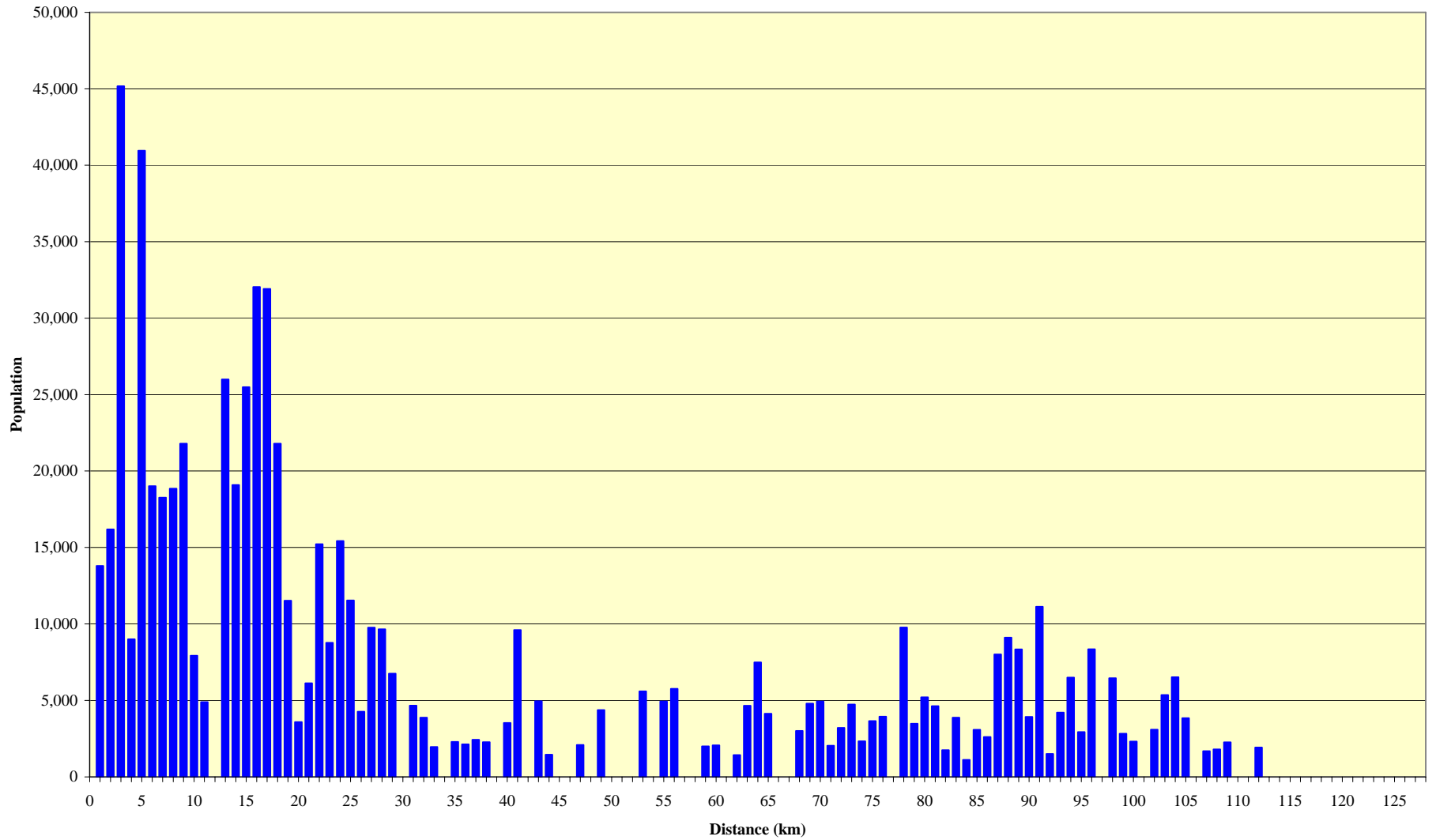
North Wales – Boundaries enclosing paler shading within the North Wales Cancer Network show the 50Km distance from the North Wales Cancer Treatment Centre 



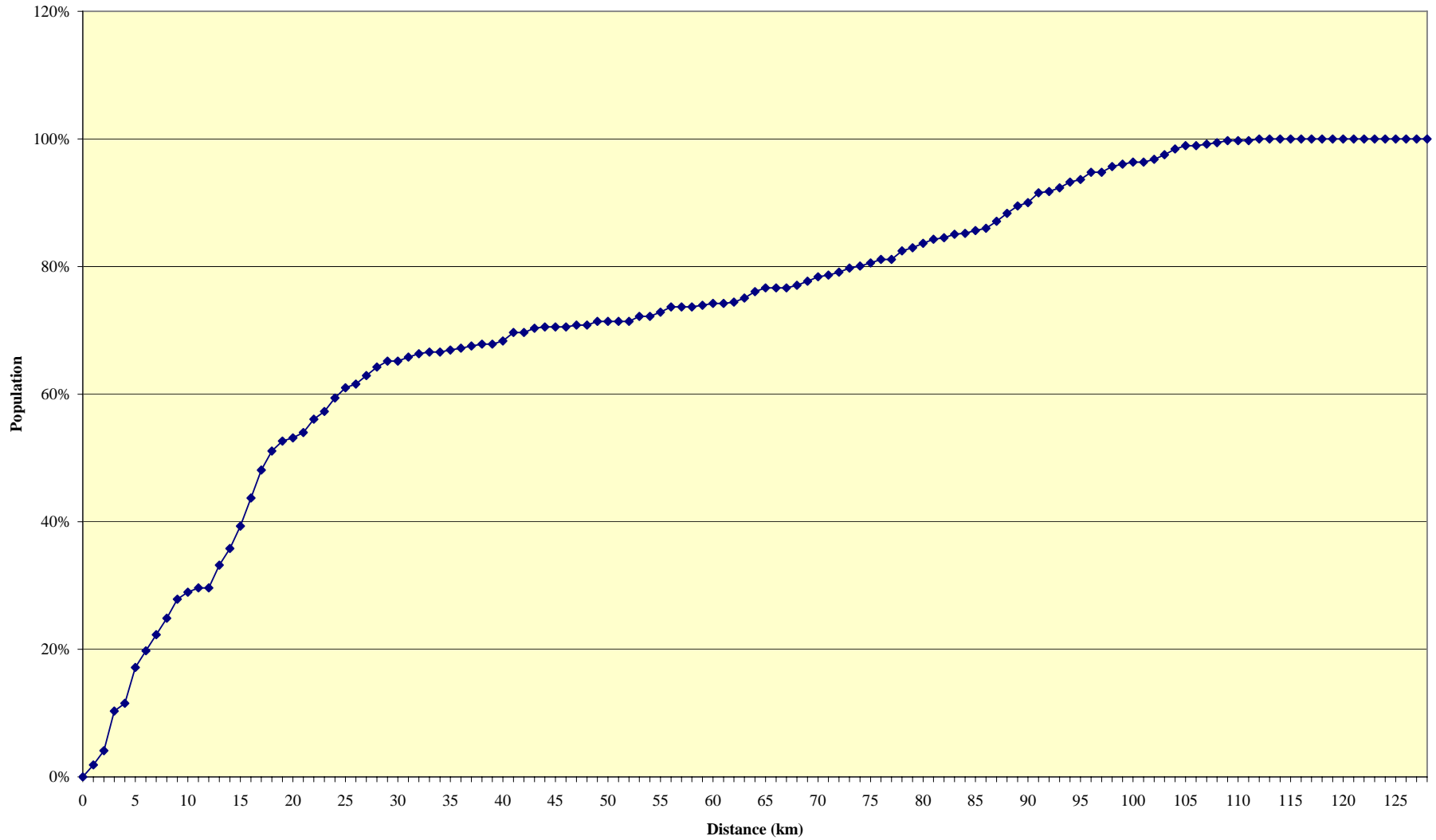
South West and South East Wales Radiotherapy Centres – Boundaries enclosing paler shading within the Networks show the 50Km distance from the Cancer Centres ☢



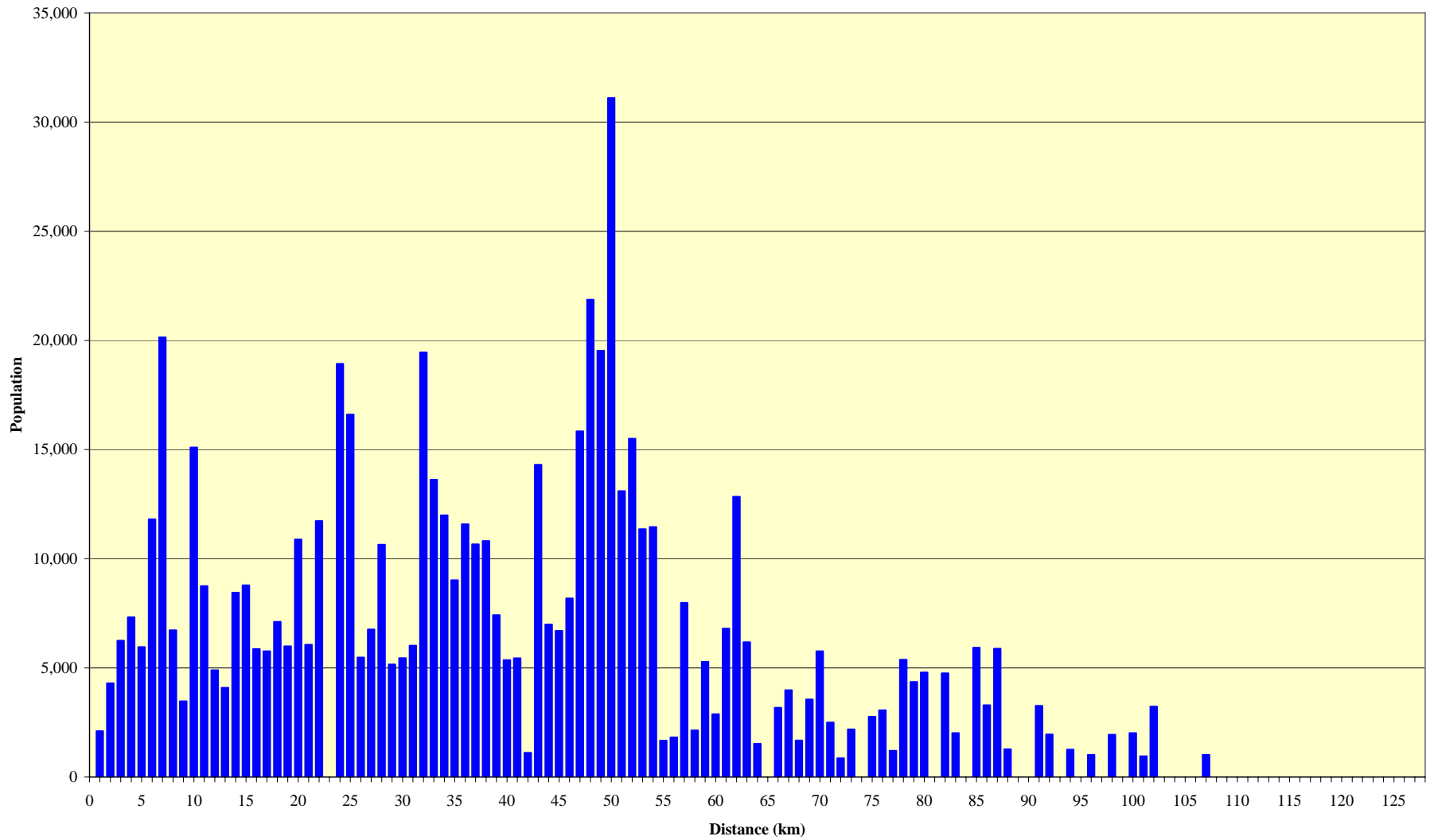
Singleton: Population Versus Distance From Radiotherapy Centre
Population within RT Provider Dominant Catchment Area



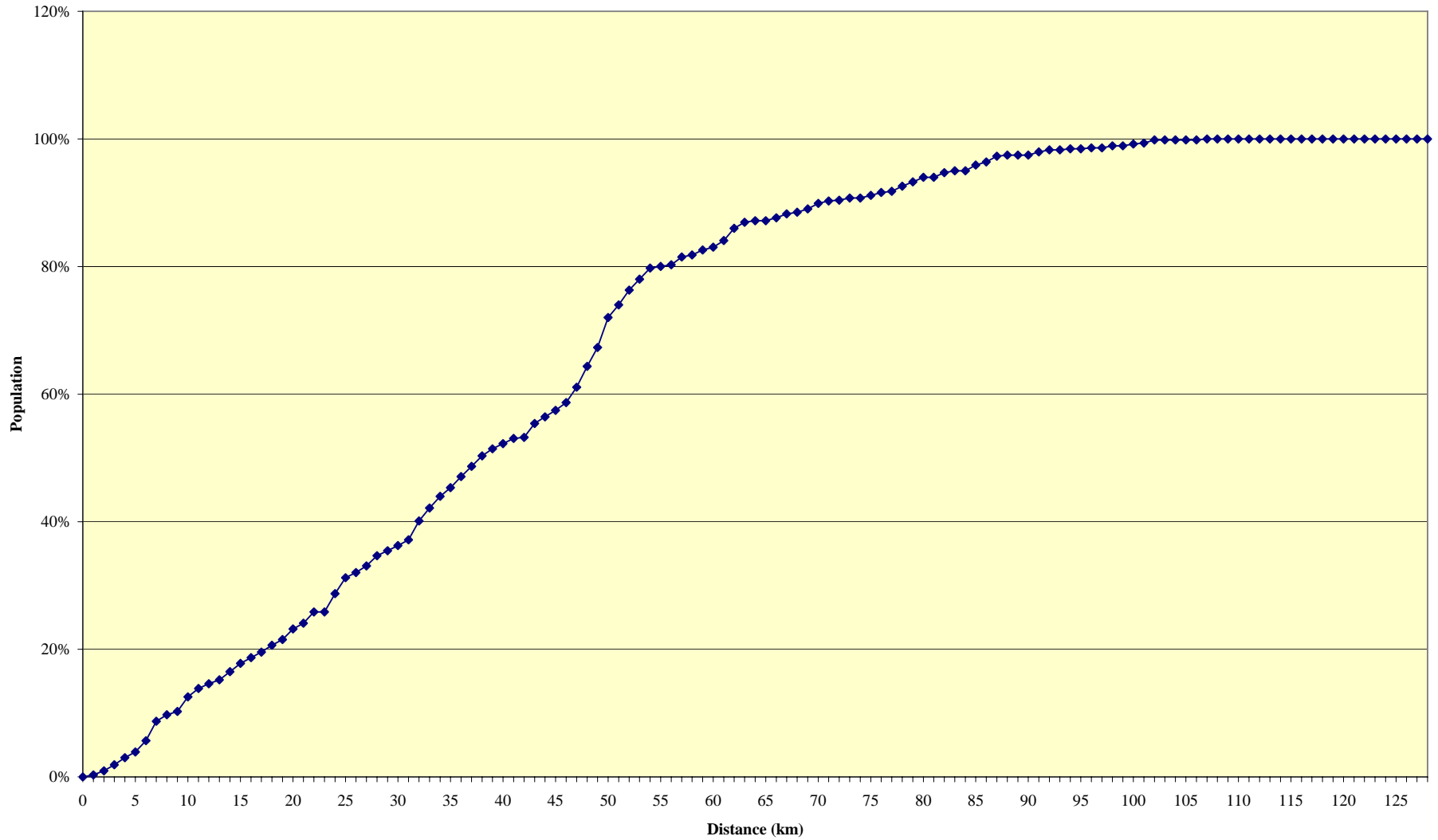
Singleton: Population Versus Distance From Radiotherapy Centre
% Cumulative Population within RT Provider Dominant Catchment Area



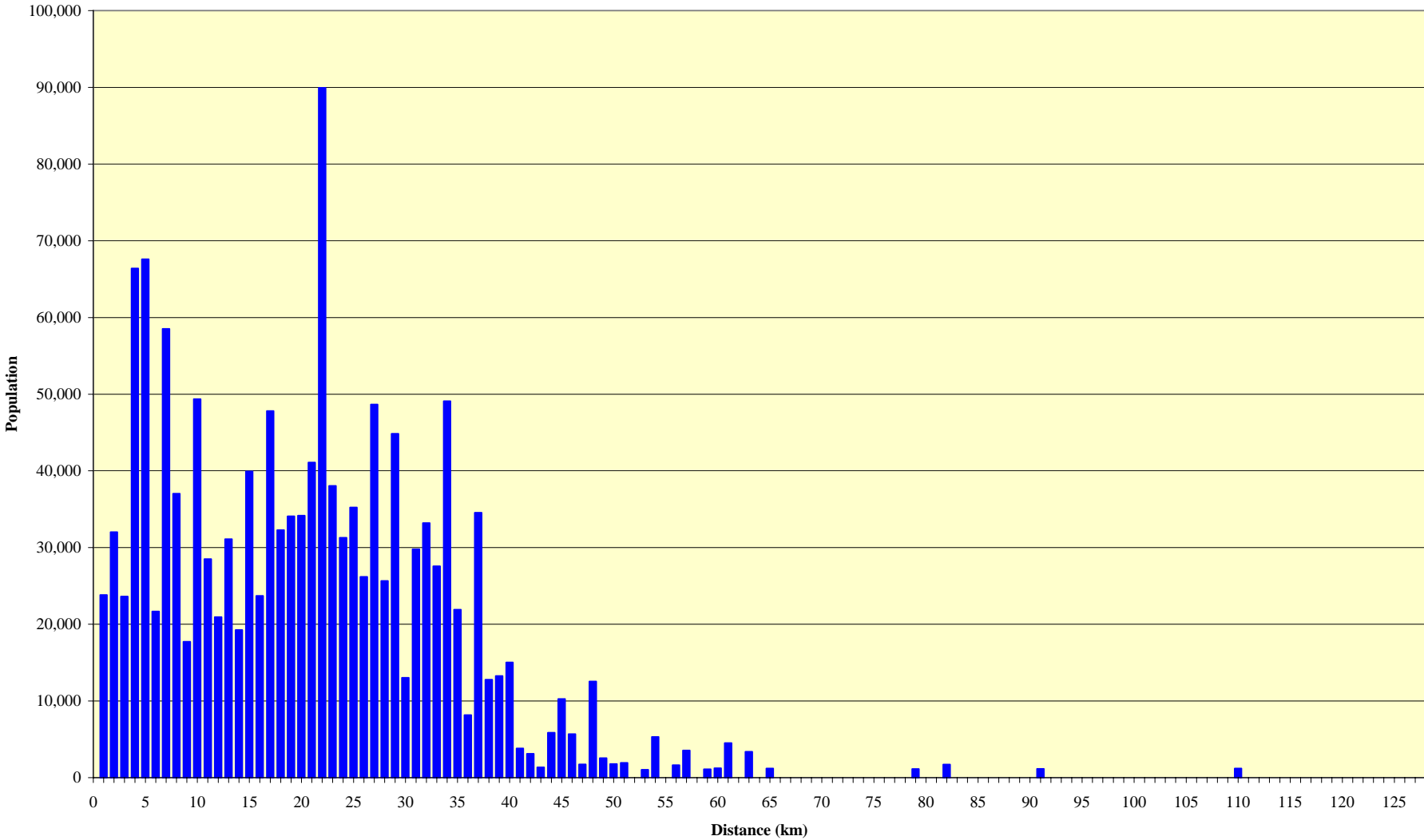
Glan Clwyd: Population Versus Distance From Radiotherapy Centre
Population within RT Provider Dominant Catchment Area



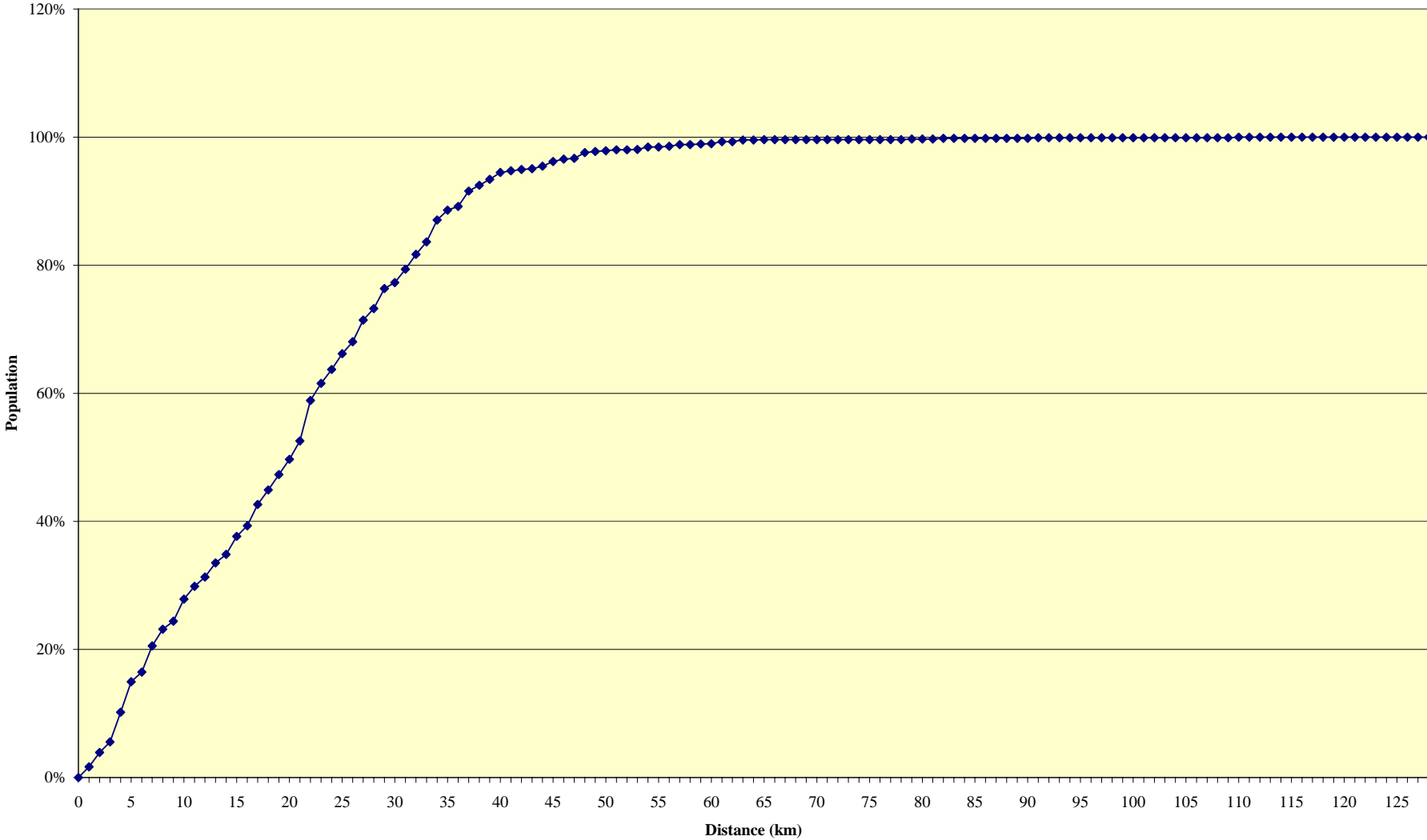
Glan Clwyd: Population Versus Distance From Radiotherapy Centre
% Cumulative Population within RT Provider Dominant Catchment Area



Velindre: Population Versus Distance From Radiotherapy Centre
Population within RT Provider Dominant Catchment Area



Velindre: Population Versus Distance From Radiotherapy Centre
% Cumulative Population within RT Provider Dominant Catchment Area



Appendix 6 - Models for projecting linear accelerator requirements

1. This work has taken account of similar work planning for the future demand and capacity for radiotherapy in Scotland.

Current Welsh Model

2. Linear accelerators in Wales work on average for 8 clinical hours per day, (except 1 linear accelerator in North Wales, because of lack of radiographers), 5 days a week and 244 working days a year. The Cancer Centres achieve between 4.06 and 4.65 fractions per clinical hour. Assuming this service model continues, it is estimated that 21 linear accelerators will be required in Wales by 2016 to meet the projected capacity of 174,000 fractions per annum. This is 10 additional linear accelerators to the 11 in service in Wales at present.

Service Model Variables.

3. It is projected that the Welsh Radiotherapy Service will require 174,000 fractions per year by 2011 – 2016. Three options for achieving this capacity are discussed.
 - a. Increase the number of linear accelerators
 - b. Increase the productivity of the linear accelerators
 - c. Combination of the above
4. In order to explore the potential productivity of the linear accelerators in Scotland, a number of variables were considered in Scotland.
 - a. No. of fractions delivered per hour,
 - d. Working hours per day
 - e. Working days per week

- f. Working days per year
5. In this, the Welsh report, the number of working hours per day is the only variable considered viable. The reasons for not pursuing the other variables are as follows.
- a. The number of fractions per hour depends on case mix, the complexity of the treatment plans, the requirement for verification of the plan and the ability of the equipment to support auto-sequencing. With the increasing complexity of treatment plans e.g. IMRT, CFRT, stereotactic radiotherapy, and the necessity of verifying the treatment with portal imaging, it is not considered likely that the number of fractions per hour will increase. They are more likely to decrease. Therefore, in these projections the number of fractions per hour will remain at 4.5.
 - b. Increasing the number of working days per week is likely to be associated with significant problems. The fractionation schedules of 5 fractions per calendar week have been established as biologically optimal for most protocols of radiotherapy and are, therefore, likely to continue unchanged for the foreseeable future. The exceptions to 5 fractions per week are rare and include emergencies for bleeding, cord compressions, usually palliative treatments. The only radical treatment which has been biologically proven is Continuous Hyperfractionated Accelerated Radiotherapy (CHART) for lung cancer. This regime took several years to establish in randomised clinical trials. At present, there are no plans to introduce such a regime in other tumour sites as there is no supporting evidence.
 - c. Servicing radiotherapy machines at weekends is possible. Discussions with manufacturers of linear accelerators have confirmed, recently, that if manufacturers' servicing was completed during weekends the additional costs would be significant (approximately double). No spare parts or expert advice from manufacturers is available to in-house maintenance teams if servicing is carried out over weekends.

Working hours per day

6. Optimising the current service model for every linear accelerator in Wales would achieve a full 8 hour clinical day (**Model A**) and would result in an immediate increase in productivity in N. Wales if the staffing is available.
7. **Model B** demonstrates a 10 hour clinical day. Working a 10 hour day on all linear accelerators would inevitably result in the loss of flexibility in radiotherapy departments in the event of breakdowns. Increased productivity is probable if **adequate staff could be funded and recruited to work shifts and extend the clinical day**. The impact would be on radiographers, medical staff, physicists, pharmacy, radiology, haematology and supporting services.
8. **Model C** demonstrates half the linear accelerators working a 10 hour day and the other half an 8 hour day, averaged to 9 hours per day.
9. In Table A5 (see also Table 10 and paragraph 71) showing the 3 models, the number of fractions per linear accelerator per annum has been reduced by 5% to correct for the unscheduled downtime experienced in departments at present. The amount of downtime has increased with the more sophisticated equipment which incorporates multi-leaf collimators and portal imaging. Inevitably, extending the working day will result in proportionately increased downtime.
10. Model A considers an 8 hour clinical day, 5 days per week, 244 days per year, 4.5 fractions per hour. In order to achieve the required capacity of 174,000 fractions per year by 2016, 21 linear accelerators will be required (10 more than at present).
11. Model B considers extending core clinical service days to 10 hours per day, 5 days per week, 244 days per year, 4.5 fractions per hour. In order to achieve the required capacity of 174,000 fractions per year, 17 linear accelerators would be required (6 more than at present).

12. Model C considers extending core clinical services to 10 hours per day on half the equipment – so averaging out at 9 hours per day, 5 days per week, 244 days per year, 4.5 fractions per hour. In order to achieve the required capacity of 174,000 fractions per year, 19 linear accelerators would be required (8 more than at present).

Table A5

Models for projecting Linear accelerator requirements

	Fractions	Hours/day	Days	Fractions/ year/linear accelerator	less 5%	Total fractions with 11 linear accelerators	Linear accelerators required to meet capacity of 174,000 fractions
	per hour		per year		downtime		
Model A	4.5	8	244	8784	8345	91,795	21 7 linear accelerators/million pop
Model B	4.5	10	244	10,980	10,431	114,741	17 5.66 linear accelerators/million pop
Model C	4.5	9	244	9,882	9,388	103,268	19 6.33 linear accelerators/million pop

The projections assume that adequate numbers of trained staff can be recruited.

Adopting Models B or C – the issues

13. Adopting service models B or C will require revision of the current core clinical service hours per week. There may be benefits in terms of increasing capacity, but successful implementation of these models raises a number of issues.

- a. Alteration of the core oncology service and support services from 40 hours to 45 or 50 hours per week.
- b. Patients would be required to attend outside the 9 a.m. to 5 p.m. model.
- c. Additional staff will be required to support the new core service.

- d. More resources will be required for training and retention of staff.
- e. The life span of linear accelerators is likely to decrease with increased use.
- f. The capacity of each linear accelerator in Wales will need to be optimised in order to ensure comparable workloads.
- g. There will be loss of flexibility in transferring patients across units during breakdowns resulting in a detrimental impact on patient outcome.
- h. Additional costs of in-house and manufacturers servicing.