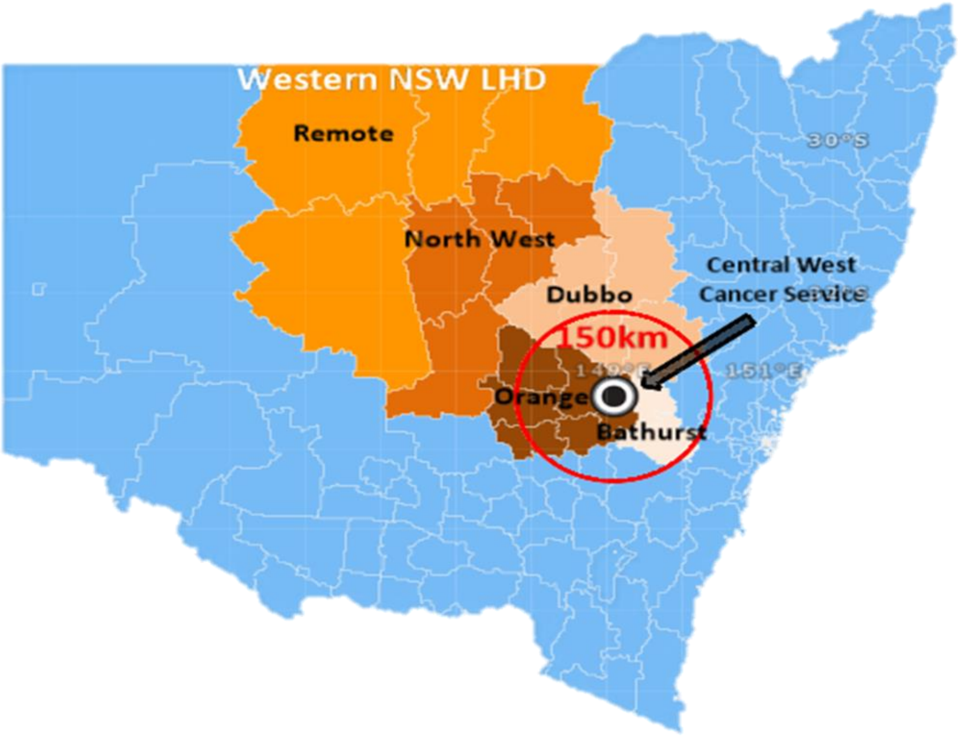
THE CHANGE TO RADIOTHERAPY UTILISATION IN A RURAL AREA AFTER THE ESTABLISHMENT OF A LOCAL SERVICE



Final Report June 2014
Rural Research and Capacity Building Program
Health Education and Training Institute: Rural and Remote Portfolio

Coordinating Principal Investigator: Sally Butler
Registered Nurse
Central West Cancer Service
Orange Health Service
Western NSW Local Health District
Email: sally.yeo@health.nsw.gov.au
Phone: (02) 6369 3380
Mobile: 0400066835

ACKNOWLEDGEMENTS

A huge thank you to the many people who have made this project possible. Your help, expertise and time given is truly appreciated. I would especially like to thank the following people for their contribution:

- Mentor: Dr Catherine Hawke
- Program Coordinators: David Schmidt and Emma Webster
- Central West Cancer Service: Ben Chapman
- Biostatisticians: Margaret Rolfe, Danushka Fox and Keira Robinson
- Western NSW Health Research Network
- NSW Cancer Institute: Frances Terlich
- Participating sites:
  - Royal Prince Alfred Hospital
  - Prince of Wales Hospital
  - Calvary Mater Newcastle
  - Illawarra Cancer Care Centre
  - Liverpool Cancer Therapy Centre
  - Macarthur Cancer Therapy Centre
  - Nepean Cancer Care Centre
  - North Coast Cancer Institute (Lismore, Coffs Harbour and Port Macquarie)
  - Crown Princess Mary Cancer Centre
  - Royal North Shore Hospital
  - St George Cancer Care Centre
  - St Vincent's Hospital
  - Riverina Cancer Care Centre
  - Genesis Cancer Care (Macquarie University Hospital, The Mater Hospital and St Vincent's Private Hospital)
  - Radiation Oncology Institute (Gosford and Wahroonga)
  - Capital Region Cancer Services

SUGGESTED CITATION

Butler, S. (2014). The change to radiotherapy utilisation in a rural area after establishment of a local service. Health Education and Training Institute. Rural Research Capacity Building Program.

The full report is available in electronic form from http://www.heti.nsw.gov.au/rural-and-remote/research-capacity-building/completed-research-projects/

CONTENTS

ABBREVIATIONS

ACT	Australia Capital Territory
ARIA	Accessibility Remoteness Index of Australia
CWCS	Central West Cancer Service
IPTAAS	Isolated Patient Travel and Accommodation Scheme
NSW	New South Wales
PSA	Prostate- Specific Antigen
RMIS	Radiotherapy Management Information System
RPAH	Royal Prince Alfred Hospital
SEIFA	Socio-Economic Indexes for Areas
WNSWLHD	Western New South Wales Local Health District

GLOSSARY OF TERMS

REGION	LOCAL GOVERNMENT AREA
BATHURST	Bathurst Regional; Oberon
ORANGE	Blayney; Cabonne; Cowra; Forbes; Orange; Parkes; Weddin
DUBBO	Dubbo; Gilgandra; Mid- Western Regional; Narromine; Warrumbungle; Wellington
NORTH WEST	Bogan; Coonamble; Lachlan (minus Lake Cargelligo); Warren
REMOTE	Bourke; Brewarrina; Cobar; Walgett

Curative Treatment: Cancer treatment with the aim to eradicate the disease and cure the cancer.

Linear accelerator: A machine that uses electricity to form a stream of fast-moving subatomic particles. This creates high-energy radiation that may be used to treat cancer. Also called linac, mega-voltage linear accelerator, and MeV linear accelerator.

Notifiable cancers- invasive and insitu neoplasms as defined by NSW Health Policy directive PD2009_012, reported mandatorily to the NSW Central Cancer Registry.

Paediatric: Paediatric patients included all patients up to and including 16 years of age.

Palliative Treatment: Cancer treatment to alleviate potential or actual symptoms as a result of the underlying cancer, without prospect of cure.

Radiation Therapy: The use of high-energy radiation from x-rays, gamma rays, neutrons, protons, and other sources to kill cancer cells and shrink tumors. It may be delivered externally, using a machine called a linear accelerator or for some cancers a superficial (orthovoltage) machine, or internally (also known as brachytherapy).

Radiotherapy utilisation rate: The number of new cases in a year treated by radiotherapy divided by the number of new cases of cancer in that year. Includes notifiable cancers only.

Rural: a residential town with an ARIA+ score greater than 0.2, 100km from a capital city and with a local government area population of less than 50,000 people.

ABSTRACT

Background: The first radiotherapy centre in Western NSW Local Health District (WNSWLHD) was opened at Orange in 2011. Prior to this patients travelled outside the health service, primarily to Sydney, to receive treatment.

Aim: To investigate if the establishment of a 'local' radiotherapy service in a geographically sparse rural area has impacted on the number of patients accessing treatment. In particular to investigate if change has been widespread and if patients' demographics, cancer and treatment intent changed significantly with the introduction of the new service.

Method: Data were collected on every WNSWLHD patient 17 years of age and above who received radiotherapy in either 2010 or 2012 in NSW or ACT. The age, gender, treatment intent, cancer type and residential town were recorded.

Results: The number of patients who accessed radiation increased from 573 to 667 between 2010 and 2012 ($x^2(1)=6.0$, $p=0.014$). The corresponding radiotherapy utilisation rates were 29.3% in 2010 and 33.4% in 2012, an improvement of 4.1%. The change in the number of patients accessing radiotherapy became significant for those living within 150km of the new service ($x^2(1)=5.1$, $p=0.02$). There was some improvement outside this area until a distance of 300km from the new service, at which radiation treatments decreased. The number of palliative treatments increased significantly only within the Orange region (Wald 10.6(4), $p=0.004$), with minimal change in the other regions. Male treatments also significantly increased as there were 81 new treatments (292 vs 373, $x^2(1)=9.6$, $p=0.002$) as did patients with a respiratory cancer (66 vs 97, x2(1)=8.7, $p=0.003$).

Conclusion: A new radiotherapy service in a sparsely populated health district significantly changed the pattern of radiotherapy use by those who lived in the Orange region, particularly those living within 150km of the new service.

KEYWORDS

Radiotherapy utilisation; rural; access; health service

EXECUTIVE SUMMARY

INTRODUCTION

In May, 2011 Central West Cancer Service (CWCS) at Orange opened. This is the first and only planned radiotherapy service for WNSWLHD. Before CWCS opened, patients travelled outside the health service, primarily to Sydney, to receive treatment.

Both NSW State and Federal governments funded the multimillion dollar service as research had established that: capacity was not meeting demand; rural people accessed radiation less than urban dwellers; and that travel distance, fuel and accommodation costs are one of the main reasons for the disparity[1, 2].

Therefore the purpose of this study was to evaluate the impact of the new service in terms of patient access, to determine if radiotherapy utilisation rates improved and investigate if certain demographic groups benefited more than others from the introduction of the local service.

KEY FINDINGS

In 2010, 573 WNSWLHD patients were treated with radiotherapy compared to 667 in 2012 (difference 94). The radiotherapy utilisation rates translate to 29% in 2010 and 33% in 2012. The 4% increase shows the new service had a beneficial impact in the first full year of operation.

The critical distance of impact from the new service was found to be 150km. This means that people living within 150km of Orange had a significantly higher utilisation of radiotherapy services in 2012, than those living 150km outside Orange. There was a decrease in the number of treatments received by those living over 300km, which indicates that the Orange service has not benefited patients in the remote region of WNSWLHD.

The study also found that the average distance travelled for patients to receive treatment decreased from 339km to 210km (difference 129km, $p=0.0001$). This is a major improvement, however 210km is still well above the NSW Health goal for 95% of the population to reside within 100km of a radiation centre.

The CWCS opened a second linear accelerator in 2013, almost doubling capacity and further decreasing the number of WNSWLHD patients referred to Sydney[3]. This will help reduce the average distance travelled, but as WNSWLHD is the second most geographically sparse health service in NSW, even taking into consideration the services outside WNSWLHD at Tamworth and Wagga Wagga[1], 64.5% of WNSWLHD residents will always be 100km from a radiation centre[1].

As this study found significant improvement in the number of patients accessing treatment within 150km of the service, the distance of reasonable travel for radiation will encompass the densest populated regions of WNSWLHD which includes Dubbo, Bathurst and Orange[4].

[1] A map of regional radiotherapy centres in NSW is provided in Appendix 1

For those in the North West and Remote regions, it is not feasible, practical, or sustainable to build a closer radiotherapy service, and thus distance will remain a significant deterrent and barrier to radiotherapy access[5].

As radiotherapy treatments actually decreased for those living over 300km from Orange, it is recommended that alternative strategies need to be considered for this group. One practical solution is that travel and accommodation costs be subsidised further for this group. Such models implemented in other countries have effectively eliminated variations in access between regions[6].

Another significant finding was the difference in radiotherapy utilisation rates when analysed by region. Dubbo, which is similar to Orange in terms of population size, specialists and services has continued to operate an outreach clinic from Royal Prince Alfred Hospital (RPAH) due to the limited capacity of CWCS[3].

Between 2010 and 2012 the radiotherapy utilisation rate in Orange increased by 10% (30% to 40%), whereas in Dubbo it only increased by 1% (27% to 28%). This suggests that a local radiotherapy service has been far more effective in increasing the radiotherapy utilisation rate than an outreach clinic.

Other groups who accessed a significantly higher number of radiotherapy treatments after the establishment of the new service, were males, patients with a respiratory cancer and palliative patients from Orange.

The reasons why these groups increased more than others is not known. As the new service had only been established for one year when the study was conducted, it is recommended a follow up study over consecutive years is undertaken to confirm the results.

RECOMMENDATIONS

1. It is recommend that WNSWLHD, NSW Health and Federal Health continue to support the second linear accelerator, in terms of resources and staffing. This is to enable the two linear accelerators to reach full capacity and be able to treat all WNSWLHD patients requiring non-complex megavoltage radiotherapy.
2. For those living in NSW and greater than 300km from a radiation centre, other strategies to increase the uptake of radiotherapy need to be strengthened. Evidence from other studies shows one practical solution would be to increase IPTAAS and subsidise 100% of travel and accommodation costs.
3. Evaluation of radiotherapy utilisation in WNSWLHD should be reviewed once the second linear accelerator reaches full capacity.

CONCLUDING COMMENTS

Overall the first radiotherapy service in WNSWLHD has improved radiotherapy utilisation rates. In the first full year of operation, the number of radiotherapy treatments increased most significantly in the Orange region and particularly within 150km of the service. Expansion of the new service will increase capacity, but it is unlikely given the results of this study, that those living over 300km away, will benefit. As there will be no closer radiation service for remote residents, more needs to be done to reduce the travel and accommodation costs if radiotherapy utilisation is to be improved for this group.

INTRODUCTION

In May 2011 WNSWLHD opened its first radiotherapy service at Central West Cancer Service (CWCS) in Orange. By the end of the year the linear accelerator had reached full capacity and in 2013 a second linear accelerator was opened[3].

Prior to this CWCS patients travelled mainly to Sydney for treatment. Radiotherapy is usually delivered daily for four to six weeks and being treated away from home leads to considerable financial, logistical, social and emotional burdens[7, 8].

These burdens have been shown to reduce the uptake of radiotherapy services[8]. Therefore it is expected that with distance reduced and access improved, radiotherapy rates should increase for patients within WNSWLHD since the establishment of CWCS.

However, the area of WNSWLHD covers 31% of NSW, meaning that 64.5% of WNSWLHD residents, still have to travel greater than 100km to have treatment at their 'local' service in Orange[3]. For these patients, even though they may be only two or three hours' drive away instead of four or five, travel distance still remains a significant deterrent.

This study examined the radiotherapy treatment patterns since the opening of the local service in a geographically sparse rural area. It shows how patterns have changed, to what extent and for which population groups. It also determined if the changes have been widespread or within the Orange region only.

These findings are important because the current literature is based on more regional, densely populated rural areas, but none in as geographically sparse an area as WNSWLHD. For example some studies have defined rural as 300-500 people/km^2 [9], comparatively WNSWLHD has a population density of 1 person/km^2[4].

Therefore these study findings will guide health service planning for WNSWLHD and evaluate if the current radiotherapy service is adequately accessible for all of WNSWLHD.

In this study we define rural as a residential town with an ARIA (Accessibility Remoteness Index of Australia) score greater than 0.2, 100km from a capital city and with a local government area population of less than 50,000 people. All participants in this study meet our definition of rural.

LITERATURE REVIEW

Literature has shown that rural people access radiation therapy less than their urban counterparts [10-13].

A recent study based on NSW and ACT cancer patients found those in urban areas had the highest rate of radiotherapy utilisation (27%), and remote the lowest (23%)[14]. The study also found a significant correlation between distance to the radiation centre and radiotherapy utilisation rate[14]. After 100km the utilisation rate started to decrease and by 400km the utilisation rate had dropped by 13% (27% to 14%)[14]. This demonstrates the further patients have to travel for radiation treatment the less likely they will be to have treatment.

The same study also found other demographic groups with low rates of radiotherapy included those over the age of 70 and males[14]. The study, although not yet published, had similar methods to this project and gives a good base to form hypotheses. The main difference between that study and this study is that focused on the radiotherapy utilisation rates in NSW and this study found the impact to access after the establishment of a rural radiotherapy centre.

The 100km distance to service was found to be significant in other Australian studies, such as one from Victoria, which found those living outside 100km had a significantly lower retreatment rates than those within 100km[11]. This literature has formed the basis for two important NSW Health plans aimed at improving access.

1. Establish radiotherapy centres in regional areas of NSW with the aim that 95% of NSW residents will reside within 100km of a radiation treatment centre[1].
2. Those travelling greater than 100km (or 200km in one week) for treatment are eligible for Isolated Patients Travel and Accommodation Scheme (IPTAAS)[15].

The IPTAAS scheme does not completely cover all accommodation and travel costs, but subsidises around half if patients stay in hospital accommodation.

Only one study was found where all logistical and financial travel and accommodation burdens were eliminated[6]. This study from Norway compared the relationship between travel distance and palliative radiotherapy rates and found no statistical differences[6].

Opposing the theory that travel distance, access and the associated costs are the main reasons for the inequality between rural and urban radiotherapy rates, were several qualitative and mixed method studies.

In a large Western Australian study, rural patients accessed cancer services later than the urban group[16]. Reasons given were not only service availability, but also cultural characteristics such as optimism, stoicism, machismo and the embarrassment of symptoms[16].

The other main barriers found in the literature specific to radiation therapy uptake were nihilism, age, waiting time and physician referral[17].

The multifactorial reasons and complexities around accessing treatment has led to an ongoing debate as to whether increasing radiotherapy services in rural areas will in fact increase the radiotherapy utilisation rate[18-20].

Studies have debated outreach services versus establishing radiotherapy services in larger rural areas[19]. There is some debate that rural services will be underutilised and unable to maintain quality and professional skills[20].

In areas of Australia where rural radiotherapy services have opened the results have been positive. In Victoria the single machine unit trial increased radiotherapy services to three rural cities[21]. Utilisation rates increased by 12% for rural people compared to 6% of Metropolitan Melbourne between 2001 and 2003/2004[22]. It also showed that in Victoria the overall utilisation rate increased from 37.4% to 39.0% and in rural areas the utilisation rate increased by 8%[22].

Similar results have been found in the North Coast Cancer Centre, where 40% of new radiation referrals are being treated locally, which has decreased the need for patients to travel to Sydney by 20%[5].

A study from the USA found that distance to the radiotherapy centre significantly impacted on mastectomy rates and when a rural service was introduced the mastectomy rate decreased from 61% to 45% within a 15mile (24km) radius of the centre[13].

In summary the literature found from Australia, USA, Canada and Europe, on rural patients, access and radiotherapy was mostly quantitative, had large sample populations (30,000 to 100,000 subjects) and were of high quality.

A weakness with many studies was the definition of rural. Some studies defined rural poorly if at all and others defined rural as populations equal in density to metropolitan areas of Australia. Another main issue in the quantitative studies was data extraction, often data bases were incomplete, and difficult to link patient details together.

A strength of the studies was the consistency in the findings. The majority of studies found rural populations had less radiotherapy than urban populations and that increasing rural services improved rural radiotherapy utilisation rates. None evaluated the impact of a radiation centre in a uniquely sparse rural area such as WNSWLHD, which is why the findings of this study will build upon current literature as well as guide future health service plans.

AIMS/OBJECTIVES/HYPOTHESES

Aim:

To evaluate the impact of a new rural radiotherapy centre in geographically sparse area of NSW.

Objectives 1-5:

1) **Age-** Determine if the age of patients accessing radiotherapy changed after a local service opened.
2) **Cancer Type-** Compare the types of cancer treated in WNSWLHD between 2010 and 2012.
3) **Gender-** Ascertain if males and females equally access radiotherapy services.
4) **Treatment intent-** Compare if the number of palliative and curative courses have changed.
5) **Geographical location-** Determine if there is certain distance from Orange where there has been a significant variation in number of treatments. Compare the differences between the regions of WNSWLHD and radiotherapy utilisation rates. Determine how far patients from WNSWLHD travel for radiotherapy since there has been a local service.

Hypotheses: With the introduction of the new radiotherapy service in Orange

1: The mean age of the treatment population will increase.

2: Increases in the number of palliative treatments will be confined to the Orange region.

3: Significant changes to radiotherapy utilisation will be within 100km of Orange.

METHODS

TYPE OF STUDY

This is a repeat cross sectional study. It uses quantitative methods to ascertain the changes in the number of radiotherapy treatments between 2010 and 2012 for WNSWLHD adult cancer patients.

SAMPLING

All patients who met the inclusion criteria were selected and every NSW and ACT radiotherapy centre was chosen as a site for data collection. This is because it captured the highest possible number of WNSWLHD patients requiring radiotherapy without causing geographical location bias.

INCLUSION CRITERIA

- Patients 17 years of age and over
- A residential address within WNSWLHD
- Received radiotherapy in the calendar years of 2010 or 2012
- Treated with a megavoltage course in NSW or ACT
- Diagnosed with a NSW Health notifiable cancer

EXCLUSION CRITERIA

- Orthovoltage, brachytherapy and complex treatments such as paediatrics, stereotactic, total body irradiation.

METHOD OF DATA COLLECTION

Data was collected directly from every radiotherapy centre in NSW and ACT. This equated to 22 in total, 21 centres are within NSW (15 public + 6 private) and one public centre is in the ACT.

Radiotherapy data managers from each centre extracted the required information from either Aria or Mosaiq, de-identified patient data and transferred it electronically to the coordinating principal investigator in password protected Excel format.

Received information contained participant's:

- Residential town and postcode
- Cancer diagnosis or ICD code
- Age
- Treatment intent
- Place of treatment
- Gender
- Year treated with radiotherapy

An exception was Riverina Cancer Care Centre. Instead of a data manager extracting the information, the coordinating principal investigator extracted and de- identified the required data

Data was extracted and received from the 22 Radiotherapy Centres within 12 months of ethical and SSA approval.

DATA CLEANING/CODING

Records of patients who did not meet the inclusion criteria were not entered into the project database.

Of the 1745 records received, 1240 (71%) were entered.

Details of excluded records are in Table1.

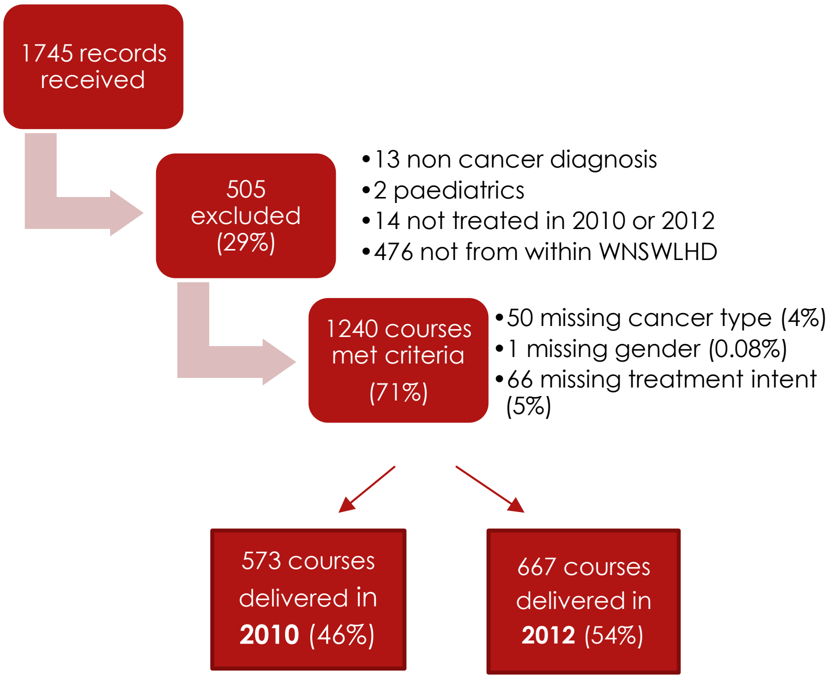
Table 1: Excluded Records

Criteria:	**n**
non cancer diagnosis	13
paediatrics	2
not treated in either 2010 or 2012	14
not from within WNSWLHD	476
TOTAL EXCLUDED	**505**

Data received from three cancer centres did not have cancer type and treatment intent recorded for all participants after computer systems changed. Cancer type was missing for 94 of 141 of participants (66%) and treatment intent missing for 100 of 141 of participants (71%). The body site treated however was provided. Using this information 47% of the missing cancer type was able to be recorded and 34% of treatment intent. This resulted in unknown cancer type for 50 participants and 66 participants missing treatment intent. Gender was not recorded for 1 participant from another data set.

These participants missing either cancer type, gender or treatment intent were still entered into the project database as it meant 100% of ages and residential town were collected, as per Figure 1.

Figure 1: Progression of Records through the study



Terms used to code data are provided in Appendix 2.

MISSING DATA

For the missing treatment intent data from Cancer Centres A, B and C, both actual and estimated numbers were analysed to check if the missing data changed the significance of the results. Estimations were made by dividing the missing number from each Cancer Centre and multiplying it by the proportion of palliative and curative treatments that the Centre treated that same year. Radiotherapy Management Information System (RMIS) data was used to find the total of palliative and curative treatments at each Cancer Centre for that year. See Appendix 3.

This method could not be used for missing cancer type as the numbers within each group were too small.

DATA ANALYSIS

ESTIMATING CANCER PREVALENCE

Five year limited duration cancer prevalence was used as the denominator in the majority of analysis to form the proportions required for chi square analysis.

As cancer prevalence is not known in WNSWLHD for 2010 or 2012, estimates were used based on 2008 rates for WNSWLHD patients 17 years and above. The number of prevalent cases for 2008 was provided by Cancer Institute NSW and grouped into gender, age category, cancer clinical grouping and region to match the criteria and definitions of this study.

The populations of WNSWLHD for 2008, 2010 and 2012 were provided by the Australian Bureau of Statistics(ABS)[23]. Local Government Areas within WNSWLHD were added together to form the regions. Age groups and gender were available in ABS reports, except for the 17-19 year age group as counts were provided by 5 year groups (15- 19 years) for 2008, 2010 and 2012. To find the number in the 17-19 year age group, single year data available from the 2006 and 2011 census was used. The proportion of 17, 18 and 19 year olds in 2006 was multiplied by the number in the 15-19 year age group in 2008 to get the number of 17+ years for 2008[24]. The method was repeated for 2010 and 2012 populations except 2011 single years were used for 2010 and 2012 calculations instead of the 2006 data[25].

Using the number of known prevalent cancer cases for 2008 and the populations of 2008, 2010 and 2012, calculations were made by dividing the number of prevalent cases by the population in 2008. This rate was then multiplied by the respective populations of 2010 and 2012.

For example the number of living male cancer cases in WNSWLHD in 2008 (diagnosed within the last 5 years 2004-2008), aged 17years + were divided by the number of males in WNSWLHD in 2008 aged 17 + years. This rate was then multiplied by the number of males in WNSWLHD aged 17 + years in 2010 and 2012 to achieve the number of prevalent males in the respective years 2010 and 2012.

RADIOTHERAPY UTILISATION RATES

Radiotherapy Utilisation Rate is defined as:

$$\frac{\text{The number of new radiotherapy courses}}{\text{The number of new cancer cases}}$$

As no patient identifiable details were collected, it was not known if the same patient was treated more than once. It was also not known if the course was a new treatment or a retreatment.

To find the number of new radiotherapy courses, the total number of courses was multiplied by the NSW radiotherapy retreatment rate stated for both 2010 and 2012 (21%) in RMIS[26, 27]. The number of retreatments were then subtracted from the total number of courses to get the number of new courses as shown in Table 2.

The retreatment rate of 21% is compatible with research from Victoria that had a retreatment rate of 25.2%[11].

The number of new cancer cases, was found using the same method as finding cancer prevalence. However instead of using five year prevalence numbers, the incidence of cancer in WNSWLHD 17+years for 2008 was used.

This data was again provided by the NSW Cancer Institute and grouped into gender, age category, cancer clinical grouping and region to match the definitions of this study and allow for more accurate analysis of the variables.

STATISTICAL TESTS

Independent samples T-tests were used for continuous variables and Chi- square used for categorical variables for the majority of the statistical analysis.

Five year cancer prevalence was used where possible as the denominator for Chi square analysis as it provided direct comparison between each variable from 2010 to 2012.

Where prevalence could not be used such as treatment intent, the proportion of one variable to another was compared i.e. palliative to curative treatment.

Univarate logistic regression was not used to analyse cancer clinical groupings because it showed if the proportion of a certain clinical group within all the clinical groupings was different between 2012 and 2010 and not if a clinical group by itself was different between 2012 and 2010.

However it was appropriate to use univariate logistic regression to analyse the change in the proportion of palliative treatments by region because, the aim was to find if Orange region compared to all the regions changed significantly.

SPSS version 22, was used the statistical package used to analyse results.

ETHICS APPROVAL

Ethical and site specific approval was granted for all 22 radiotherapy centres. Details are provided in Appendix 4.

RESULTS

In total there were 94 new radiotherapy treatments between 2010 and 2012 (573 vs 667), a total difference of 8%. Using five year limited duration cancer prevalence for WNSWLHD as the denominator, the increase was significant ($x^2(1)=6.0$, $p=0.014$). The odds of radiotherapy in 2012 to 2010 was 1.2 with a 95% CI (1.03-1.31).

As per Table 2, the radiotherapy utilisation rate increased by 4% from 2010 to 2012. This is a marked improvement, however still far below the estimated rate of 48.3%[28].

Table 2: Radiotherapy Utilisation in WNSWLHD

Year	No of Courses	Retreatment (21%)	New Course	Cancer Incidence	Radiotherapy Utilisation Rate
2010	573	120	453	1545	29.3%
2012	667	140	527	1577	33.4%

GEOGRAPHICAL LOCATION

The distance from each participant's residential town to the radiotherapy centre at which they were treated was measured using Google maps. The average distance travelled decreased by 128.5km from 2010 to 2012. Using independent samples t-test this difference is highly significant, as seen Table 3.

Table 3: Distance Travelled to the Radiotherapy Centre

Year	Mean (km)	p value	Mean difference (95% CI)	Test
2010	338.7	>0.0001	128.5km (111km-145.5km)	Independent Samples T- Test
2012	210.2			

The distance from each participant's residential town to the local service at Orange was also measured using Google maps. This was to ascertain if the dispersion of people having radiation therapy has changed.

Table 4 illustrates that patients lived an average of 20km closer to Orange in 2012 than 2010. This shows people living closer to Orange are accessing more radiotherapy than before the service opened (p=0.002).

Table 4: Distance from participant's residential location to CWCS, Orange

Year	Mean (km)	p value	Mean difference (95% CI)	Test
2010	143.3	0.002	20km (7km-32km)	Independent Samples T- Test
2012	123.6			

To assess if there was a certain distance from the new service that changed the number of patients having radiotherapy (scope of impact) the travel distances to Orange were broken into 50km increments.

As shown in Figure 2, the biggest increase was for those living within the 100-149km distance, followed by those living within 50km of the service. Past 300km radiotherapy treatments decreased, showing the service has had no impact beyond this point and that utilisation actually declined. Using Chi square, the change in the number of patients accessing radiotherapy became significant for those living within 150km of the new service (Table 5). This appears to be the scope of impact after the first full year of operation.

Figure 2: 50km distances from participant's residential location to Orange

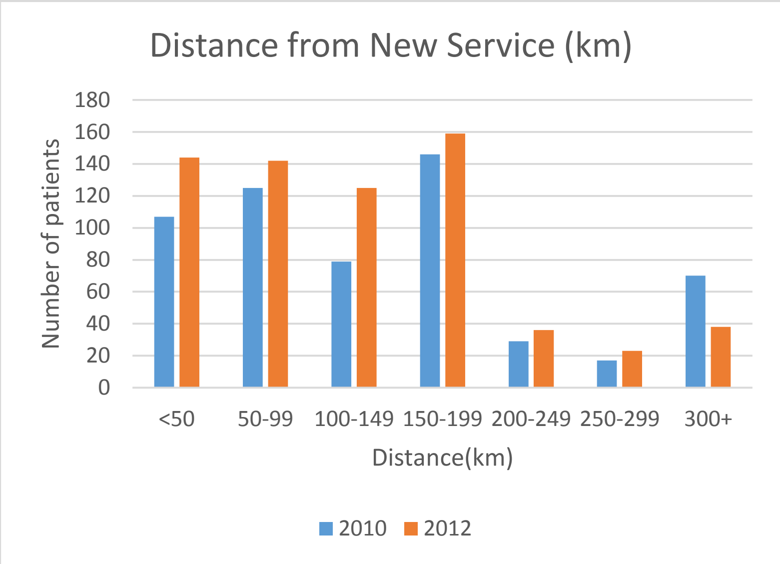


Table 5: Number of radiation treatments within a distance of Orange

Distance to Orange	2010 n=573 n (%)	2012 n=667 n (%)	p value	OR (95% CI)	Test
<50km	107(19%)	144(22%)	0.20	1.2 (0.9-1.6)	Chi- Square
<100km	232(41%)	286(43%)	0.40	1.1 (0.9-1.4)	
<150km	322(56%)	417(63%)	0.02	1.3 (1.04-1.6)	
<200km	457(80%)	570(86%)	0.008	1.5 (1.1-2.0)	
<250km	486(85%)	606(91%)	0.001	1.8 (1.3-2.5)	
<300km	503(88%)	629(94%)	<0.0001	2.3 (1.5-3.5)	
300km+	573(100%)	667(100%)			

The scope of impact in terms of distance, although insightful is limited in its interpretation as it does not show the regional differences that result in less radiotherapy such as physician referral, specialist and outreach clinic availability. To overcome this the Local Government Areas of WNSWLHD were divided into five regions defined by the main service town and areas of similar ARIA and SEIFA scores to provide stronger strategic focus. These regions were copied from the WNSWLHD Health Needs Assessment[4].

Table 6: Number of radiation treatments by residential region

Region	2010 n=573 n (%)	2012 n=667 n (%)	p value	OR (95% CI)	Test
Bathurst	86 (15%)	102(15%)	0.28	1.2(0.9-1.6)	Chi-Square
Orange	219(38%)	296(44%)	0.001	1.4(1.1-1.7)	
Dubbo	195(34%)	206(31%)	0.69	1.0(0.8-1.3)	
North West	40(7%)	42(6%)	0.90	1.0(0.7-1.6)	
Remote	33(6%)	21(3%)	0.08	0.6(0.3-1.1)	

As shown in Table 6, the Orange region has had the largest increase in radiotherapy treatments, with minimal effect outside this region. Treatments increased from 219 to 296 (difference 77), which was a significant increase (p value= 0.001).

Table 7 reinforces this finding, as the radiotherapy utilisation rate increased the greatest in the Orange region. It increased by 10%, whereas the Dubbo Region which is comparable in terms of population size and medical services only increased by 1%. The 9% decrease in the remote region is concurrent with the decrease in the 300+km region, however as there are smaller numbers in this group, there is less reliability in the result.

Table 7: Radiotherapy Utilisation Rates by Residential Region

Region	2010 RTU	2012 RTU	Change %
Bathurst	32%	37%	+ 5%
Orange	30%	40%	+ 10%
Dubbo	27%	28%	+ 1%
North West	31%	32%	+ 1%
Remote	31%	20%	-9%

TREATMENT INTENT

As five year prevalence for palliative and curative cancers could not be used as a denominator, treatment intent was analysed by comparing the proportion of palliative to curative treatments between 2010 and 2012, of which there was no statistical difference (Table 8).

Table 8: Proportion of palliative to curative treatments

Treatment Intent	2010 n=573 n (%)	2012 n=667 n (%)	p value	OR (95% CI)	Test
Palliative	175(31%)	254(38%)	0.15	1.2(0.9-1.5)	Chi square
Curative	336(59%)	409(61%)			

As 11% of the 2010 and 0.6% of the 2012 data was missing treatment intent the estimated values were also analysed. The p value was very similar to the p value obtained from the original data. (p=0.112 vs p=0.15).

Breaking palliative treatments into regional areas it was found 62 of the 79 (78%) new palliative treatments were from within the Orange area, as seen in figure 3. This significant finding is also shown in Table 9, as the change in the proportion of palliative treatments for

Orange had a p value of 0.004, whereas the other regions did not significantly change from 2012 to 2010.

Figure 3: Palliative courses by Residential Region

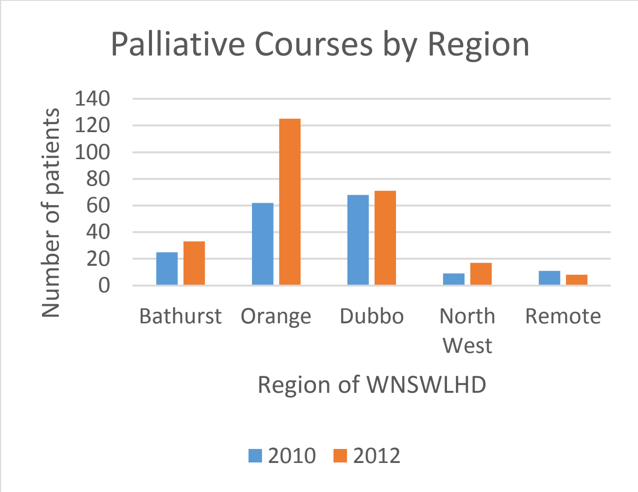


Table 9: Number of palliative courses by Residential Region

Region	2010 n=175 n (%)	2012 n=254 n (%)	p value	OR (95% CI)	Test
Bathurst	25(14%)	33(13%)	0.46	1.3(0.7-2.3)	Univarate logistic Regression. (Wald: 10.6(4) p=0.03)
Orange	62(35%)	125(49%)	0.004	1.9(1.2-3.0)	
North West	9(3%)	11(7%)	0.74	1.2(0.5-3.0)	
Remote	11(6%)	8(3%)	0.47	0.7(0.3-1.8)	
Dubbo	68(39%)	71(28%)	reference		

GENDER

There were 81 new male treatment courses from 2010 to 2012 (292 to 373) compared to14 new treatment courses for females (280 to 294). The proportion of male to female treatments was not statistically different (p= 0.086) however the proportion of male courses to the number of males living with cancer (five year prevalence), showed that the increase in 2012 was very significant (p=0.002). For females the number of courses to the number living with cancer did not change from 2010 to 2012 (p=0.75). This is shown in Table 10.

Table 10: Gender changes to radiation treatments using prevalence as the denominator

Gender	2010 n=573 n (%)	2012 n=667 n (%)	p value	OR (95% CI)	Test
Male	292(51%)	373(56%)	0.002	1.3 (1.1-1.5)	Chi-square
Female	280(49%)	294(44%)	0.75	1.0 (0.9-1.2)	

AGE

Results show the mean age increased by 1.2 years which is not significant (p=0.09).

Dividing into age categories and analysing each group by the number of that same age living with cancer, demonstrated that the difference since the new service opened was also not significant.

Table 11: Changes to Age between 2010 and 2012

Age (years)	**2010 n=573 n (%)**	**2012 n=667 n (%)**	**p value**	**OR (95% CI)**	**Test**
Mean	64.9 yrs.	66.1 yrs.	0.09	mean diff: 1.2 yrs.(-0.2-2.5)	Independent Samples T-Test
17-49	66(12%)	58(9%)	0.46	0.9(0.6-1.3)	Chi- Square
50-64	205(36%)	224(34%)	0.48	1.1(0.9-1.3)	
65-79	237(41%)	294(44%)	0.08	1.2(1.0-1.4)	
80+	65(11%)	91(14%)	0.07	1.4(1.0-1.9)	

CANCER TYPE

Overall there was minimal change in the type of cancers treated. The five most common cancer types treated were; breast, prostate, lung, skin and rectum. Cancer types were categorized into clinical groupings and were analysed by comparing the cancer clinical group treated over the number living with that same cancer clinical group in 2010 and 2012.

Respiratory, upper gastrointestinal (GI) and lymphohaematopoietic cancers significantly increased from 2010 to 2012. As the upper GI and lymphohaematopoietic groups were quite small the significance could be unreliable.

The respiratory cancers treated increased by 19% (31 new courses) in 2012. Of the 31 new courses, 27 (87%) were palliative.

Despite cancer type missing for 7% of the data in 2010 and 1% in 2012, it is unlikely the results would have differed.

Table 12: Cancer clinical groupings

Cancer Clinical Group	**2010 n=573 n (%)**	**2012 n=667 n (%)**	**p value**	**OR (95% CI)**	**Test**
Breast	136(24%)	146(22%)	0.64	1.1(0.8-1.4)	Chi Square
Urogenital	109(19%)	139(21%)	0.07	1.3(1.0-1.7)	
> *(Prostate)*[2]	*92(16%)*	*123(18%)*			
Respiratory	66(12%)	97(15%)	0.003	1.8(1.2-2.7)	
Skin	63(11%)	62(9%)	0.83	1.0(0.7-1.4)	
Colorectal	45(8%)	43(6%)	0.75	0.9(0.6-1.4)	
Head and Neck	28(5%)	37(6%)	0.24	1.4(0.8-2.4)	
Gynaecological	23(4%)	29(4%)	0.43	1.3(0.7-2.3)	
Upper GI	15(3%)	32(5%)	0.008	2.4(1.2-4.7)	

[2] The significance of prostate treatments was not tested as prevalence was obtained for only cancer clinical groups and not cancer types

Neurological	14(2%)	16(2%)	0.61	1.3(0.5-3.5)	
Lymphohaematopoietic	13(2%)	29(4%)	0.01	2.3(1.2-4.5)	
Ill-defined and Unknown	12(2%)	17(3%)	0.3	1.6(0.7-3.7)	
Other	9(2%)	10(1%)	0.84	1.1(0.4-2.8)	

DISCUSSION

For all of WNSWLHD, the radiotherapy utilisation rate increased by 4% (29% to 33%) showing the introduction of the CWCS at Orange has had a beneficial impact.

Despite the 4% increase, radiotherapy utilisation is still 15% below the targeted 48.3%[28], demonstrating there are still many residents of WNSWLHD who would benefit from radiotherapy but are not having treatment.

GEOGRAPHICAL LOCATION

GEOGRAPHICAL DISTANCE

An important finding of this study was that the average distance travelled for radiation therapy decreased from 339km to 210km (difference 129km).

This was a very significant decrease, however 210km for the average patient is still substantially different to the NSW Health goal of 100km for 95% of the population[1].

There are two explanations contributing to this finding:

1. 12% of patients living in the North West and Remote regions will always be further than 210km from their local service
2. As the one linear accelerator at CWCS reached full capacity by 2012, 39% of the patients were referred to Sydney.

Therefore considering NSW Health plans, the second linear accelerator that has since opened in Orange will double capacity and be able to treat all WNSWLHD patients requiring non-complex megavoltage radiotherapy[3], which should decrease the average distance travelled and reduce the number of patients to referred to Sydney.

As for patients living in the North West and Remote regions, even considering radiotherapy services outside WNSWLHD such as the Tamworth radiotherapy centre, it too is also greater than 210km for those in the Northwest and Remote regions of WNSWLHD[1], and will have minimal effect on the distance they travel for radiotherapy.

Therefore this shows that the 5% of NSW residents not included in the NSW Health target to have 95% of residents within 100km of a radiotherapy centre, are a vast majority of the patients living within WNSWLHD.

Factoring in that this study found a significant impact in treatment rates within 150km of the service, this distance of 150km will mean that two thirds of WNSWLHD or those from the Dubbo, Orange and Bathurst regions will be within reasonable distance of a radiotherapy centre.

For those further away the distance travelled for radiation will remain an issue, as accommodation, fuel and time away from family and work will be costly[7, 8]. For those past 300km this study has demonstrated that they will not benefit at all from the local service. This group of WNSWLHD will remain the most disadvantaged. As it is also a low socioeconomic region, travel costs will be substantial even with IPTAAS subsides[4].

Close to 10% of WNSWLHD or less than 1% of NSW live further than 300km from Orange. As it is not feasible nor practical to have a radiotherapy centre closer than the service at Orange, IPTAAS subsides need to be increased for people greater than 300km if radiotherapy utilisation rates are to be improved. This is because the associated travel and accommodation costs that patients endure whilst undergoing radiotherapy are a known deterrent to treatment[17]. Additionally, the one study where travel and accommodation was arranged and paid for by the government, found that there was no regional difference in treatment rates[6].

GEOGRAPHICAL REGION

Regions of WNSWLHD were also analysed as there are different radiation referral systems, models of care and specialist availability in each[3].

For example, as CWCS in Orange did not have the capacity to treat all of WNSWLHD with one linear accelerator in 2012, the outreach clinic at Dubbo continued to operate from RPAH[1].

This has provided a unique opportunity to observe the change in radiotherapy utilisation rates in two very similar rural areas using two different radiation models of care.

The implementation of outreach clinics versus establishing local services has been widely debated in the literature as rural areas such as Tamworth had a very good uptake of radiation therapy when an outreach clinic was operated from Prince of Wales Hospital[19].

Results from this study show that in 2010 where all regions of WNSWLHD were serviced by an outreach clinic the radiotherapy utilisation rate was 30% in Orange and 27% in Dubbo, which is quite similar. In 2012, once the new service was fully operational the radiotherapy utilisation rate increased by 10% in Orange (40%) and by 1% in Dubbo (28%). This clearly demonstrates that local service has achieved better radiotherapy uptake than outreach clinics in WNSWLHD.

It also shows that the Orange region has been most affected by the introduction of the new service. Bathurst had the second most improvement, followed by Dubbo and North West. The Remote region had no improvement and in fact the radiotherapy utilisation rate fell by 9%.

TREATMENT INTENT

It was hypothesised that palliative treatments would increase only within the Orange region because it is known from the literature that palliative treatment decreases with travel time[12]. This hypothesis was proven true with 62 of the 79 (78%) new palliative courses from the region of Orange. This is a key finding and confirms that the impact of the new service was contained to the Orange area.

There were 73 (10% total difference) new curative courses delivered in 2012, which was not significant proportionally to the number of palliative treatments in 2012.

GENDER

The significant increase in the number of males treated to the number living with cancer was an unexpected finding of this study. Literature around gender and radiotherapy is mixed. A Canadian study found females had less palliative radiation than males(12) and Gabriel, Barton and Delayney in 2013 found males had a lower proportion of radiotherapy than females(14).

There were no studies found comparing the difference between rural males and females as the studies pertaining to rural patients requiring radiotherapy focused on either females with breast cancer or males with prostate cancer.

Of the 81 new males treated (292 vs 373 in 2012), the greatest portion (31/ 81 or 38%) were treated for prostate cancer. As prostate cancer can spike periodically depending on the number of PSA tests prescribes annually and the fact that prevalence rates were based on a 2008 standardised rate, there is the possibility that the actual number of prevalent males living with cancer differed to the estimated number of prevalent males, which could have influenced the p value found.

Variation in the number of PSA tests prescribed is evident in the Medicare item reports from 2008 to 2010, which show PSA tests in NSW increased by 40% and from 2008 to 2012 PSA tests in NSW increased by 49%(29).

Opposing this theory is that the number of males treated with radiotherapy for prostate cancer increased only gradually from 2008 to 2012 as per RMIS(27, 30). i.e. from 2008 to 2010 prostate treatments in NSW increased by 6% and from 2008 to 2012 prostate treatments increased in NSW by 9%(26, 27, 30).

Therefore the statistical method used to test significance would not have resulted in a misleading p value.

Another explanation for the increase is that as some males diagnosed with prostate cancer can elect to have active surveillance, they may have waited until a local service was established before having radiation therapy. This theory, however is unsupported by the literature. For example a large USA study found rural men did take advantage of all prostate treatment options (brachytherapy, prostatectomy, radiation or active surveillance) and their treatment decision was not necessarily based on access(31).

Therefore the reason for the significant increase is not known; most likely it is a combination of factors, such as physician referral, PSA tests prescribed, treatment options and improved access. The result does justify further research such as a follow-up study to ascertain if the increase was a one off or if the new service did significantly impact on the numbers of males accessing radiotherapy in WNSWLHD.

Female treatments increased marginally (280 to 294 in 2012) and as expected the number of breast cancers treated increased only slightly (136 to 146 in 2012). This shows there has been no impact on the number of females accessing radiotherapy since the new service.

AGE

Many of the studies found in the literature demonstrated that elderly populations are less likely to have radiation therapy than the general population. One of the main reasons for this was difficulty accessing transport, which is why it was hypothesised that mean age would significantly increase[14, 17].

This hypothesis was disproved because the mean difference was 1.2 years and was not significant (p=0.09). The age categories were also analysed and although the 80+ year had the lowest p value of the age categories, it was also not significant (p=0.07).

CANCER TYPE:

Overall there was minimal change in the types of cancers treated between 2010 and 2012. Cancer type was categorised into Cancer Institute NSW clinical groupings as cancer type groups became too small to report and risked patient confidentiality.

The five most common clinical groupings treated were; breast, urogenital, respiratory, skin, and colorectal and five most common cancer types were; breast, prostate, lung, skin and rectum. This does not match the top five cancers treated with radiotherapy in NSW, which are breast, prostate, lung, rectum and head and neck[27].

Respiratory, upper GI and lymphohaematopoietic clinical groups had the most significant increases with p values of 0.003, 0.008 and 0.01 respectively.

Upper GI and lymphohaematopoietic were small groups and therefore had wide confidence intervals which makes the result less reliable and potentially misleading.

The increase in respiratory cancers however is significant because group numbers were larger. The difference in the number treated between 2012 and 2010 was 19% (97 vs 66). Of the 31 new patients, 27 (87%) were palliative courses. The reason for this is unknown, but as this result accounts for only 1 year of operation, follow up study over consecutive years would give a more reliable result.

LIMITATIONS

There are several design and analytical limitations of this study. One limitation was the denominator estimations. Known prevalence of WNSWLHD by age, gender, clinical grouping and geographical region would have been preferred, but because the earliest prevalence data from the Cancer Institute NSW is from 2008, it was not practical to wait potentially another four years before analysing the results of this study.

To overcome this limitation the inclusion criteria of this study was matched very closely to the 2008, 2010 and 2012 ABS populations and 2008 known prevalence counts. Log linear regression would also have been a more reliable way to estimate prevalence than the method used, but the required skills and data needed to model the estimations is a level of analysis beyond what would be practicable for this study.

Despite this limitation, the radiotherapy utilisation rates calculated were very comparable to radiotherapy utilisation rates found in other studies. For example the most relevant, accurate and recent estimation currently in the literature is a 2004-2006 study that found the utilisation rate for NSW was 26%[14]. Our study found the radiotherapy utilisation rate for 2010 and 2012 was 29% and 33%, which verifies reliability in the results.

Another limitation was the missing information from three data sets that accounted for 8% of total treatment intent and 8% of total cancer type. As treatment site was provided in those particular data sets around half of what was missing could be coded. This resulted in 5% of total treatment intent missing and 4% of total cancer type. Despite this limitation the missing data was not found to impact on the results as tested by comparing p value using estimated treatment intent values and actual numbers.

No identifiable details were collected in order to protect the confidentiality of patients. Not having patient identifiable details did mean patients could not be tracked between treatment centres and therefore it was not known if the same patient was treated twice. This is another limitation of the study but was managed by calculating in a retreatment rate of 21% for radiotherapy utilisation rates and using prevalent cases instead of prevalent people in the denominator estimations.

The final limitation was the time span of the service evaluated. As the service's first linear accelerator only reached full capacity in 2012, a follow up study evaluating the change since a second linear accelerator has been established will strengthen the results of this study.

CONCLUSION

The first radiotherapy service in WNSWLHD has improved radiotherapy utilisation rates. In the first full year of operation, the number of radiotherapy treatments increased most significantly in the Orange region and particularly within 150km of the service. Expansion of the new service will increase capacity, but it is unlikely from the results that those past 300km will be affected. As there will be no closer radiation service for remote residents, more needs to be done to reduce the travel and accommodation costs if radiotherapy utilisation is to be improved for this group. Males, palliative patients from the Orange region and patients with a respiratory cancer, were other groups that increased significantly in 2012.

RECOMMENDATIONS

1. As the capacity of one linear accelerator is limiting the number of patients treated locally, it is recommend that WNSWLHD, NSW Health and Federal Health continue to support the second linear accelerator, in terms of resources and staffing. This is to enable the two linear accelerators to reach full capacity and reduce the number of WNSWLHD patients referred to Sydney for non-complex megavoltage radiotherapy.
2. For those living in NSW and greater than 300km from a radiation centre, other strategies to increase the uptake of radiotherapy need to be strengthened. Evidence from other studies shows one practical solution would be to increase IPTAAS and subsidise 100% of travel and accommodation costs.
3. Evaluation of radiotherapy utilisation in WNSWLHD should be reviewed once the second linear accelerator reaches full capacity.

REFERENCES

1. NSW Health. Radiotherapy Services in NSW: Stategic Plan to 2016. Statewide Service Plan.No 7. North Sydney: NSW Department of Health, 2010.

2. NSW Health. Factors that impact on referral rates for radiotherapy. Planning Document. North Sydney: Statewide and Rural Health Services and Capital Planning Branch, 2011.

3. Western NSW Local Health District. Western NSW Local Health District Cancer Plan 2013- 2018. Dubbo: WNSWLHD; 2012.

4. Western NSW Local Health District and Western NSW Medicare Local. Western NSW Health Needs Assessment 2013. Dubbo: WNSWLHD & ML; 2013.

5. Commonwealth Department of Health and Ageing and Victorian Department of Human Services. Establishing radiation oncology in regional areas: Experiences of the national radiotherapy single machine unit trial and other regional radiation oncology models. Canberra: Australian Government Department of Health, 2010.

6. Nieder C, Norum J, Spanne O, Bilberg I, Vagstad G, Dalhaug A. Does distance to treatment centre influence the rate of palliative radiotherapy in adult cancer patients? Anticancer Research. 2009;29(7):2641-4.

7. Mercuri A, Susannah K. Needs of cancer patients treated in rural and urban cancer departments. The Radiographer. 2005;52(3):21-5.

8. Martin-McDonald K, Rogers-Clark C, Hegney D, McCarthy A, Pearce S. Experiences of regional and rural people with cancer being treated with radiotherapy in a metropolitan centre. International Journal of Nursing Practice. 2003;9:176-82.

9. Koning CC, Aarts MJ, Struikmans H, Poortmans PM, Lybeert ML, Jobsen JJ, et al. Mapping use of radiotherapy for patients with non-small cell lung cancer in the Netherlands between 1997 and 2008. Clinical Oncology. 2012;24(2):46-53.

10. Roder D, Zorbas H, Kollias J, Pyke C, Walters D, Campbell I, et al. Risk factors for poorer breast cancer outcomes in residents of remote areas of Australia. Asian Pacific Journal of Cancer Prevention. 2013;14(1):547-52.

11. Khor R, Bressel M, Hun Tai K, Ball D, Duchesne G, Rose W, et al. Patterns of retreatment with radiotherapy in a large academic centre. Journal of Medical Imaging and Radiation Oncology. 2013;57(5):610-6.

12. Lavergne R, Johnston G, Gao J, Dummer T, Rheaume D. Variation in the use of palliative radiotherapy at end of life: Examining demographic, clinical, health service, and geographic factors in a population based study. Palliative Medicine. 2011;25(2):101-10.

13. Schroen AT, Brenin DR, Kelly MD, Knaus WA, Slingluff CL. Impact of patient distance to radiation therapy on mastectomy use in early- stage breast cancer patients. Journal of Clinical Oncology. 2005;23(28):7074-80.

14. Gabriel G, Barton M.B., Delayney G.P. Radiotherapy Utilisation in NSW and ACT 2004-2006: A data linkage and GIS experience. Collaboration for Cancer Outcome, Research and Evaluation (CCORE), Ingham Institute, Liverpool Hospital, Sydney Australia. RANZCR 2013.

15. NSW Health. Isolated Patient Travel and Accommodation Assistance Scheme 2014 [updated 2014, May 13; cited 2014 June10]. Available from: http://www.health.nsw.gov.au/transport/Pages/iptaas.aspx.

16. Emery JD, Walter FM, Gray V, Sinclair C, Howting D, Bulsara M, et al. Diagnosing cancer in the bush: a mixed- methods study of symptom appraisal and help- seeking behaviour in people with cancer from rural Western Australia. Family Practice. 2013;30(5):541-50.

17. Gillan C, Briggs K, Goytisolo Pazos A, Maurus M, Harnett N, Catton P, et al. Barriers to accessing radiation therapy in Canada: a systematic review. Radiation Oncology. 2012;7(1):167-74.

18. Rodger A. Radiotherapy services beyond the major metropolitan areas: a debate. Cancer Forum. 2002;26(3):1-3.

19. Denham JW. How do we bring an acceptable level of radotherapy services to a dispersed population? Radiation Oncology. 1995;39(2):171-3.

20. Roberts G, Dunscombe P, Samant R. Geographic delivery models for radiotherapy services. Australasian Radiology. 2002;46(3):290-4.

21. Chapman A, Shakespeare T, Turner M. Improving acess to radiotherapy for regional cancer patients- the national radiotherapy single machine unit trial. Cancer Forum. 2007;31(2):1-3.

22. Shakespeare T, Turner M, Chapman A. Is rural radiation oncology practice quality as good as the big smoke? Results of the Australian radiotherapy single machine unit trial. Australasian Radiology. 2007;51(4):381-5.

23. Australian Bureau of Satistics. Population by Age and Sex, Regions of Australia, 2012 [updated 2013, August 29; cited 2014, March 10]. ABS Cat no. 3235.0. Available from: http://www.abs.gov.au

24. Australian Bureau of Satistics. 2006 Census Age by Sex [single years].2007 [cited 2014, March 10]. Available from: https://www.censusdata.abs.gov.au.

25. Australian Bureau of Satistics. 2011 Census Age by Sex [single years]. 2012 [cited 2014, March 10]. Available from: https://www.censusdata.abs.gov.au.

26. NSW Health. 2010 Radiotherapy Management Information System Report. Sydney: NSW Department of Health, 2011.

27. NSW Health. 2012 Radiotherapy Management Information System Report. Sydney: NSW Department of Health, 2013.

28. Barton MJ, Susannah; Shafiq, Jesmin; Wong, Karen Hsin Wen; Thompson, Stephen; Delayney, Geoff; Hanna, Timothy. Review of Optimal Radiotherapy Utilisation Rates. Collaboration for Cancer Outcomes, Research and Evaluation (CCORE); Ingham Institute, Liverpool Hospital Sydney, Australia, 2013.

29. Australian Institute of Health and Welfare. Prostate cancer in Australia.Cancer Series 79. Cat no CAN 76. Canberra: AIHW, 2013.

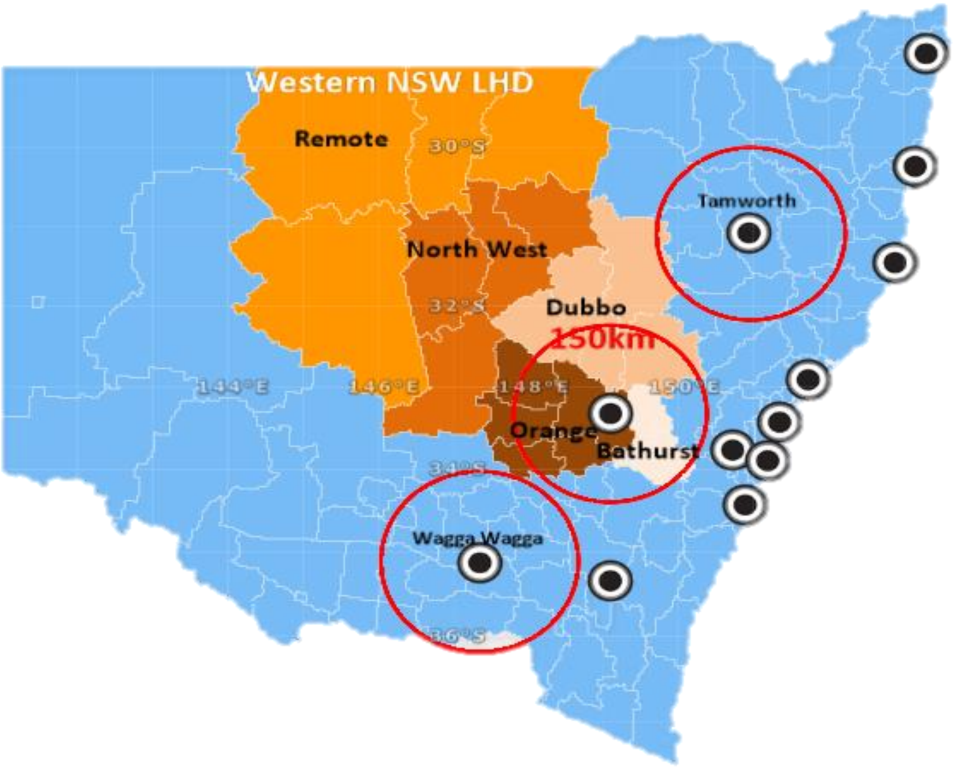
30. Department of Human Services. Medicare Australia Statistics: Medicare Item Reports: Australian Government; 2014 [cited 2014, June 5]. Available from: http://www.medicareaustralia.gov.au/statistics/mbs_item.shtml.

31. NSW Health. 2008 Radiotherapy Management Information System Report. Sydney: NSW Department of Health, 2009.

32. Baldwin L-M, Andrilla H, Porter M, Rosenblatt R, Patel S, Doescher M. Treatment of early- stage prostate cancer among rural and urban patients. Cancer. 2013;119(16):3067-75.

APPENDICES

APPENDIX 1: MAP OF REGIONAL RADIOTHERAPY CENTRES



APPENDIX 2: TERMS USED TO CODE DATA

TREATMENT INTENT

Palliative: Palliative

Curative: Definitive, Adjuvant, Prophylactic, Curative, Radical, Primary

Table 13: Coding treatment intent when treatment site sole information

If treated site:	Then coded:	% of data coded using this method:
T spine	Palliative	
L spine	Palliative	
WBRT	Palliative	
L spine + sacrum	Palliative	
S Pine + SIJ	Palliative	
C spine	Palliative	
LT ch met	Palliative	
		Total: 3.7%
Post HDR prostate	Curative	
Prostate IMRT	Curative	
Bladder pH1	Curative	
		Total: 1.6%

RESIDENTIAL LOCATION

Residential Location was the patient's residential town/suburb. If there was no town available, but there was a postcode recorded then the town with the largest population from the postcode provided was entered. Travelling distances were then estimated from the new town entered.

45/1240 of entries used this method (3.6%).

CANCER TYPE

Table 14: Coding cancer type when Treatment Site sole information

If treated site:	Then coded:	% of data coded using this method:
Ph1 Prostate	Prostate	
Prostate	Prostate	
Post HR Prostate	Prostate	
Prostate IMRT	Prostate	
		Total: 12.6%
RT Breast	Breast	
LT Breast	Breast	
		Total: 3.1%
Bladder	Bladder	
		Total: 7.7%
Anus Ph1	Rectum	
		Total: 1.5%

Table 15: Coding cancer type when ICD code sole information

Clinical Grouping	**Cancer Type**	**ICD code**
Skin	Melanoma	C43.0 - C43.9
	Skin	C44.0- C44.9
Head and Neck	Lip	C00- C00.9
	Tongue	C01- C02.9
	Mouth	C03- C06.9
	Salivary Glands	C07- C08.9
	Tonsil	C09- C09.9
	Oropharynx	C10- C10.9
	Nasopharynx	C11- C11.9
	Hypopharynx	C12- C13.9
	Nose	C30.0
	Ear	C30.1
	Sinus	C31- C31.9
	Larynx	C32- C32.9
	Eye	C69- C69.9
Upper GI	Oesophagus	C15- C15.9

	Stomach	C16- C16.9
	Small Intestine	C17- C17.9
	Liver	C22- C22.9
	Gallbladder	C23- C24.9
	Pancreas	C25- C25.9
	Gastrointestinal	C26- C26.9
Colorectal	Colon	C18- C18.9
	Rectum	C19- C20
	Anus	C21- C21.8
Respiratory	Lung	C33- C34
	Thymus	C37
Bone and Connective Tissue	Bone	C40- C41.9
	Connective Tissue	C47- C49.9
Breast	Breast	C50- C50.9,
		D05.0- D05.9
Gynaecological	Cervix	C53- C53.9
	Endometrium	C54.1
	Ovary	C56
	Uterine	C55
	Vagina	C52
	Vulva	C51- C51.9
Urogenital	Prostate	C61
	Testis	C62- C62.9
	Ureter	C66
	Urethra	C68.0
	Renal	C65
	Kidney	C64
	Bladder	C67- C67.9
Neurological	Meninges	C70- C70.9
	Brain	C71- C71.9
	Cranial Nerve	C72- C72.9
Endocrine	Thyroid	C73
	Pituitary	C75.1
	Adrenal Gland	C74- C74.9
Lymphohaematopoietic	Chronic Myeloproliferative	D47.1
	Leukaemia	C90.1- C95.91
	Lymphoma	C81- C85.9
	Multiple Myeloma	C88- C90.01
Ill-defined and Unknown	Unspecified Site	C76- C76.8
	Unknown Primary	C80

APPENDIX 3: TREATMENT INTENT ESTIMATIONS:

Table 16: 2010 treatment intent estimations

2010	Intent	new course +retreatment (From RMIS)	% of total	collected data	n missing (E) x D	E+G= New Estimation
A	B	C	D	E	G	H
Treatment Centre A	Curative	593	73.66%	3	5.893168	9
	Palliative	212	26.34%	2	2.106832	4
	Missing			8		
	Total	805	100%	13		13
Treatment Centre B	Curative	25	58.14%	3	2.325581	5
	Palliative	18	41.86%	6	1.674419	8
	Missing			4		
	Total	43	100%	13		13
Treatment Centre C	Curative	299	67.19%	6	33.59551	40
	Palliative	146	32.81%	10	16.40449	26
	Missing			50		
	Total	445	100%	66		66

Table 17: 2012 treatment intent estimations

2012	Intent	new course +retreatment (From RMIS)	% of total	collected data	n missing (E) x D	E+G= New Estimation
A	B	C	D	E	G	H
Treatment Centre A	Curative	550	70.69%	2	1.413882	3
	Palliative	228	29.31%	3	0.586118	4
	Missing			2		
	Total	778		7		7
Treatment Centre B	Curative	210	84.34%	6	0	6
	Palliative	39	15.66%	1	0	1
	Missing			0		
	Total	249		7		7
Treatment Centre C	Curative	325	67.71%	23	1.354167	24
	Palliative	155	32.81%	10	0.65618	11
	Missing			2		
	Total	480		35		35

APPENDIX 4: ETHICS APPROVAL

Table 18: Human Research Ethics Committee approvals

Human Research Ethics Committee (HREC):	**Sites approved:**	**Date of Approval:**	**Reference:**
Greater Western	Public RT Centres in NSW	7/12/12	LNR/12/GWAHS/92
ACT Health	CRCS	28/11/12	ETHLR.12.286
RCCC	RCCC	6/3/13	
Macquarie University	MUH-Genesis Care	10/7/13	5201300437
St Vincent's Hospital	Mater, STV-Genesis Care	9/7/13	LNR/12/GWAHS/92: Ethically Ratified

Table 18: Research Governance Approvals

Research Governance Approval:	**Radiotherapy Treatment Centre:**	**Date of Approval:**	**Reference:**
Greater Western LHD	CWCS	9/1/13	LNRSSA/13/GWAHS/3
South Eastern Sydney LHD	SGCCC and POWH	7/2/13	13/G/033
Illawarra Shoalhaven LHD	ICCC	8/2/13	DT13/6704
Hunter New England LHD	CMN	1/2/13	
Western Sydney LHD	CPMCC	4/2/13	Access/13/WMEAD/1
St Vincent's LHD	SVH (public)	8/3/13	13/040
Sydney LHD	RPAH	19/3/13	X13-0082
Mid North Coast LHD	NCCI (PM, CH, Lis)	12/3/13	
Nepean Blue Mountains LHD	NCCC	13/3/13	Access/13/Nepean/1
South Western Sydney LHD	LCTC and MCTC	15/3/13	LNRSSA/13/LPOOL/43
Northern Sydney LHD	RNSH	10/5/13	1303-088M

Table 19: Site Specific Approval

Site Approval:	**Radiotherapy Treatment Centre:**	**Date of Approval:**	
Radiation Oncology Institute	ROI (Gos, Wah)	24/1/13	