

Strategic investment in MRI Simulators for radiotherapy services in Scotland

What were we asked to look at?

The National Radiotherapy Technical, Specification and Evaluation Group (TSE) approached SHTG to provide analytic support as part of a strategic proposal to introduce magnetic resonance imaging (MRI) Simulators onto the radiotherapy capital equipment replacement programme.

Why is this important?

Rising incidence rates of cancer, alongside an ongoing desire for improvements in treatment outcomes, means that the demand for MRI planned radiotherapy cannot be met with existing service provision. The introduction of MRI simulators in NHS Scotland will help to meet the demand for MRI, whilst enhancing radiotherapy service provision and supporting the implementation of national and local strategies.

What was our approach?

SHTG conducted a demand analysis to quantify the projected increase in MRI planned radiotherapy and a budget impact analysis of introducing MRI simulators at the five Scottish radiotherapy centres.

Beyond being reviewed as part of the TSE's strategic proposal, this work has not been formally peer reviewed.

What next?

The strategic investment plan for MRI Simulators will be presented to Scottish Government and other key stakeholders.

Key findings

- At current service levels, an estimated 3,124 MRI planned courses can be provided in 2020 rising to 3,846 treatment courses by 2029. The anticipated demand for MRI guided radiotherapy is an estimated 11,016 treatment courses in 2020, rising to 13,281 courses by 2029.
- A more conservative scenario was presented whereby the application of MRI was targeted to anatomical sites most expected to benefit from MRI planning. In this scenario, demand is estimated to be 5,984 courses in 2020, rising to 6,867 courses by 2029.
- The overall amount required to fund an MRI simulator service across Scotland (one MRI simulator per radiotherapy delivery centre) is expected to be £10 million for the first year and £35 million over a 10-year period.

Contents

Introduction	3
Health technology description.....	3
MRI Demand analysis.....	4
Budget Impact analysis	9
Conclusion.....	9
Equality and diversity.....	11
Acknowledgements.....	11
References	12

Introduction

The provision of radiotherapy treatment is an established service delivered from five centres in Scotland. The centres are located in Inverness, Aberdeen, Dundee, Edinburgh and Glasgow, with a Satellite Centre at Monklands Hospital (managed by NHS GG&C). A Scottish Government funded equipment replacement programme (CERP) has been in place since 1999. CERP plan caters for the ongoing replacement of treatment-related equipment and systems at the five centres (Linear Accelerators, Simulators, Brachytherapy equipment, Treatment Planning Systems, Record and Verify systems and other ancillary equipment).

The National Radiotherapy Technical, Specification and Evaluation Group (TSE) have developed a strategic investment plan for magnetic resonance imaging (MRI) simulators in NHS Scotland. A key objective of the plan is to inform stakeholders how the introduction of MRI simulators will help to meet the projected demand in access to MR imaging for the radiotherapy treatment planning of oncology patients, and improve the design of individualised radiotherapy treatment plans. Introduction of the MRI simulators aligns with the delivery of NHS Scotland's 'Route Map to the 2020 Vision for Health and Social Care',¹ alongside progressing the 'Detect Cancer Early' programme, the 'Better Cancer Care' action plan² and the 'Health Care Quality Strategy'.³

Following a request from TSE for analytical support, SHTG conducted a demand analysis to quantify the projected increase in MRI planned radiotherapy and a budget impact analysis of introducing MRI simulators at the five Scottish radiotherapy centres.

Health technology description

The design of an individualised treatment plan for a radiotherapy patient requires the acquisition of a three or four-dimensional image of the patient's anatomy, normally using a type of computed tomography (CT) scanner known as a "CT simulator". The CT image sets provide information on the density of the tissues and thus permits calculation of radiation dose. The CT image sets are used to locate the tumour and the organs at risk of radiation damage. The CT scan must be obtained with the patient in their treatment position, so that the 'treatment set-up' can be reproduced reliably and accurately at each subsequent treatment appointment.

MRI simulators are specialised devices designed specifically for radiotherapy treatment planning, and provide better delineation of target tissues and organs at risk. MRI simulators have a larger bore size, which allow for adequate positioning of patients rather than the narrow bores used by conventional MRI scanners. They may however, still be used for 'standard' diagnostic MRI imaging.

MRI may be used in combination with CT scans for treatment planning. MRI provides soft-tissue detail that is simply indiscernible on a CT scan and the combined imaging provides far better delineation of target tissues and organs-at-risk. MRI can provide both anatomical and functional information for radiotherapy treatment planning as well as quantitative information to assess tumour response for adaptive treatment.

There is high demand for MRI imaging across Scottish Health Boards, yet only a small proportion of patients receive an MRI scan as part of their radiotherapy treatment planning, primarily due to difficulties in accessing MRI facilities. To avoid treatment delays, reliance is placed on CT scanning which is considered sub-optimal to MRI in both target volume definition and anatomic identification of organs at risk, for many tumour sites^{4,5}.

The development of MRI simulators has been very rapid and, in some types of treatment, it is now possible to entirely replace CT imaging with MRI, an approach known as MRI-only treatment planning. There is greater potential for dose escalation and more effective local tumour control through MRI planning.⁵ The additional capabilities of MRI simulators present an opportunity and potentially improving clinical outcomes whilst reducing the impact of side effects arising from radiotherapy and brachytherapy, which in turn, could minimise re-admissions, follow-up clinic appointments, diagnostic interventions and endoscopies.

MRI simulators are now widely available in many European and North American radiotherapy facilities and the number of UK centres with this technology is growing. Indeed, the Northern Centre for Cancer Care in Newcastle is a long-time user of this technology and they have scanned over 10,000 patients on their MRI simulator (personal communication – TSE group members). In acknowledgement of the growing routine use of these devices, professional organisations such as the American Association of Physicists in Medicine are now developing guidance on the “clinical implementation, optimisation and quality assurance of MRI simulators” (AAPM Task Group 284).

MRI Demand analysis

Data from a review of radiotherapy treatment plans in NHS Grampian for a 12-month period (FY 2018-19) was used as the basis for estimating future demand for MRI simulation across the five centres in Scotland. Aggregate data for NHS Grampian is presented in Table 1.

The data show that diagnostic MRI scans were used in combination with CT scans for 341 treatment plans out of a total of 1,202 computerised plans (28%). An analysis of the treatment workload by a clinical oncologist indicated that as many as 682 plans would have benefited from the use of MRI (57% of total computerised plans) – meaning MRI was used in only around half of the computerised treatment plans that could have benefitted from its application. Further, MRI could potentially have been used in 311 of the 548 (56.7%) non-computer (i.e. virtual) planned courses.

In total, it was estimated that 1,092 virtual and computer planned courses could have benefited from the use of MRI. This would be the equivalent of approximately 1011 patients benefiting from the use of an MRI simulator. There is therefore significant unmet need amongst this patient population that could be alleviated through MRI simulator service provision.

Table 1: Summary data of radiotherapy treatment plans for NHS Grampian

NHS Grampian (2018/19)	
Total treatment courses	1750
<i>Computer planned courses</i>	1202
<i>Virtual simulations</i>	548
Computer MRI eligible (56.7%)	682
<i>Computer MRI received (28%)</i>	341
Estimated virtual MRI eligible (56.7%)	311
Total potential MRI planned courses (incl 10% rescan)[∞]	1092
Total potential MRI patients (incl 7.4% getting >1 course)	1011
Breakdown by tumour site*	
<i>Central Nervous System - malignant & benign</i>	70
<i>Head & Neck - including lymphoma & plasmocytoma</i>	127
<i>Gynaecologic (Endometrial, Cervix, etc)</i>	40
<i>Gastro-Urinary (prostate, bladder, renal)</i>	234
<i>Bowel (Rectal, Anal)</i>	143
<i>Sarcoma</i>	9
<i>Oligometastatic (Nodes, bone mets, etc)</i>	16
Select anatomical site total (computer planned courses only)	639

[∞] Computer MRI eligible + virtual MRI eligible + rescan

* Subset of total computer MRI eligible treatment plans. Selected sites are those considered to benefit most from MRI simulation.

Similar data could not be obtained from other health boards in time for this assessment. The parameters outlined in Table 1 were extrapolated for NHS Scotland by scaling the Grampian data relative to the size of the treatment centres. Centre size was defined in terms of the proportion of overall treatment courses in Scotland being delivered at individual centres. Based on 2015/16 totals, the distribution was 47% for NHS GGC, 26% for NHS Lothian, 11% for NHS Grampian, 9% for NHS Tayside and 7% for NHS Highland.

Projected demand for radiotherapy and MRI planning is presented in Table 2. These figures include an annual increase of 2.10% for all treatment courses and treatment specific site incidence rates varying between 0.10% - 2.54% (Personal communication – ISD).

The analysis shows that based on current provision, an estimated 3,124 MRI planned courses could be achieved in FY 2020 rising to 3,846 treatment courses by FY 2029. This is well below the estimated 11,016 courses that could benefit from MRI planning in FY 2020, rising to 13,281 courses in FY 2029. As the demand for MRI will always outstrip supply, a more realistic scenario would be more targeted application of MRI planning to those anatomical sites expected to have greatest benefit. Demand for these sites is estimated to be 5,984 courses in FY 2020, rising to 6,867 courses by FY 2029.

These projections are, however, subject to some uncertainty due to extrapolation from limited data (i.e. availability of data from only one out of five treatment centres). Additionally, whether a patient is suitable for MRI is based on clinical opinion, therefore the size of the MRI eligible patient sub-group may not necessarily be accurate as opinions may vary amongst clinicians.

Table 2: Estimated demand for MRI treatment planning across NHS Scotland

NHS Scotland – projected 10-year demand for Radiotherapy										
	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30
Total treatment courses	17662	18033	18412	18798	19193	19596	20007	20428	20857	21295
<i>Computer planned courses</i>	<i>11391</i>	<i>11630</i>	<i>11874</i>	<i>12124</i>	<i>12378</i>	<i>12638</i>	<i>12904</i>	<i>13175</i>	<i>13451</i>	<i>13734</i>
<i>Virtual simulations</i>	<i>6271</i>	<i>6403</i>	<i>6537</i>	<i>6674</i>	<i>6814</i>	<i>6958</i>	<i>7104</i>	<i>7253</i>	<i>7405</i>	<i>7561</i>
Computer MRI eligible	6459	6594	6733	6874	7019	7166	7316	7470	7627	7787
<i>Computer MRI received (current provision)</i>	<i>3124</i>	<i>3256</i>	<i>3325</i>	<i>3395</i>	<i>3466</i>	<i>3539</i>	<i>3613</i>	<i>3689</i>	<i>3766</i>	<i>3846</i>
<i>Excess MRI demand</i>	<i>3335</i>	<i>3338</i>	<i>3408</i>	<i>3479</i>	<i>3553</i>	<i>3627</i>	<i>3703</i>	<i>3781</i>	<i>3861</i>	<i>3941</i>
Estimated Virtual MRI eligible	3556	3630	3706	3784	3864	3945	4028	4112	4199	4287
Total potential MRI planned courses (incl 10% rescan)[∞]	11016	11247	11483	11724	11971	12222	12479	12741	13008	13281
Total potential MRI patients (incl 7.4% getting >1 course)	10198	10412	10631	10854	11082	11315	11553	11795	12043	12296

Breakdown by tumour site*	Annual increase	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30
<i>Central Nervous System - malignant & benign</i>	0.78%	646	651	656	662	667	672	677	682	688	693
<i>Head & Neck - including lymphoma & plasmocytoma</i>	1.64%	1193	1212	1232	1252	1273	1294	1315	1337	1358	1381
<i>Gynaecologic (Endometrial, Cervix, etc)</i>	1.72%	376	383	389	396	403	410	417	424	431	439
<i>Gastro-Urinary (prostate, bladder, renal)</i>	2.54%	2237	2294	2352	2412	2473	2536	2600	2666	2734	2803
<i>Bowel (Rectal, Anal)</i>	0.15%	1304	1306	1308	1310	1312	1314	1316	1318	1320	1322
<i>Sarcoma</i>	0.10%	82	82	82	82	82	82	82	83	83	83
<i>Oligometastatic (Nodes, bone mets, etc)</i>	0.10%	146	146	146	146	146	146	147	147	147	147
Select anatomical site total (computer planned courses only)		5984	6074	6166	6260	6356	6454	6554	6656	6760	6867

∞ Computer MRI eligible + virtual MRI eligible + rescans

* Subset of total computer MRI eligible treatment plans. Selected sites are those considered to benefit most from MRI simulation.

Budget Impact analysis

The TSE strategic investment plan outlines the installation of one MRI simulator at each of the five treatment centers across Scotland. The budget impact analysis here includes both capital expenses as well as revenue costs associated with staffing and operational resources.

Quotes for capital expenses were obtained from suppliers wherever possible. Estimates for non-pay revenue costs and working time equivalent needs for staffing the service were provided by members of the TSE group. Wages were calculated at NHS Scotland 2020/21 rates at the midpoint of respective banding and included the 24% uplift for employer contribution towards pension.

Results are presented in Table 3. Capital expenditure for MRI simulators is expected to be £8 million. Total revenue costs for running an MRI simulator service would be approximately £2.35 million in year 1 and a cumulative cost of £24.65 million over a 10-year period. The net budget impact to the service would be approximately £10.35 million in year 1 and approximately £35 million over a 10-year period.

Conclusion

Increasing incidence rates of cancer, alongside an ongoing desire for improvements in treatment outcomes, means that the demand for MRI planned radiotherapy cannot be met with existing service provision. The introduction of MRI simulators in NHS Scotland will help to meet the demand for MRI, whilst enhancing radiotherapy service provision and supporting the implementation of national and local strategies.

The overall amount required to fund an MRI simulator service across Scotland is expected to be £10.35 million for the first year and £35 million over a 10-year period.

Table 3: MRI Simulator Budget impact

Staffing Costs	Annual wage	Total WTE	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10
Radiography Therapist B7	40894	9	441,164	891,152	1,350,140	1,818,307	2,295,838	4,830,628
Radiography Therapist B6	33305	9	359,294	725,775	1,099,584	1,480,870	1,869,782	3,934,173
Physicist B8a	49480	5	306,776	619,688	938,857	1,264,410	1,596,475	3,359,112
Band 4	24,973	1	24,773	50,042	75,816	102,105	128,921	271,260
Admin B3	22,594	4	112,066	226,374	342,968	461,893	583,197	1,227,094
Cleaning B2	20,606	0.1	2,555	5,161	7,820	10,531	13,297	27,978
Cumulative Staffing			1,246,629	2,518,191	3,815,185	5,138,118	6,487,510	13,650,244
Non pay revenue	per year		Year 1	Year 2	Year 3	Year 4	Year 5	Year 10
Service & Maintenance	75,000		375,000	750,000	1,125,000	1,500,000	1,875,000	3,750,000
Electricity	20,000		100,000	200,000	300,000	400,000	500,000	1,000,000
PACS Storage	2,500		12,500	25,000	37,500	50,000	62,500	125,000
Laundry	2,500		12,500	25,000	37,500	50,000	62,500	125,000
Depreciation	120,000		600,000	1,200,000	1,800,000	2,400,000	3,000,000	6,000,000
Cumulative non-pay			1,100,000	2,200,000	3,300,000	4,400,000	5,500,000	11,000,000
Total Revenue			2,346,629	4,718,191	7,115,185	9,538,118	11,987,510	24,650,244
Capital Expense			Total Capital	Capital expenses not recurring				
MR Simulator	1,000,000		5,000,000					
Building works	300,000		1,500,000					
Accessories QA	150,000		750,000					
IT, commission and set-up	50,000		250,000					
Contingency (10%)	100,000		500,000					
Total Capital Costs			8,000,000					
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 10
Total MR SIM Scale up			10,346,629	15,064,821	17,461,814	19,884,747	22,334,139	34,996,874

Equality and diversity

Healthcare Improvement Scotland is committed to equality and diversity in respect of the nine equality groups defined by age, disability, gender reassignment, marriage and civil partnership, pregnancy and maternity, race, religion, sex, and sexual orientation.

The process for producing evidence syntheses has been assessed and no adverse impact across any of these groups is expected. The completed equality and diversity checklist is available on www.healthcareimprovementscotland.org

Acknowledgements

Healthcare Improvement Scotland development team

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