Technologies
scoping report

In response to an enquiry from the Scottish Government Health and Social Care Directorates

Number 7 June 2012

In radiotherapy for cancer, what are the patient safety benefits and resource implications of the various in vivo methods of dosimetry to check received radiation dose, compared with pretreatment verification only?

What is a scoping report?

Scoping reports ascertain the quantity and quality of the published clinical and cost effectiveness evidence on health technologies under consideration by decision makers within NHSScotland. They also serve to clarify definitions related to the research question(s) on that topic. They are intended to provide an overview of the evidence base, including gaps and uncertainties, and inform decisions on the feasibility of producing an evidence review product on the topic. Scoping reports are undertaken in an approximately 1 month period. They are based upon a high level literature search and selection of the best evidence that Healthcare Improvement Scotland could identify within the time available. The reports are subject to peer review but do not undergo external consultation. Scoping reports do not make recommendations for NHSScotland. Further information on scoping reports is available at www.healthcareimprovementscotland.org.

Key definitions

In vivo dosimetry: measurement of actual radiation dose delivered to the patient

Pretreatment verification: independent check of treatment plans before radiotherapy

Background

The effectiveness and safety of radiotherapy requires accurate dose delivery. A key recommendation from the British Institute of Radiology report Towards Safer Radiotherapy from 2008 was that in vivo dosimetry should be routinely used at the beginning of treatment for most radiotherapy patients. This allows errors detected at an early stage of treatment to be corrected in later fractions, so that the overall dose is as prescribed.

There are different methods of in vivo dosimetry that apply to different radiotherapy techniques. In conventional radiotherapy techniques, where radiation beams are directed at the centre of a tumour, single-point detectors are placed on the patient’s skin at the point of entry or exit. The three types of single-point detectors commonly used are diodes, thermoluminescent dosimeters (TLD) and metal oxide semiconductor field effect transistors (MOSFETs). MOSFETs are not considered further in this scoping report, as this type of single use detector is no longer being manufactured.

In the newer radiotherapy modalities of intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT), radiation is directed from several angles to more precisely target the shape of a tumour. The method of in vivo dosimetry which can be used in these types of radiotherapy is transit or exit dosimetry using an electronic portal imaging device (EPID). This requires complete computed tomography (CT) scan-based planning information and sophisticated software for dose estimation and analysis.

In Scotland, there are five cancer centres delivering radiotherapy: the Western General Hospital (Edinburgh), the Beatson Oncology Centre (Glasgow), Aberdeen Royal Infirmary, Ninewells Hospital (Dundee), and Raigmore Hospital (Inverness). All centres undertake conventional radiotherapy, but not all currently offer IMRT or VMAT. In 2009, the centres were in various stages of research and commissioning of in vivo dosimetry for certain cancer sites (Scottish Radiotherapy Advisory Group (SRAG) 09/43a). However, reductions in health service budgets have limited progress on implementation, and prompted further assessment of the risks and benefits of this technology.

No data are centrally held in Scotland to quantify the problem of radiation overdoses or underdoses in radiotherapy, nor to monitor the impact of in vivo dosimetry.

Previous scoping work on this topic by NHS Quality Improvement Scotland in 2010 concluded that there was insufficient published evidence to produce an evidence note.

The following questions were scoped:

1. In radiotherapy for cancer, what are the patient safety benefits and resource implications of the various in vivo methods of dosimetry to check received radiation dose, compared with pretreatment verification only?

2. In radiotherapy for cancer, what are the patient safety risks and resource savings of performing in vivo dosimetry on 10% of patients rather than 100%?

3. In radiotherapy for cancer, when there is no in vivo dosimetry, what are the patient safety risks and resource savings of performing pretreatment verification on 10% of patients rather than 100%?

Literature search

A systematic search of the secondary and primary literature was carried out between 12–15 December 2011. Key resources were searched for policy documents, reviews, clinical summaries, economic studies and ongoing trials. Websites of professional bodies relating to medical physics, radiotherapy and oncology were also searched. Medline, Medline in process, Embase and CENTRAL were searched for primary literature. All searches were limited to items published since 2001 and written in English. A full list of resources searched and primary literature search strategies are available on request.

Evidence base

Table 1 Included evidence sources

<table>
<thead>
<tr>
<th>Publication Type</th>
<th>Number of Publications</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case series</td>
<td>7</td>
<td>3-10</td>
</tr>
<tr>
<td>Cost studies</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Opinion</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>

Findings

1. In radiotherapy for cancer, what are the patient safety benefits and resource implications of the various in vivo methods of dosimetry to check received radiation dose, compared with pretreatment verification only?

The literature search yielded a large volume of information on the technical aspects of in vivo dosimetry, but very little quantifying its benefits. No comparative evidence was found on patient outcomes related to radiation overdoses or underdoses. A number of primary studies were found which reported the deviation of the measured from the calculated radiation dose, or the number of measurements outside tolerance levels, for certain tumour sites.

Mans et al. reported in 2010 on 4,337 patients from the Netherlands Cancer Institute receiving IMRT for cancer of the prostate, rectum, head and neck, breast, lung or other sites9. In vivo EPID dosimetry identified 17 serious errors across all tumour sites. In seven cases, the errors were due to patient anatomy changes due to considerable weight loss, (recovery from) atelectasis, patient contour change, and emptying of a postoperative cavity that was filled during the planning CT. Four data transfer errors occurred due to system communication faults or human factors. In two cases, parameters were suboptimally tuned in the treatment planning system. Two treatment plans were accidently modified in the record and verify system. One treatment plan was dosimetrically undeliverable due to non-adherence to planning protocols. One delivery failure occurred when the linear accelerator failed to deliver one segment of a step-and-shoot IMRT beam. The authors concluded that nine of these errors would not have been detected with pretreatment verification only.

Venables et al. reported in 2004 on 429 patients from 33 United Kingdom (UK) hospitals receiving conventional radiotherapy for breast cancer in the Standardisation of Breast Radiotherapy (START) trial3. In vivo dosimetry was undertaken using TLDs and a composite entrance and exit dose recorded. The average ratio of dose measured to dose prescribed was 0.99 (standard deviation (SD) 0.04). Eight patients had initial measurements which differed from the prescribed dose by more than 10%. These were thought
to be due to a combination of high or low breast density and incorrect positioning of the patient or the TLD in seven cases. In the eighth case, an incorrect wedge factor was applied in the monitor unit calculation.

Strojnik reported on a Slovenian study from 2007 of 209 rectal cancer patients, in which diodes measured entrance and exit doses during four-field box radiotherapy. Mean differences from expected values were +0.9% (SD 2.1%; n=421) for entrance dose, and -0.5% (SD 3.3%; n=415) for exit dose. The mean absorbed dose in the isocentre differed from the treatment plan by +0.2% (SD 1.4%). Initial in vivo measurements exceeded tolerances of 5% for entrance doses or 8% for exit doses in six patients. Four of these were within tolerance limits on repeated measurement. Errors for the remaining two patients were due to an incorrect CT image set for one patient, and incomplete CT images due to obesity in the other. The authors concluded that in vivo dosimetry prevented two cases of inaccurate treatment; but noted that these errors could also have been detected by checking focus skin distance.

Appleyard et al. reported in 2003 and 2005 on a UK study of 578 cancer patients receiving conventional radiotherapy to the breast, head and neck, abdomen and pelvis, or intra-thoracically. Diodes were used to measure entrance doses. Mean deviations from expected dose were +1.15% (SD 3.04%; n=1,073) for breast; +0.35% (SD 2.20%; n=326) for head and neck; +0.52% (SD 2.75%; n=712) for abdomen and pelvis; and -0.01% (SD 2.75%; n=119) for intra-thoracic. Problems highlighted by in vivo dosimetry were a systematic error in breast positioning using an older technique, which was resolved when commercial breast positioning boards were introduced; and greater measurement uncertainty in relation to wedged fields for head and neck, and abdomen and pelvis radiotherapy, due to difficulty positioning the detector in fields with a high angle of incidence.

A Panamanian study from 2007 reported on 80 patients receiving isocentric box radiotherapy to the pelvis using an 18MV beam and a multileaf collimator. The Rizzotti-Leunen method was used to determine the dose at the isocentre based on entrance and exit measurements of each field using Isorad™ red semiconductor diodes (Sun Nuclear Corporation, Melbourne, FL). Differences between the expected and measured doses had a mean of -0.09% (SD 2.18%) at the entrance; 0.77% (SD 2.73%) at the exit; and -0.11% (SD 1.76%) at the isocentre.

Ten rhinopharynx or thyroid cancer patients receiving IMRT were included in a Danish study by Engström et al. in 2005. In vivo dosimetry was undertaken by inserting a naso-oesophageal tube containing TLDs. The ratio of measured to calculated dose was 1.002 (SD 0.051; n=177).

A UK study examining the resource implications of in vivo dosimetry was included as a commentary in the British Journal of Radiology in 2008. Capital costs for a diode dosimetry system (at September 2007, including VAT but excluding installation) were estimated at £6,000 per linear accelerator. Annual running costs on one linear accelerator were estimated at £18,882.

The feasibility of replacing pretreatment verification with in vivo EPID dosimetry was examined by McDermott and colleagues in a Dutch study from 2007 of 75 prostate cancer patients receiving IMRT. For each field separately, corresponding (gamma) pixel values from each fraction were sorted into ascending order. Information from the fractions was combined by using the 'low', which was defined as half way between the minimum and the median. A comparable level of accuracy with pretreatment verification was obtained by performing in vivo dosimetry during three fractions, which took 1 or 2 hours less time per patient plan.

Resource implications were examined by Malicki et al. in a Polish retrospective study from 2009 of 6,864 cancer patients receiving conventional radiotherapy to the head and neck, breast, pelvis or lung. The authors described technological advances between 2001 and 2005 in their institution's practice of in vivo dosimetry with semiconductor-type detectors to measure entrance dose. Statistically significant improvements in dose accuracy over the period were reported for all cancer sites. Mean deviations between measured and calculated doses decreased from -1.5% to +0.5% for head and neck; +3.4% to +1.4% for breast; +3.9% to +0.1% for pelvis; and -2.1% to +1.8% for lung. Monthly costs increased from €4,376 (equivalent to £3,700 in January 2012) to €10,696 (equivalent to £8,900 in January 2012) mainly...
due to increased staff numbers.

2. In radiotherapy for cancer, what are the patient safety risks and resource savings of performing in vivo dosimetry on 10% of patients rather than 100%?

No evidence was found to address this question.

3. In radiotherapy for cancer, when there is no in vivo dosimetry what are the patient safety risks and resource savings of performing pretreatment verification on 10% of patients rather than 100%?

No evidence was found to address this question.

Summary

No comparative evidence was found on patient safety benefits of in vivo dosimetry versus pretreatment verification only. An extremely large sample would be required to demonstrate a clinically significant difference in radiation over- or under-doses between the two quality assurance approaches. Case series evidence highlighted dosing errors found through in vivo dosimetry. Large discrepancies between measured and calculated radiation doses were often explained by detector positioning problems.

A UK study estimated capital costs of £6,000 and annual costs of £18,882 for a diode dosimetry system on one linear accelerator. This study did not meet usual level of evidence requirements for scoping reports, but was included as the only UK evidence.

The evidence presented on patient safety benefits and resource implications is inadequate to inform decision-making on investment or disinvestment in in vivo dosimetry in its various forms. No evidence was found on the patient safety risks or resource savings from reducing the number of patients receiving in vivo dosimetry. No evidence was found on the patient safety risks or resource savings from reducing the number of treatment plans undergoing pretreatment verification.

Further work for Healthcare Improvement Scotland

No further work on this topic is anticipated.

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. As a scoping report summarises information and does not provide recommendations a full EQIA assessment is not deemed necessary.

The process for producing scoping reports will be assessed when available, however no adverse impacts across any of the groups is expected.

Acknowledgements

Healthcare Improvement Scotland would like to acknowledge the helpful contribution of the following, who gave advice on the content of this scoping report:

Mr Andiappa Sankar, Oncology Physicist, Edinburgh Cancer Centre
Ms Margaret Cormack, Principal Radiotherapy Physicist, Raigmore Hospital, NHS Highland
Healthcare Improvement Scotland development team
Joanne Abbotts, Author/Health Services Researcher
Jenny Harbour, Information Scientist
Doreen Pedlar, Project Co-ordinator
Marina Tudor, Team Support Administrator

© Healthcare Improvement Scotland 2012
ISBN 1-84404-935-3
References


