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Overview

Evaluating Competing and Emerging Technologies for Stereotactic Body Radiotherapy and Other Advanced Radiotherapy Techniques

A.G.R. Martin [*], S.J. Thomas [†], S.V. Harden [*], N.G. Burnet [*‡]

[*] Oncology Centre, Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK
[†] Medical Physics Department, Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK
[‡] University of Cambridge, Department of Oncology, Cambridge Biomedical Campus, Addenbrooke's Hospital, Cambridge, UK

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Abstract

Stereotactic body radiotherapy (SBRT) refers to the precise irradiation of an image-defined extracranial lesion, using a high total radiation dose delivered in a small number of fractions. A significant proportion of SBRT treatment has been successfully delivered using conventional gantry-based linear accelerators with appropriate image guidance and motion management techniques, although a number of specialist systems are also available. Evaluating the competing SBRT technologies is difficult due to frequent refinements to all major platforms. Comparison of geometric accuracy or treatment planning performance can be hard to interpret and may not provide much useful information. Nevertheless, a general specification overview can provide information that may help radiotherapy providers decide on an appropriate system for their centre. A number of UK randomised controlled trials (RCTs) have shown that better radiotherapy techniques yield better results. RCTs should play an important part in the future evaluation of SBRT, especially where there is a smaller volume of existing data, and where outcomes from conventional radiotherapy are very good. RCT comparison of SBRT with surgery is more difficult due to the radically different treatment arms, although successful recruitment can be possible if the lessons from previous failed trials are learned. The evaluation of new technology poses a number of challenges to the conventional RCT methodology, and there may be situations where it is genuinely not possible, with careful observational studies or decision modelling being more appropriate. Further development in trial design may have an important role in providing clinical evidence in a more timely manner.

Key words: Clinical trials; dosimetry; stereotactic ablative radiotherapy; stereotactic body radiotherapy

Statement of Search Strategies Used and Sources of Information

This paper reflects expert opinion and current literature accessed by the authors; no formal search strategy has been defined.

Introduction

Radiotherapy is the most effective non-surgical treatment for cancer. It is required in the care of 50% of cancer patients and already forms a major part of the treatment for 40% of those who are cured. Continuing investment in developing radiotherapy technologies is appropriate in the context of providing the best possible cancer care and is supported by the National Health Service [1]. Radiotherapy will also be a key component of Cancer Research UK's vision to cure 75% of patients of their cancer by 20 years' time [2]. Earlier diagnosis may play an important part in that vision, and presents opportunities for the increased use of newer radiotherapy developments, such as stereotactic body radiotherapy (SBRT), as well as other newer technologies [3]. Just how such new technologies should be evaluated can be a challenging problem, with different solutions required in different circumstances.

Stereotactic body radiotherapy (SBRT) refers to the precise irradiation of an image-defined extracranial lesion, using a high total radiation dose delivered in a small

Author for correspondence: A. Martin, Oncology Centre, Box 193, Cambridge Biomedical Campus, Addenbrooke's Hospital, Hills Road, Cambridge CB2 0QQ, UK. Tel: +44-1223-336800; Fax: +44-1223-763120.
E-mail address: alexander.martin@addenbrookes.nhs.uk (A.G.R. Martin).

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number of fractions [4]. It is also often referred to as stereotactic ablative radiotherapy (SABR), which better describes the extreme dose intensity that is often central to the treatment and has an abbreviation that carries more evocative power [5].

SBRT has developed from intracranial stereotactic radiosurgery (SRS), where the use of extreme hypofractionation for target ablation was pioneered. In order to deliver large fractions of radiotherapy safely and effectively, treatment systems must be able to show very high overall system accuracy and be capable of producing very conformal treatment plans, with a steep dose gradient outside the target (Figure 1). An additional challenge in SBRT is accounting for inter- and intrafraction movement of the target and organs at risk. Thus, image guidance is a key component of SBRT delivery.

The use of SBRT has been increasing worldwide over the last 20 years. A significant proportion of SBRT treatment has been successfully delivered using conventional gantry-based linear accelerators with appropriate image guidance and motion management techniques [6–8] (Figure 2 [9]). However, a number of specialist SRS/SBRT systems are now also available [6]. Some of these systems are based on the traditional linear accelerator gantry, e.g. Versa HD (Elekta) and TrueBeam STx (Varian), whereas others have moved away from this design in search of greater non-coplanar beam arrangements, e.g. CyberKnife (Accuray) and Vero (Brainlab).

Evaluating Different Stereotactic Body Radiotherapy Technologies

Evaluating the different competing SBRT technologies is difficult, and it is therefore hard for formal comparisons to provide clear, universal guidance to radiotherapy providers. One reason for this is that all major SBRT systems are continuously under development, with market competition driving the regular release of software upgrades. These can lead, for example, to improved image fusion, better dose distributions, faster planning or treatment times, superior image guidance quality or a more seamless integration of all of these elements. Hardware upgrades, such as multileaf collimators or new motion management technology, also appear on a fairly regular basis. As a result of these continuous refinements, any detailed comparison between different SBRT platforms is only really valid at the moment of analysis.

The geometric accuracy of radiation delivery is of paramount importance when using extreme hypofractionation. Historically there has been an expectation that radiosurgery systems should be able to show ‘sub-millimetre accuracy’, based on phantom studies incorporating image acquisition and import, treatment planning and beam delivery. However, this ‘phantom transfer error’ is only one source of systematic error for the treatment. Errors from change in target size or position between planning scan and treatment, and any additional patient set-up errors also contribute to the total systematic error. This is probably greater in SBRT than in (intracranial) SRS, due primarily to greater potential for target movement. Finally, differences in target delineation by clinicians also need to be considered, and where possible reduced by utilising the best possible imaging [10,11]. As a result of all of these factors, any difference in machine accuracy between different SBRT platforms will probably be relatively small compared with the overall systematic error.

Treatment planning would seem to be an area where a quantitative comparison between different SBRT technologies might be possible. A number of treatment parameters are often used in the appraisal of radiosurgery or SBRT treatment plans, providing an objective measure of

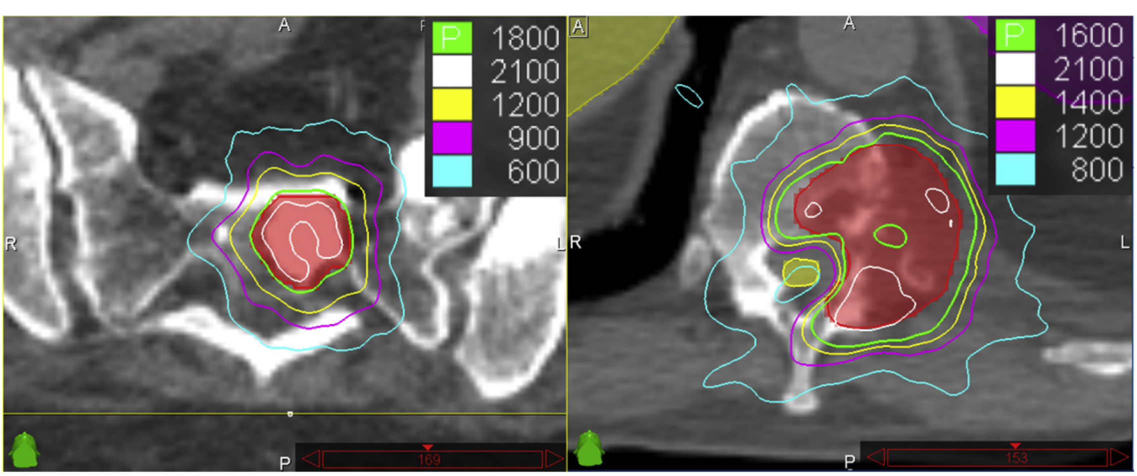

Fig 1. Left: stereotactic body radiotherapy plan to treat a metastasis in the sacrum, using a dose of 18 Gy in one fraction, prescribed to the 75% isodose. Isodose key top right, with figures in cGy. Note the close conformity of the prescription isodose line (green) with the planning target volume (red overlay) and the steep external dose gradient on all sides. Right: stereotactic body radiotherapy plan to treat a metastasis in a thoracic vertebra, using a dose of 16 Gy in one fraction, prescribed to the 70% isodose. Isodose key top right, with figures in cGy. Note the concave isodose arrangement following the shape of the planning target volume (red overlay), and the especially steep dose gradient towards the spinal cord (yellow overlay).

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