

Radiotherapy target volume definition and peer review RCR guidance

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Foreword

Quality assurance in radiotherapy is something none of us would ignore: when implementing a new technique, setting up a clinical trial or simply ensuring that our linear accelerators are safe to deliver therapy to our patients on a day-to-day basis. An increasing body of evidence supports the benefits of clinician to clinician peer review in improving contouring. Many of us are struggling to implement this effectively given work pressures in our departments and lack of time in our job plans.

This timely document, developed by a working party headed by Tom Roques, under the auspices of the RCR's Clinical Oncology Professional Support and Standards Board, gives a clear rationale for making this essential change. The emphasis is on local solutions with proportionate oversight depending on tumour site. The recommendations provide a practical framework of formative support for all clinicians involved in radiotherapy planning, regardless of their professional group.

My thanks to all those on the working party who gave their time to developing an extremely valuable resource. The document was circulated widely with feedback being incorporated from many sources including the heads of radiotherapy services in all four nations. My thanks again to all those who commented at various stages of review – the document is improved by these inputs.

The document has been referenced in the NHS England reorganisation of radiotherapy services, indicating an understanding of the importance of embedding peer review in routine practice. As a community, we need to implement peer review as rapidly as possible. Our patients deserve no less.

Dr Jeanette Dickson
Vice-President, Clinical Oncology



Whenever there is uncertainty there has to be judgment. And wherever there is judgment there is an opportunity for human fallibility.¹

Don Redelmeier

1. Summary and minimum standards

Recommendations

1. Radiotherapy target volume contours should be subject to systematic review by appropriately trained and experienced peer professionals. All radiotherapy departments should have processes that enable optimal target volume delineation and subsequent peer review.
2. Target volume guidelines should be specified in protocols which should be standardised across a clinical network or ideally nationally.
3. A standard nomenclature should be used to label target volumes and organs at risk. Target volume labels should include dose. Consistent colours should be used for volumes within each department.
4. Professionals involved in contouring should have protected time in their job plans for target volume definition and for peer review of target volumes. No other tasks should be booked simultaneously. The amount of time required will vary depending on tumour sites and complexity. Job plans should be designed to enable peer review without delaying treatment pathways.
5. Trusts should provide consultants with an appropriate working environment, including information technology (IT) infrastructure, to facilitate target volume definition.
6. Prospective peer review of contours should occur in cases where considerable individual judgment is required. In all other situations, a proportion of contours should be quality assured retrospectively.
7. Trusts and Cancer Alliances should facilitate peer review between departments by investing in appropriate IT infrastructure.
8. Each department should have an agreed process for peer review of target volumes. The frequency and nature of peer review should be specified for each tumour site depending on the complexity of the volumes.
9. A planning note should be written for each radiotherapy course explaining how and why target volumes were defined, with reference to protocols as necessary.
10. Radiotherapy departments should include audit of their processes to quality assure and peer review target volumes in their annual audit programme.
11. Departments should audit radiotherapy outcomes in terms of loco-regional control and toxicity and should therefore be able to use such data to better inform target volume definition in the future.
12. Clinical oncologists should be able to evidence good contouring and engagement in quality assurance of target volumes as part of annual appraisal.

2. Introduction

Purpose of the guidelines

Radiotherapy target volume delineation is a key part of the chain of tasks from consenting a patient for radiotherapy to treatment delivery.^{2,3} The site known to have cancer and the areas at risk of tumour spread are defined on a series of cross-sectional images on a computer to create a 3-dimensional volume of part of the body to which a treatment dose of radiotherapy can be applied. Incorrectly outlining the area at risk means that areas of cancer may be undertreated, reducing the chance of cure. However treating too large a volume increases the volume of normal tissue that is treated and increases the risk of side-effects. There are also specific structures or organs that must be identified and avoided in radiotherapy planning to minimise the risk of damage.

Target volume definition requires an assessment of clinical information and imaging to know the location of the primary tumour (or where it was in the case of adjuvant treatment), an understanding of the possible routes of microscopic spread and an appreciation of potential positional errors. The uncertainties involved in this complex decision-making process mean that the oncologist must use judgment to consider the potential benefits and possible harms of treatment for each individual case. Wherever complex human judgments are made there is the potential for variability, bias and error.

The Royal College of Radiologists (RCR) Clinical Oncology Professional Support and Standards Board has commissioned these guidelines to support oncologists to make better contouring decisions. They define minimum standards for volume definition and for peer review of contours. Building on work in the UK, Canada, Australia and the USA and these guidelines set out how UK clinical oncologists should best define target volumes, which treatments may benefit most from peer review and how and when peer review of target volumes should be performed and recorded.⁴⁻¹³ The guidelines offer examples of good practice and provide tools to help implement peer review in a department.

While these guidelines are written as though a consultant clinical oncologist is defining the volumes and providing peer review (the 'operator' in the Ionising Radiation [Medical Exposure] Regulations [IR[ME]R] terms), other competent specialists may also perform these tasks, for example radiographers, radiologists or senior oncology trainees. Indeed, such cross-disciplinary working is to be encouraged and should be assumed throughout this document. Other specialists acting as operators should be able to demonstrate the same level of competence as consultant oncologists, measured to the same standards.

The guidelines are written to be relevant for external beam photon radiotherapy (EBRT) but there are elements of the processes of volume delineation and peer review that could also apply to brachytherapy, superficial therapy or protons. These techniques are not specifically covered here.

Variation in contouring

Eliminating variation completely is neither possible nor desirable because clinical target volume (CTV) definition involves judgment around many different variables: there is not a unique correct target CTV for a given tumour and there is no test that can prove that a volume is absolutely correct.¹⁴ However, from many studies in many different cancer types, the magnitude of inter-individual variation in contouring is known to be substantial.¹⁵ Variation in target volume delineation may lead to overly large volumes which risk an increase in normal tissue toxicity or volumes that are too small and can lead to a geographic miss or failure to control disease. Variation in contouring of organs at risk may also lead to incorrect assumptions about the risk of damage to those organs. Variation may be within an acceptable range or it may unacceptably large because of lack of expertise, absence of a clear protocol, cognitive biases or errors.

Reducing variation and increasing standardisation between individuals and departments has been effective in improving quality in many areas of medicine.^{16,17} Errors have been described in other specialties where clinical judgment is used – for example in pathology and diagnostic radiology.^{18,19} Reducing variation is highly likely to be the correct approach in a scenario as complex as radiotherapy treatment planning.

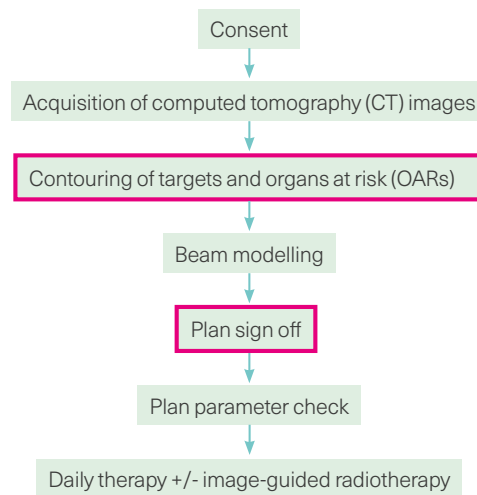
Protocols can provide a peer-defined standard for all aspects of treatment, including contouring, but there are few nationally agreed protocols for contouring such as that for anal cancer.²⁰ Protocols often cannot describe the variation in normal and pathological anatomy that is apparent in individual patients. Tools including online contouring atlases and real-time workshops aim to reduce variability through education, but as human beings with cognitive biases who are also potentially error-prone, even the judgment of experts can be imperfect. In addition to education and training, quality assurance is required to increase standardisation of practice and to reduce the risk of error.

Unlike other steps in the radiotherapy planning process, volume definition is not usually independently verified or quality assured. Historically one clinical oncologist working alone has usually defined the target volumes; additional formal checking processes have not been part of standard practice. There is evidence that incorrect volume definition can directly affect clinical outcomes and that a systematic approach to volume definition, including peer review by colleagues, can produce more consistent and accurate volumes.²¹⁻²³

Quality assurance in radiotherapy

The 2008 RCR document *Towards Safer Radiotherapy* (RCR) has helped establish a culture in UK radiotherapy of quality assurance, error detection and reporting.²⁴ Error detection relies on a systematic way of working in which checking processes find incidents and enable their correction before they have a clinical effect. In the parts of the process where checks are undertaken, the number of radiotherapy errors which are reported to cause direct harm to patients is very small.

Figure 1. Example of workflow for radiotherapy planning and delivery. Red boxes indicate parts of the pathway that are not usually checked.



When radiotherapy errors occur, they can be devastating for patients and costly for the NHS. Radiotherapy contours are stored electronically and can be audited after the treatment has finished. Any errors that were not corrected could therefore leave both the oncologist and the trust liable to litigation. Steps to improve radiotherapy quality, accuracy and safety are entirely consistent with an improving safety culture, which is integral to the vision of the NHS throughout the UK.²⁵

Quality assurance of contouring has become a standard part of most radiotherapy clinical trials both in the UK and around the world, as it is now known that protocol non-compliance can lead to adverse outcomes.^{21,22,26-28} Most trials now produce a detailed radiotherapy protocol which explains how the contours are to be defined, often with the addition of worked examples and atlases.

There are usually two parts to the clinical trial radiotherapy quality assurance process. In pre-accrual quality assurance, potential investigators must satisfactorily undertake an outlining exercise when their contours are compared to an agreed reference standard (usually made up of several constituent experts' outlines) with qualitative feedback, before they can participate in the trial. In on-trial or individual case review, the contours are reviewed by member(s) of the trial management group with reference to diagnostic information, either in real time before the patient starts treatment or retrospectively. The burden of quality assurance for each trial is proportional to the complexity or risk of the trial (for example, more required for a new indication for radiotherapy or where there is dose escalation). Clinical trials teams have therefore developed a methodology for peer review that could be adapted for use for patients treated outside trials.²⁹

The case for colleague peer review of volumes

Peer review of target volumes is the concept of a formal review by another expert of the delineated contours used to produce a radiotherapy plan. Reviewing target volumes also implies a review of dose and fractionation. Review should ideally occur before therapy begins to allow corrections to be made if needed. Different models for peer review have been described depending on tumour site, number of physicians involved and the logistics of job planning and IT.^{6,8-10,12}

A meta-analysis of peer review reports that 11% of treatment plans are changed by peer review some of which will directly affect outcomes.³⁰ In some studies, and particularly in tumour sites where volume definition is more complex, peer review recommends changes in a much higher proportion of contours. There is evidence that peer review changes practice even in tumour sites such as breast where clear protocols can describe most treatments.⁹ There is no evidence that experienced oncologists do not also benefit from peer review, though the number of changes recommended by a peer review programme may reduce with time.

While aiding complex decision-making, reducing variation and detecting occasional random errors are the main measurable benefits of peer review, there are other benefits to physicians and departments and therefore to patients. In particular, a peer review process fosters a culture of transparency, quality and safety, and encourages knowledge-sharing and teaching. Ensuring that oncologists work in teams makes cross-cover arrangements safer. Regular meetings provide space for oncologists to reflect on a very complex part of their practice and helps them to be more confident that target volumes have been defined optimally.³¹

Although peer review will require time from the participants, an effective peer review process may add efficiencies elsewhere in the radiotherapy pathway. For example, as physician confidence that the correct contours are being drawn first time increases, contours may be completed faster as well as more accurately. Peer review of contours before a plan has been created will reduce the need for re-planning.

The Canadian Partnership for Quality Radiotherapy has championed peer review and made peer review of all curative treatments a standard, ensuring it is part of routine care in many Canadian centres.³² A survey of UK Heads of Service has elicited strong support for peer review but found understandable concerns about how to find the time to embed it into routine clinical practice.

The anticipated benefits of peer review of radiotherapy target volumes include:

- Setting and maintaining standards within centres and nationally
- Providing peer support for difficult decision-making in contouring
- Reducing inter-individual variation in contouring
- Promoting a culture of quality, safety and transparency
- Improving communication with the rest of the radiotherapy planning team
- Improving training for clinical oncology trainees, radiographers and physics students
- Detecting major discrepancies (errors) which require a clinically significant change to the target volumes
- Ensuring patients have confidence in the quality assurance of the whole radiotherapy process.

Challenges and resource implications

The human resource implications of implementing this guidance should not be underestimated in a specialty where consultant capacity is already stretched by the continually increasing demand for, and complexity of, oncological treatments. However, without optimising this aspect of the planning process it is not possible to be assured that radiotherapy targets are being defined with the required accuracy. Therefore routine quality assurance by peer review of volumes is proposed as a standard part of quality clinical practice and should be included in consultant job plans.³³ Employers have a duty to support such quality assurance as part of their role as defined by IR(ME)R.³⁴ Consultants and service leads will need to think about how best to align job plans of those with the same site-specific expertise within and sometimes between trusts.

Effective and efficient contouring and peer review depends on an optimal working environment and, in particular, IT infrastructure. Trusts and radiotherapy partnerships will need to assess whether their current hardware and software for contouring and peer review are fit for purpose and make plans to upgrade these where necessary.

Peer review should be supportive and facilitating but there are risks that it could be seen as threatening to some individuals depending on the characters and experience of those involved. There is also the possibility that peer review could become a box-ticking exercise or that review could endorse suboptimal treatment if all participants are making the same errors. Peer review could even introduce errors if all the relevant information, including reasons why contours have defined as they have been, is not available at the review. Peer review outcomes should therefore be monitored and audited to ensure that all those involved – and especially patients – are deriving as much benefit as possible.

Recommendation 1:

Radiotherapy target volume contours should be subject to systematic review by appropriately trained and experienced peer professionals.

All radiotherapy departments should have processes that enable optimal target volume delineation and subsequent peer review.

3. Patient preparation for radiotherapy

A healthcare professional with appropriate competencies can refer a patient for radiotherapy. Radiotherapy must be justified by an oncologist or radiographer with appropriate training in radiation oncology (IR[ME]R).

Decisions around radiotherapy should take into account the preferences of the patient and their desired level of involvement in the process. A shared decision-making approach between patient and clinical team will include the provision of adequate verbal and written information to enable the patient and, where appropriate, their carer(s), to understand the potential benefits and risks of radiotherapy and to understand the alternative options which might be considered. Sufficient time should be allowed between the provision of information and formal documentation of consent to allow the patient to absorb and understand the information and to reflect on it with others.

The process of informed consent should be undertaken with the patient by a professional with appropriate competency to explain in detail the aims and expected frequent and serious side-effects of treatment, both acute and late. Consent should be documented on a consent form. The practicalities, aims and potential benefits, side-effects and potential complications of treatment should be covered in written and verbal information and in the consent process. If, following peer review of outlining, there is any material change in perceived benefit or risk, this should be further discussed with the patient and documented as part of the ongoing process of informed consent.

4. Radiotherapy protocols

Departments should have agreed radiotherapy protocols for each tumour (sub)site. These should be agreed between departments working in partnerships and be ratified by the appropriate subgroup of the regional Cancer Alliance or equivalent in the devolved nations. It is acknowledged that these arrangements are currently in transition. Protocols should include information on how to define target volumes and OARs, dose-fractionation schedules, acceptable normal tissue constraints and planning techniques. Clinical trial protocols can provide useful examples of protocols and should be updated and adapted for local use.

Recommendation 2:

Target volume guidelines should be specified in protocols which should be standardised across a clinical network or ideally nationally.

In some clinical scenarios target volumes can be described by normal tissue contours, for example in curative prostate or adjuvant whole breast treatment. The protocol should explain how to define volumes for all patients undergoing that therapy. If the protocol is followed, target volumes should be concordant. These volumes are referred to as **protocol-specified volumes**.

In other situations there is more individual judgment required when defining volumes and more opportunity for variation or error. This includes where a gross tumour volume (GTV) is first defined and then expanded or when an individualised CTV is needed, taking into account features of the particular tumour or patient, for example, in most head and neck and curative lung cancer treatment. The protocol will give principles for contouring this tumour type, but contours for each patient will necessarily vary. These volumes are referred to as **individualised volumes**. See Appendix 1 for examples of protocol-specified and individualised volumes.

No guideline or protocol can fully describe all individual cases. It is therefore appropriate to deviate from a protocol on a case-by-case basis if there are particular clinical or technical reasons to do so. Protocol deviations should be prospectively peer-reviewed and justification for deviating from normal practice should be documented within the patient record.

Volumes should be labelled systematically to make clear what has been contoured and the dose to be delivered (for example, planning target volume 60 [PTV_60] or PTV_6000 for Gray [Gy] and centiGray [cGy] respectively) according to internationally agreed naming conventions such as those published by Santanam.³⁵ This reference uses cGy as the standard unit of absorbed radiation dose but many UK departments use Gy. It is recommended that departments choose to use either Gy or cGy in all documentation, adapting the international recommendations accordingly.

It is recommended that standard colours are used for contours within a department and ideally within radiotherapy partnerships. For example all GTVs could be contoured as red and all spinal cord planning organ at risk volumes (PRVs) as yellow. A consistent approach will minimise the risk of errors when interpreting contours. The views of staff members with visual issues such as colour-blindness need to be considered when selecting contour colours.

Recommendation 3:

A standard nomenclature should be used to label target volumes and organs at risk. Target volume labels should include dose. Consistent colours should be used for volumes within each department

5. Practical aspects of volume definition

Clinical oncologists should have dedicated and protected direct clinical care (DCC) time in their job plan for volume definition and peer review. No other tasks, including patient reviews, should be booked simultaneously.³⁶ The timing of volume definition and peer review should take patient flow through the radiotherapy pathway into account to minimise treatment delays. Responsibility for ensuring compliance with this recommendation rests with the Departmental Clinical Director/Head of Service. Concerns should be escalated via governance forums and the Trust Medical Director if necessary.

Recommendation 4:

Professionals involved in contouring should have protected time in their job plans for target volume definition and for peer review of target volumes. No other tasks should be booked simultaneously. The amount of time required will vary depending on tumour sites and complexity. Job plans should be designed to enable peer review without delaying treatment pathways.

All relevant information must be available to the oncologist at the time of volume definition. This includes relevant diagnostic imaging, which should be viewable on a separate monitor to the planning computed tomography (CT), clinic letters, operation notes, histopathology reports, clinical photographs, endoscopy reports and so on. It is the responsibility of the oncologist to ensure that these are reviewed and documented within the patient record.

Volume definition should take place where the oncologist is not likely to be disturbed. The location will vary depending on the preferences and working pattern of the oncologist and facilities available within the department.

An appropriate working environment must be available for contouring with due consideration for ergonomics as set out by the RCR.³⁵ Visual displays should be of sufficient resolution and luminance for diagnostic cross-sectional imaging and should ideally include colour capability given the growing reference to positron emission tomography-computed tomography (PET-CT) and other dual modality functional imaging. These should be subject to a regular quality assurance programme.³⁷ Other functionality such as the outlining tools (for example, stylus, pen, mouse and so on), and technique (drawing points or a continuous contour) should be optimised. A general principle is that all available technology should be deployed to maximise the accuracy of contouring.

Recommendation 5:

Trusts should provide consultants with an appropriate working environment, including information technology (IT) infrastructure, to facilitate target volume definition.

Although in many cases oncologists contour in isolation, it is often helpful to have dialogue with the practitioners who generate the treatment plan to ensure a common approach to planning objectives, particularly in complex cases where there are critical normal structures close to the target. Where this does occur it should be documented. This approach enhances mutual understanding, education and teamwork as well as ensuring alignment of priorities during planning between the oncologist and planning staff.

6. Which contours should be peer reviewed?

Prospective peer review should be performed in situations where a clinically important difference in judgment between oncologists might occur. These situations are usually where radiotherapy is being given with curative intent (radical or adjuvant). They include:

- All individualised volumes
- Any protocol-specified volume that does not conform to the department protocol
- Any protocol-specified volume defined within a new protocol where the volume is different to that used previously. Prospective review should continue until adequate audit shows that the new protocol is being followed appropriately
- Palliative treatments where volume definition is as complex as for curative or adjuvant cases. Examples could include stereotactic radiotherapy for oligometastases, re-treatments and where high doses are used.

For other situations a quality assurance programme should be in place to assess quality of volume delineation. Departments should have an agreed programme for retrospective audit of volumes. For example 10% of these volumes could be randomly selected and audited at a peer review meeting. As random errors in a complex process are unpredictable, including some of these volumes in prospective peer review is encouraged.

Retrospective audit of volumes should be performed for:

- Protocol-specified volumes that are defined according to protocol
- Routine palliative radiotherapy treatments
- Techniques where fields are defined according to a protocol rather than volumes.

Radiotherapy treatment is becoming more individualised as more information is available from imaging, tumour biology and genomics. It is therefore likely that increasing numbers of target volumes will need prospective quality assurance in the future.

Recommendation 6:

Prospective peer review of contours should occur in cases where considerable individual judgment is required. In all other situations, a proportion of contours should be quality assured retrospectively.

7. Peer review meetings and documentation

The term 'peer review' as applied to radiotherapy contouring implies that all contours are reviewed by more than one consultant oncologist with the relevant site-specific expertise.

Timing of peer review

Peer review should take place before the first fraction of radiotherapy is delivered. For many tumour sites, review should occur after contouring but before a plan is created to reduce the risk of having to produce a second plan if changes are made. If the subsequent plan then meets the agreed PTV and OAR constraints it may not require formal peer review. In some tumour types (for example breast and lung) there may be benefit to reviewing the final plan rather than just the contours.⁶ Peer review can be performed collaboratively at a peer review meeting (which may be formal or informal) or remotely as is usually the case in clinical trials quality assurance. Where possible, patients should be enrolled in clinical trials with prospective quality assurance of target volumes.

Organisation of peer review

Real-time quality assurance meetings are strongly encouraged. They should ideally occur at a regular time and be scheduled in job plans to enable participation of the wider team. They should be timed so as not to add unnecessary delays into treatment pathways. Quality assurance meetings should include at least two clinical oncologists with relevant site-specific expertise. In some departments this will necessitate the meeting being linked by video-conferencing or online. The IT infrastructure should allow all participants to view the contours. It may be useful for such a meeting to also be attended by oncologists in training, radiologists, physicists and dosimetrists/radiographers. The time needed for a peer review meeting will vary according to the number and complexity of cases to be discussed, the participants and their experience with the process.

Setting up and resourcing such meetings will be challenging in many departments. Consultant time should be acknowledged in job plans and be adequately funded. Scheduling of the meetings and of other radiotherapy tasks before and after should be reviewed so that patient flow and cancer waiting times targets are not adversely affected. Arrangements for leave cover need to be considered. Innovative IT solutions to enable networked peer review meetings will need to be devised and resourced in many departments. While peer review should be structured, some flexibility is also important. For example it may be helpful to review a GTV with a colleague (oncologist or radiologist) before going on to define the CTV. See Appendices 3 and 4 for examples of peer review in practice.

Recommendation 7:

Trusts and Cancer Alliances should facilitate peer review between departments by investing in appropriate IT infrastructure.

Peer review can also be completed on an on-demand basis by reviewing cases with colleagues throughout the week once contours are completed. This approach can be more efficient but should be complemented by intermittent meetings to facilitate education and consistency across the department.

Contours can also be peer reviewed remotely as is the case in clinical trials quality assurance where an established methodology exists. Contours and plans are sent electronically for review and feedback by a peer or team of experts. Excellent communication between the oncologist and reviewers is key to ensure all relevant information has been taken into account when agreeing a final plan. This approach may have particular value in rare tumour types where expertise is necessarily centralised.

Recommendation 8:

Each department should have an agreed process for peer review of target volumes. The frequency and nature of peer review should be specified for each tumour site depending on the complexity of the volumes.

Content of peer review

The clinical particulars of the case should be discussed with access to relevant clinical data including diagnostic imaging, pathology reports, operation notes and so on. The overall treatment intent, radiotherapy dose and fractionation, and concomitant therapy should be noted. The oncologist who has defined the volume (principal clinician) should ideally be present to explain how the target volumes have been defined. Areas of uncertainty should be highlighted and discussed. Other experts should also look for evidence of deviations from protocol and for random errors (for example GTV that has been inadvertently missed).

If a consensus cannot be reached, the final decision to proceed with treatment rests with the principal clinician in discussion with the patient. If a reviewer is very concerned and feels that their view has not been assessed, weighed and reflected on by the principal clinician such that the patient is at risk then other governance structures can be used. For example advice may be sought from a clinical director or governance lead who may ask for a review from a pre-specified team in a neighbouring centre.

Once target volumes have been agreed, treatment plans which are created to agreed PTV and normal tissue constraints are checked by more than one dosimetrist/physicist. They are usually signed off by a clinical oncologist so there is a checking process in place without the need for each plan to be peer reviewed as well. Any plans not meeting agreed constraints should be reviewed at a quality assurance meeting and any agreed deviations from protocol should be recorded.

Documentation of contouring and peer review

The principal clinician should add a planning note to the patient's case record for all radiotherapy treatments, akin to an operation note (an example planning note and peer review record is included at Appendix 5). This should document how volumes were defined, with reference to protocols as necessary. For a protocol-specified volume, reference to a protocol may be all that is needed. More detailed notes may be needed for individualised volumes, for cases where a protocol has not been followed or where there are deviations from a standard protocol. This should facilitate future audit of treatment volumes retrospectively, particularly when patterns of recurrence are being studied.

Recommendation 9:

A planning note should be written for each radiotherapy course explaining how and why target volumes were defined, with reference to protocols as necessary.

When peer review is performed it should be documented. Documentation also acts as a checklist to ensure all relevant metrics have been reviewed. The document should include a record of the participants and of any changes made to target volumes, radiotherapy doses or concomitant treatments. The terms 'major change' and 'minor change' are suggested to help provide some quantification. While these terms have not been consistently defined in the literature and between tumour sites, major changes might include a change in treatment paradigm, alterations in contours that were needed to prevent a geographic miss, clinically significant changes in dose to part of a target volume or a significant change to a critical OAR. Minor changes might include smaller modifications to target volumes to enable better coverage or OAR sparing with the implication that the original contours would still have been clinically acceptable (See Appendix 6 for a list of examples of major and minor changes). If remote quality assurance is performed (for example, within a clinical trial) the principal clinician should write a planning note and should include evidence of remote quality assurance in the form of a standardised report.

Collecting quantitative data such as conformity index is unlikely to help inform individual cases but may be useful in a research context. A useful appraisal of different quantitative metrics can be found in the literature.²⁵

Audit of peer review

There is a risk that the peer review meetings may have biases – for example if all clinicians are making the same incorrect assumptions about a contour and coming to an incorrect conclusion by groupthink. External quality assurance of peer review meetings is therefore recommended, for example by clinicians attending other peer review meetings. Peer review meetings in a department should be audited annually and discussed at an appropriate forum such as the local radiotherapy board.

Recommendation 10:

Radiotherapy departments should include audit of their processes to quality assure and peer review target volumes in their annual audit programme.

Outcomes of radiotherapy treatment, including both tumour control and late effects, should also be audited locally or nationally, analysed and reflected upon. When a cancer is not cured, a retrospective review of the treatment volumes with the imaging at recurrence is recommended, with co-registration if possible, to feedback any learning points and contribute to audits of patterns of failure. For example, loco-regional recurrences can be classified as in-field, marginal or out-of-field and such information may inform better volume definition in the future.

Recommendation 11:

Departments should audit radiotherapy outcomes in terms of loco-regional control and toxicity and should therefore be able to use such data to better inform target volume definition in the future.

8. Education, RCR exams and appraisal

Clinical oncologists and other professionals involved in contouring should be able to evidence competency and continuing professional development (CPD) with respect to volume definition for the relevant tumour sites as part of appraisal and revalidation. This could be demonstrated in several ways:

- Evidence of attendance at relevant peer review meetings
- Evidence that their individualised volumes have been peer reviewed at such meetings
- Evidence that their protocol-specified volumes are defined according to protocol and that a suitable proportion of them have internal or external peer review
- External quality assurance of volumes in a radiotherapy clinical trial where test cases undergo central quality assurance or where patient volumes within the trial are prospectively audited
- Participating in QA workshops such as the FALCON programme organised by the European Society for Radiation and Oncology (ESTRO).

Recommendation 12:

Clinical oncologists should be able to evidence good contouring and engagement in quality assurance of target volumes as part of annual appraisal.

Expertise in radiotherapy target definition, as in all radiotherapy tasks, is likely to increase with experience and number of patients treated. Oncologists should treat a number of patients with each cancer type consistent with retention of competency and should comply with any nationally agreed standards in this regard.

9. Defining target volumes

GTV – gross target volume

The GTV is defined as the gross palpable or visible/demonstrable extent and location of malignant growth.³⁷ As such, GTV definition is the first link in the chain of tasks that results in the delivery of the desired dose of radiotherapy to the desired target.

Errors, and particularly omissions, in GTV definition have the potential to cause a geographic miss or suboptimal coverage of the tumour. The GTV is expanded to form the CTV and PTV so any errors in GTV definition are likely to be magnified in the CTV and PTV. Hence small errors in GTV definition can result in a PTV, and hence a dose distribution to the cancer, which is suboptimal.

The oncologist should review all images in the planning scan dataset (usually CT) to look for other unexpected findings – new visible tumour, metastases, other gross pathology and so on. The planning CT is not usually acquired at a diagnostic image quality and the radiation exposure does not require a formal diagnostic report. Concern on the part of the oncologist regarding a possible previously undetected abnormality on the radiotherapy planning scan should prompt full review of the planning scan by a diagnostic radiologist with appropriate follow-up action as required. However, clinical oncologists are not responsible for ensuring that all anatomical abnormalities on a radiotherapy planning scan are detected.³⁸

The radiotherapy planning CT should be viewed on a quality monitor using appropriate windowing.³⁶ Diagnostic imaging using other modalities (magnetic resonance imaging [MRI] or positron emission tomography [PET]) should be fused where appropriate and the accuracy of the fusion assessed. A dedicated MRI or PET in the treatment position will give better results than deformed co-registration. Use of sagittal and coronal reconstructions can be particularly helpful when outlining irregular or vertically orientated structures such as the oesophagus.

Oncologists should have access to specialist diagnostic radiologists with specific understanding of the requirements of radiotherapy planning to help define GTV when needed. To facilitate contemporaneous radiologist access for the purpose of defining GTV, IT developments such as live online review should be supported. Radiologists should have training in the volumetric concepts of modern radiotherapy planning. Any radiologist involvement in volume definition should be recorded as part of documentation of peer review.

Autosegmentation algorithms have the potential to speed up contouring and to reduce variability and bias. There are a number of algorithms and methodologies which are most effective where tumour boundaries are well delineated by relatively large changes in pixel density compared with adjacent normal tissue; the lung is one site where autosegmentation may have greatest utility. Separation from consolidated/atelectatic lung or normal soft tissue structures will serve to limit the required contrast definition. Such contours should therefore always be checked by the treating physician on a slice-by-slice basis.

Contours should not be cut and pasted from slice to slice of the planning CT as this risks errors being copied from one slice to another. If a contour is not defined on every slice, intervening contours can be automatically interpolated and the resulting contours individually checked for accuracy.

CTV – clinical target volume

The CTV is the tissue volume that contains a demonstrable GTV and/or sub-clinical microscopic malignant disease that has to be eliminated in order to cure the cancer.³⁹

CTV encompasses possible sites of microscopic tumour spread. An absence of definitive data on pathological spread of cancer beyond the visible margins of disease and the lack of visibility of this target on the imaging used to inform planning, together imply that there will be variation in CTVs defined by different people. An element of this variation may be unavoidable, since this is a subjective judgment. Individual patient characteristics also need to be taken into account, for example defining a smaller CTV to reduce adverse effects in someone for whom radiotherapy tolerability is a concern. However, variation in CTV definition from the same GTV can be minimised by the use of consensus protocols.

The person performing contouring should apply their knowledge of relevant anatomy and pathophysiology to logically define possible routes of tumour spread.

While an isotropic expansion from GTV to CTV may initially be helpful, most tumours do not have the propensity for spread in every plane to the same degree. If a standard expansion is used, each slice contour should then be reviewed and edited to take account of natural barriers to tumour spread and possible routes of spread (for example, a normal vertebral body adjacent to a lung carcinoma should not be included in the CTV). While contours are usually defined on axial CT slices, planning systems allow reconstructions in other planes. These should be used where possible to help CTV definition.

When a CTV is being defined for postoperative (adjuvant) radiotherapy, a review of the operation note and pathological findings as well as discussion with the surgeon and pathologist about most likely sites of recurrence is often very helpful. Fusion of any preoperative imaging with the planning CT can be helpful to aid the definition of the CTV. Accuracy of the fusion should be assessed and any changes in anatomy due to surgery should be taken into consideration if rigid registration is used. If deformable registration is used, again accuracy of fusion should be assessed. It can be helpful for the surgeon to view the planning CT with the oncologist to help define possible sites at high risk for recurrence.

A number of CTVs for the same tumour may be defined so that different doses of radiotherapy can be delivered to each CTV to take account of different levels of risk.

Nodal atlases should be used when defining at-risk nodal volumes where there is no GTV visible. They need to be interpreted with caution in cases where there are nodes involved or if surgery has taken place as normal anatomy may have been altered.

ITV – internal target volume

The ITV consists of the CTV plus an internal margin. The internal margin is designed to take into account the variation in the size and position of the CTV relative to the patient's reference frame (usually defined by the bony anatomy); that is, variations due to organ motion such as breathing or filling of the bladder or rectum.⁴⁰

Where motion can be estimated in individual patients, an ITV should be created directly from the CTV to account for movement in each plane – for example using a respiration correlated or 4-dimensional (4D) CT for lung cancer.

PTV – planning target volume

Each department should audit systematic and random errors for each tumour site at an appropriate interval. These should be used to calculate departmental CTV–PTV margins for each site using equations such as the van Herk formula.⁴¹ When there is a significant change in technique or equipment such as a new immobilisation device, margins should be re-audited.

It may occasionally be appropriate to modify the CTV–PTV margin for individual patients. This would depend on factors relevant to the individual case, for example an increased or decreased risk of set-up errors. The CTV–PTV margin will also depend on the method of image verification. For example smaller margins could be acceptable if daily cone-beam CT with soft tissue matching is used.

PTVs should be expanded directly from the CTV or ITV and should then not be edited. Coverage of a PTV may be compromised in order to keep organs at risk within tolerance but this compromise should be visible within the plan rather than being estimated by the oncologist changing the PTV. This may be achieved by creating a second PTV to describe the coverage necessary for the clinical case (for example, PTV_optimised).

There are occasions where PTVs need to be systematically edited to produce more appropriate coverage – for example editing PTVs back from the skin surface in intensity-modulated radiotherapy (IMRT) for head and neck cancer.

OAR – organs at risk

Organs at risk (OARs) should be contoured according to agreed protocols. They should be quality assured as rigorously as tumour target volumes, for example with review by specialist radiologists as required.

A margin may be added to the OAR to create a planning organ at risk volume (PRV) when damage to a small volume of normal tissue may produce very severe side-effects (for example in the spinal cord or optic nerves).

Approved by the Board of the Faculty of Clinical Oncology; 22 June 2017.

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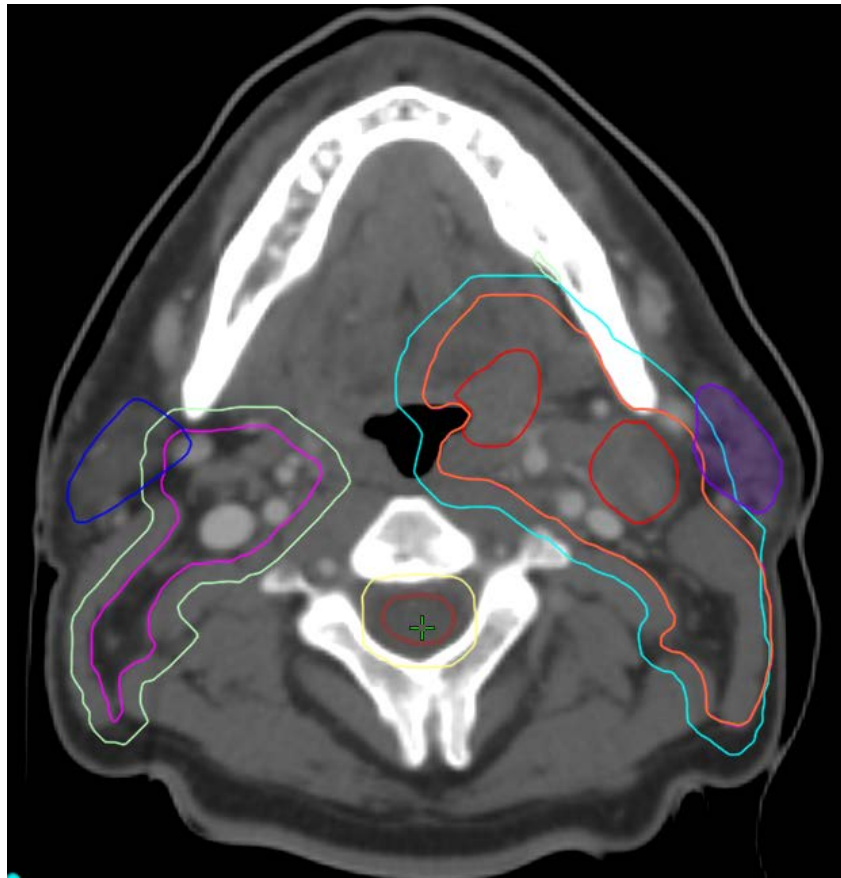
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Appendix 1. Examples of protocol-specified and individualised volumes

Site	Protocol-specified	Individualised
Bladder	Curative radiotherapy to whole bladder	All curative treatments except for radiotherapy to the whole bladder
Breast	Adjuvant radiotherapy to whole breast +/- nodes	Radiologically identified residual nodes such as supraclavicular or internal mammary nodes, being treated with curative intent
Colorectal and anal	–	All curative treatments
Gynaecological	–	All curative treatments
Head and Neck	Curative radiotherapy to whole larynx for T1/2 glottic cancer	All curative treatments except for curative radiotherapy to whole larynx
Lung	–	All curative treatments including SBRT
Prostate	Curative radiotherapy to whole prostate	Prostate + nodes Adjuvant radiotherapy to prostate bed
Sarcoma	–	All curative treatments
Upper gastrointestinal	–	All curative treatments

Appendix 2. Sample contouring labels and suggested colours

Suggested contour labels and colours for a head and neck treatment – prescribed dose 65 Gy in 30 fractions to high dose target volume and 54 Gy in 30 fractions to low dose target volume.



Target volume	Colour
GTV	Red
CTV_65	Orange
PTV_65	Cyan
CTV_54	Magenta
PTV_54	Light green
SpinalCord	Brown
SpinalCord_PRV	Yellow
Parotid_L	Purple
Parotid_R	Blue

Appendix 3. Examples of peer review meetings in UK departments

In addition to the examples listed here there are several papers that detail how peer review is carried out in individual departments in the UK and abroad. These include references by Ballo, Brammer, Amarasena, Lefresne, Lymberiou, Mackenzie and Rooney.^{4-6,8-10,12}

1. Head and neck peer review meetings with two head and neck oncologists (Norwich)

Job plans of the two oncologists have been aligned so that both have a contouring programmed activity (PA) on a Monday morning with no other activities scheduled at that time. At a thirty-minute head and neck team meeting on the preceding Wednesday oncologists, trainees, dosimetrists and physicists briefly discuss each case to agree on dose, fractionation and selection of nodal levels as well as which oncologist will contour which patients. Volumes which may need radiologist support can be identified so that discussion with a specialist radiologist can take place without delaying contouring. Workflow has been streamlined so that head and neck patients are scanned on a Thursday or Friday so as to be ready for contouring on Monday.

On Monday mornings the oncologist contours target volumes and organs at risk, liaising with his colleague during the process if needed. Peer review is therefore dynamic and may occur several times during the course of contouring for complex volumes or just once when the contours are complete for simpler cases. This means that changes are made early on in the planning process making corrections more efficient – so if the GTV is changed by peer review, such changes can be reflected in the CTVs when they are defined subsequently. The isotropic expansion from CTV to PTV is completed only when both oncologists have agreed on CTV definition. Contours are then electronically signed as complete so that planning can begin.

A planning note is completed electronically and acknowledges changes made by peer review and the fact that both oncologists have contributed to the final contour sign off. Peer review usually takes ten to twenty minutes per case but because review happens in real time during contouring it may reduce time spent considering uncertainty and correcting contours. Both oncologists are much more confident that target volumes are optimal when they have been peer reviewed.

2. Lung cancer meetings in a centre with six lung oncologists (Belfast)

CT voluming and assessment of plans is done at various times throughout the week, as dictated by the differing job plans of clinicians. Trainees are encouraged to select patients from any consultant and contour them before discussing with the relevant consultant. When a doctor is on annual leave other consultants will cross-cover activity. Relevant clinical data is written on the radiotherapy planning information to enable voluming (stage, World Health Organization [WHO] performance status, results of respiratory function tests, Medical Research Council [MRC] dyspnoea score, proposed fractionation and treatment paradigm).

On a Wednesday morning clinicians meet for up to 90 minutes to discuss all cases that have been volumed or are available for dose–volume histogram (DVH) and plan evaluation. At least two oncologists are required to be present to make the meeting quorate. The meeting is also attended by a specialist radiographer and oncology trainees. There is access to the radiotherapy planning system and the radiology and online oncology notes systems. A Microsoft Access database is used to record patient details, meeting attendance and peer review outcomes (see picture below).

The screenshot displays a web-based form titled "Peer Review Lung Database". The form is organized into several columns and rows, with various input fields and checkboxes. The fields include:

- Demographics:** ID (with a "New" button), Initial, BPR, Cons, Histology, Treatment Paradigm, PET/CT staging, FEV1, TF, Respiratory Compensation, Peer Review Treatment Indication, Peer Review Treatment Indication Changed, Peer Review Volume Date, and Changed Peer Review Volume.
- Physical Characteristics:** Age, PS, T, N, PLNS, M, MRC Dys, %FEV1, %TF, brain staging, iv contrast, Gender, and GTV volume.
- Volume and Dose Parameters:** PR Volume change - date accepted, Peer Review DVH Date, MLD, Lung V20/V18, oesophageal V50, Spinal Cord PRV max, mean heart, PR DVH accepted if previously declined, Peer Review Dose Date, Dose prescription, Changed Peer Review Dose?, PR Dose accepted if previously declined, and Comments.
- Algorithm and Salvage Options:** VMAT or IMRT, Type B algorithm, 99%+ PTV 95% dose, 99%+ CTV 95% dose, 95%+ PTV 95% D, 99%+ PTV 90% dose, Salvage, 2 primaries, Oligomet, Lung nodules (T3/4), and Replan needed.

Screenshot to show data fields which are completed at peer review meeting.

The treatment paradigm is discussed and agreed. Volumes are reviewed by the meeting in the context of the radiology and clinical details (pathology and endobronchial ultrasound [EBUS] reports). Any required changes are discussed and made at the meeting if possible. If a modification is recommended this is recorded in the database and a date made for review of the changes (usually the following week). The degree of change is graded as major or minor. Plans for evaluation are reviewed in the context of the clinical data (fitness of the patient, co-existent comorbidities and proposed concomitant medications). Any change in dose or advice to proceed to IMRT/volumetric modulated arc therapy (VMAT) is recorded. A treatment is allowed to progress with retrospective review at the meeting if there is clinical priority, although the department is aware that the meeting may necessitate changes that are usually more difficult to implement once treatment has begun. Additional cases are often discussed so that advice from colleagues can help management decisions such as whether a patient has a radical treatment option.

The meeting allows team building and rapid cascading of new information from clinical trials and discussion of possible service developments. All clinical oncologists involved feel more confident when their patient's treatment has been discussed at peer review. The database allows a record of peer review meetings attended and consultant cases put through the meeting which can be used for appraisal.

3. Online head and neck cancer peer review meetings using Skype for Business (Taunton and Exeter)

Taunton is a relatively small radiotherapy centre with one head and neck oncologist. Exeter, Taunton and Torbay already video link weekly for the head and neck cancer multidisciplinary team meetings (MDTMs). In 2014, the Exeter and Taunton clinical oncology centres worked together to identify IT solutions to facilitate cross-site peer review of radiotherapy contours and treatment plans for their patients.

An initial barrier was the use of different treatment planning systems (TPS) on each site (Taunton – Pinnacle; Exeter – Eclipse). NHS Secure File Transfer would not allow a live and interactive review unless each centre had access to each other's TPS. However, software that could incorporate different planning systems, allowing participant users to present cases, would obviate the need to duplicate an identical TPS. Skype for Business (SfB, previously Microsoft Lync 2013) was selected for this purpose.

SfB allows PC users to communicate by text, by voice using a microphone or headset, or by video-conferencing. The software also allows users to share screens which can then be viewed between sites in different locations. Permission can be granted by the host PC for a remote user to take control of the host PC, allowing the remote user to scroll through images to view and edit contours or plans. The host PC can also allow the remote user to 'present' their screen, with review and editing of the remote user's contours or plans in turn. All communications via SfB take place within the N3 network, a wide-area network connecting healthcare providers within England and Scotland, providing data security and confidentiality.

In practice, one oncologist from Taunton, two from Exeter and, more recently, one from Torbay, have protected time in their job plans for one hour of contouring peer review on a Monday after the head and neck MDTM. The meeting is led from the radiotherapy contouring suite at Taunton and is linked to the radiotherapy physics department at Exeter. Clinical staff at Exeter, trainees, radiographers and physicists, are invited to join the weekly meeting via an email invitation from Taunton MS Outlook which contains a link to the session. Close working of the IT departments in both hospitals and application of appropriate firewall permissions means that full communication now occurs. Comments and observations regarding the cases reviewed as well as details of modifications to contours and plans are kept in the patients' electronic record (MOSAIQ at Taunton, Aria at Exeter).

SfB has provided resilience for a lone head and neck oncologist in a small centre and allowed all sites to provide quality assurance of peer reviewed radiotherapy contouring and planning for head and neck cases.

4. On demand head and neck peer review in a centre with four head and neck oncologists (Birmingham)

An on demand peer-review approach has been piloted so as not to introduce any delay into the radiotherapy pathway by waiting for a weekly meeting. Cases are submitted by contouring clinicians for peer review on a voluntary basis. On completion of contouring, an 'await peer review' comment is entered on the contouring software by the contouring clinician. The clinical scenario, rationale for dose and volume selection, treatment start date or 'review-by' date and any specific clinical concerns are detailed. The focus of peer review is on target volumes; OARs in each case are contoured by an experienced head and neck specialist radiographer and reviewed by the contouring clinician.

Clinical details and relevant pre-treatment imaging are reviewed by the peer prior to contour review. All clinicians follow institutional protocols with delineation guidance reflecting contemporary UK practice. The guidelines are closely aligned to relevant prospective national studies: oropharynx (CompARE trial), larynx and hypopharynx (NIMRAD trial), parotid (CO-STAR trial). The peer review can be done either independently, or alongside the contouring clinician. If the case is rare or complex, or a corroborative opinion is requested by the contouring clinician, peer review can be performed by more than one peer either together or sequentially. Once peer review of contours is complete and any amendments finalised by the contouring clinician, a 'peer review completed' saved entry confirms the case is ready for planning.

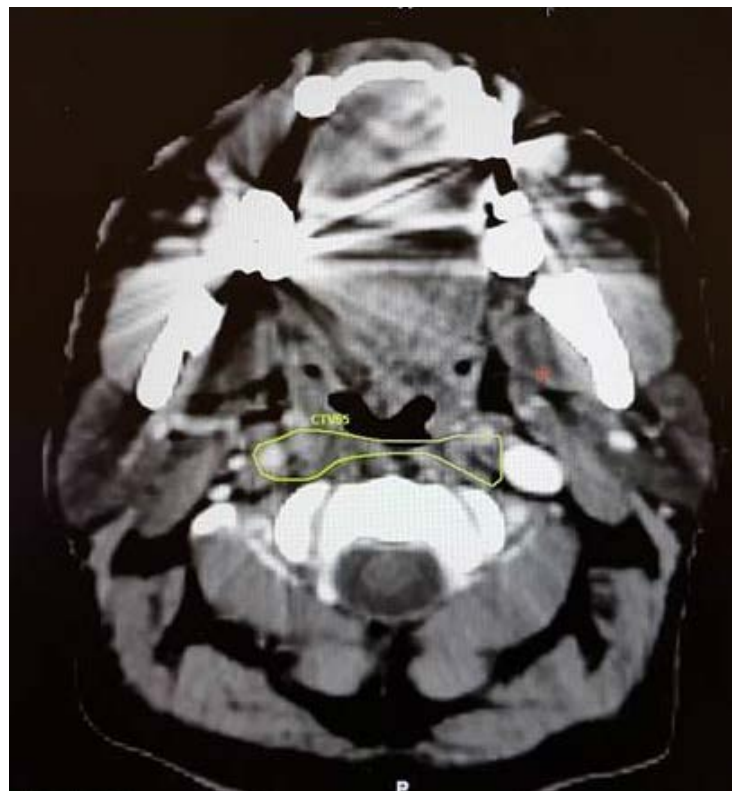
A pilot study has been undertaken to evaluate this approach in 62 cases. The mean review time was 17 minutes per case. Eleven percent of cases required significant changes and these cases were usually complex – for example sinonasal cancer or post induction chemotherapy cases. The mean (and median) time saved in completing peer review between an on-demand approach versus a weekly approach was 27.9 (18.8) working hours respectively ($p < 0.001$). The next steps are to improve the pathway through integration with MOSAIQ and to complement on-demand peer review with intermittent review meetings.

Appendix 4. Individual case examples of peer review

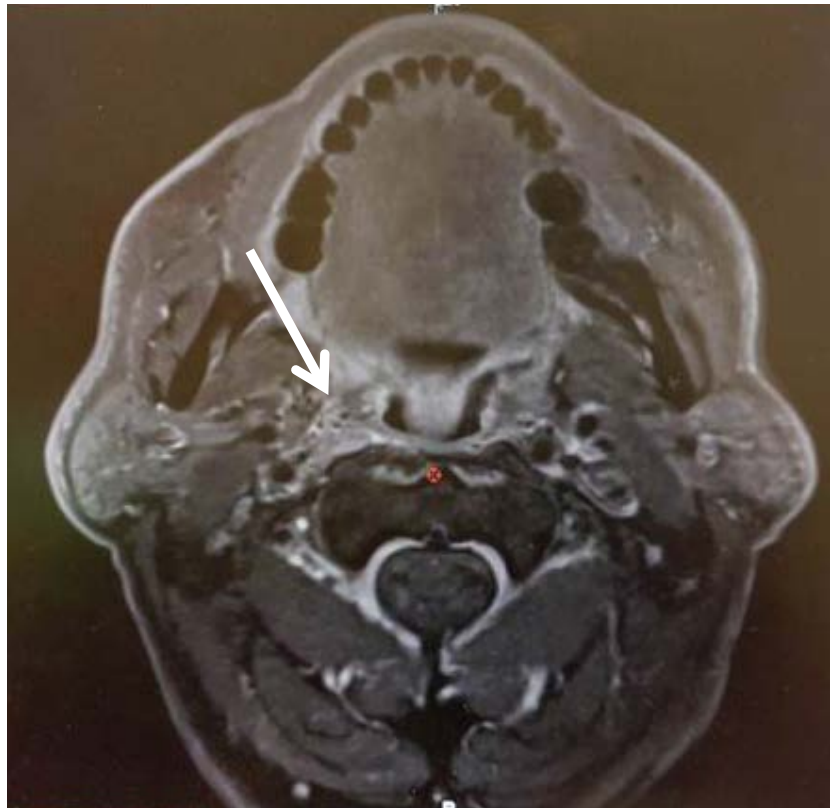
1. An example of peer review correcting a judgment error

A patient with T4N1 Epstein-Barr virus associated nasopharyngeal cancer was being planned for curative radiotherapy following neo-adjuvant chemotherapy. At diagnosis a right retropharyngeal (RP) node was thought to be involved. Pre-chemotherapy and post-chemotherapy MRI images were fused with the planning CT scan to aid contouring. The RP node was not enlarged on the post-chemotherapy MRI but should have been included as GTV according to local protocol. This was not recognised at contouring so the involved node was excluded from the GTV and CTV_65. Peer review was undertaken on demand by a second specialist consultant. At review this unintentional error was detected and corrected with both clinicians present before a plan was created. The involved RP node was contoured as GTV which resulted in an additional 28mm expansion of the CTV_65 to cover the RP nodes.

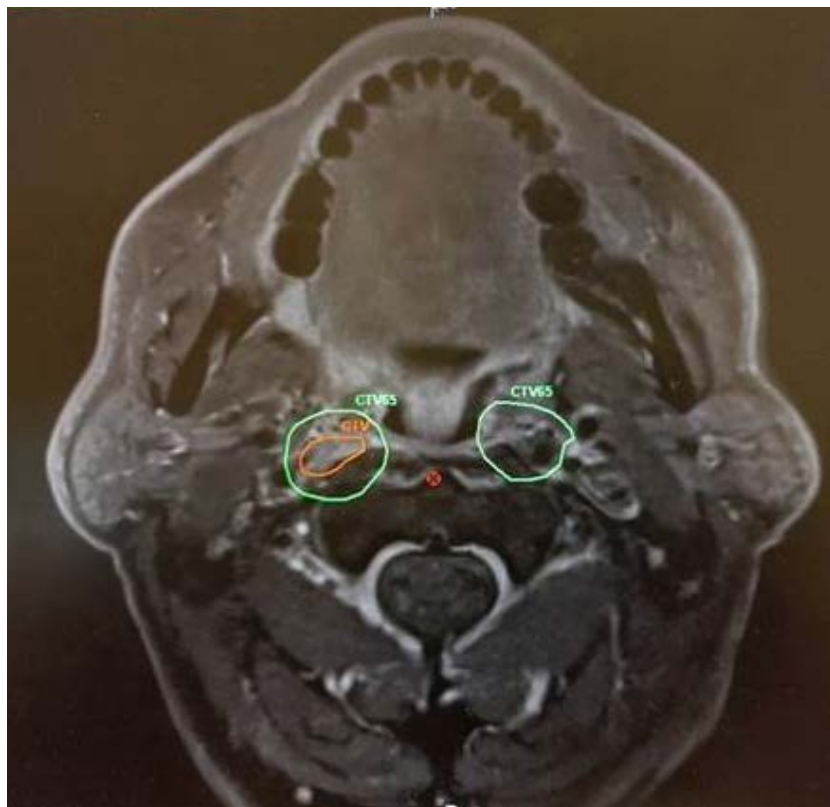
Without peer review the involved node would not have received the intended radiation dose making a recurrence at that site more likely. There are no good surgical salvage options for RP nodes so any recurrence would likely be incurable.



Planning CT prior to review. Most inferior contour for CTV_65 is shown (yellow)



Diagnostic MRI showing involved right retropharyngeal node



Peer reviewed GTV(orange) and CTV_65 (green) contoured on MRI fused with planning CT

2. An example where peer review might have prevented recurrent cancer

A patient was assessed for curative radiotherapy for a locally advanced lung cancer. Her PET-CT described multiple N2 lymph nodes and biopsy of a subcarinal lymph node produced cells consistent with squamous carcinoma. Her radiation oncologist outlined a left upper lobe primary and subcarinal and hilar lymphadenopathy. The paratracheal lymph nodes were not included as these were not mentioned by name in the pathology or PET-CT report, although on retrospective review of the PET-CT images these nodes were moderately fludeoxyglucose (FDG) avid. They also looked abnormal on endobronchial ultrasound.

The patient subsequently relapsed in the paratracheal lymph nodes and received palliative systemic treatment. A review determined that the paratracheal lymph nodes had been excluded from the GTV and received minimal dose. The oncologist noted that she had started attending peer review meetings where cases had a 'second look' and that her colleague had described target nodal revisions of a similar type being advised by the meeting. The patient's family lodged a complaint and compensation was sought.

Appendix 5.
Example of
documentation – a
combined planning note
and peer review record

This sample form is available to download from www.rcr.ac.uk/publication/RT-target-definition-peer-review

Planning note		Peer review record
Demographics	Name/date of birth/hospital number	
Tumour site and stage	IDC-10; TNM	
Intent	Curative/adjuvant/palliative Clinical trial Y/N and trials number	
Complexity	Individualised, protocol-specified, palliative, other	
Treatment technique	Inverse planned IMRT; SBRT etc	
Background	Comments on planning CT, clinical findings etc.	
Dose/fractionation/chemo		Major changes – Minor changes
Description of GTV		Major changes – Minor changes
Description of CTVs		Major changes – Minor changes
Description of PTVs		Major changes – Minor changes
Description of OARs		Major changes – Minor changes
Other comments	E.g. need for on treatment imaging	
Name(s)		
Date		
Approx. time taken		
Peer review technique		Face to face/videolink/distant review Pre-treatment: yes/no
Was PR helpful in other ways?		

Appendix 6. Examples of major and minor changes found at peer review

Tumour site	Examples of major changes	Examples of minor changes
All	<ul style="list-style-type: none"> Change in treatment modality – for example, addition of concomitant chemotherapy Change in radiotherapy dose or fractionation Any change needed to prevent a geographic miss of GTV 	<ul style="list-style-type: none"> Editing a contour by a small amount – for example <10 mm on <2 contiguous slices
Head and neck	<ul style="list-style-type: none"> Deciding to include a suspicious node within high dose CTV Including or excluding a whole nodal level in a CTV 	<ul style="list-style-type: none"> Excluding an uninvolved muscle from CTV Minor editing of CTVs to correspond to the consensus atlas contours for N0 neck
Lung	<ul style="list-style-type: none"> Change from concurrent to sequential chemotherapy Change from conventional fractionation to stereotactic body radiotherapy (SABR) Alteration of GTV to reduce geographic miss (inclusion of lymph node felt to be involved, addition of spiculation felt to be pathological) Modification of OAR that affects plan acceptability (e.g. DVH becomes out of tolerance) 	<ul style="list-style-type: none"> Alteration of OAR that does not affect plan acceptability Minor modification of GTV that does not affect target coverage (area may have been included on other GTV contours in other phases of respiration)
Upper gastrointestinal	<ul style="list-style-type: none"> Incorrect expansion of GTV to CTV longitudinally Change in longitudinal GTV by more than 5 mm Incorrect delineation of areas of elective nodal irradiation, for example completely absent or whole stomach included PTV margin ≥ 3 mm deviation from protocol 	<ul style="list-style-type: none"> Incorrect delineation of areas of elective nodal irradiation for example, some areas not included Incorrect PTV margin but ≤ 3 mm deviation from protocol

Appendix 7.
Other useful
resources

Radiation Therapy Oncology Group (RTOG) index of contouring atlases
www.rtog.org/CoreLab/ContouringAtlases.aspx

European Society for Radiotherapy and Oncology (ESTRO) Falcon contouring
www.estro.org/school/articles/e-learning/falcon/falcon

eContour – open access web-based contouring resource
<https://econtour.org/>

ProKnow – online analytical tools for radiation oncology to reduce variability
<https://proknowsystems.com/>

Quantec – Quantitative analyses of normal tissue effects in the clinic
[www.redjournal.org/issue/S0360-3016\(10\)X0002-5](http://www.redjournal.org/issue/S0360-3016(10)X0002-5)

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