

# Image-guided ablation

# Foreword

This publication is intended to inform radiologists, oncologists, all members of the medical profession involved in the care of patients with cancer, hospital trusts, commissioners of healthcare, strategic health authorities and government departments about the current status of a rapidly developing, minimally invasive cancer therapy, image-guided ablation (IGA), which includes radiofrequency ablation (RFA), microwave ablation, and image-guided cryoablation. The demand for these cancer therapies is currently outstripping our ability to deliver them in a timely fashion, and there is concern that many patients undergo unnecessary surgery because of such issues.

The Royal College of Radiologists is grateful to Drs Fergus Gleeson and Mark Anderson (Consultant Clinical Radiologists, Churchill Hospital, Oxford), Dr David Breen (Consultant Clinical Radiologist, Southampton University Hospital) and Mr Zahir Soonawalla (Consultant Hepatobiliary Surgeon) for writing the paper, and the Faculty Board and the Standards Sub-Committee of The Royal College of Radiologists for approving it.

**Dr Tony Nicholson**

Dean of the Faculty of Clinical Radiology  
The Royal College of Radiologists

# Introduction

There are numerous minimally invasive ablative therapies, including: radiofrequency ablation (RFA), microwave ablation, high-intensity focused ultrasound (HIFU), laser-induced interstitial thermotherapy (LITT), cryoablation, and percutaneous ethanol injection. This is a rapidly evolving field with proponents (and potentially, applications) for each technique. The technology is improving, with larger and more controlled areas of ablation being achieved with each technological advance. Microwave ablative therapy was until recently hampered by large probe size and poorly controlled ablative zones, but these problems appear to now be resolved. HIFU produces well-controlled areas of ablation, but is slow and is relatively under-researched. RFA is presently the most commonly performed ablative therapy and is now recognised as part of standard clinical treatment. It is also the modality that has the best available evidence base in the literature on which recommendations can be based; because of this, the report will focus on RFA, but will where possible produce generic recommendations applicable to all methods of ablation.

Ablative therapy is most commonly performed in patients with primary and metastatic liver tumours (particularly metastatic colorectal carcinoma), in renal cell carcinoma, and increasingly primary bronchogenic carcinoma or metastatic pulmonary disease. It may also be performed in patients with benign and metastatic bone tumours, and may be performed by both radiologists and surgeons, either percutaneously (using ultrasound, computed tomography [CT] or magnetic resonance imaging [MRI] guidance) or under direct vision (using intraoperative ultrasound during laparotomy or laparoscopic surgery).

This document will provide an overview of the requirements for the provision of an ablative service, including patient referral base, teamworking, equipment, staff, time, training, facilities, outpatient and inpatient requirements, follow-up, patient information leaflets, research and audit.

# The procedure

RFA is a minimally invasive ablative treatment that produces cell death by coagulative necrosis through conductive heating. Radiofrequency through a high frequency alternating current in the immediate surrounding tissue produces molecular vibration resulting in frictional heating that causes coagulative necrosis. The radiofrequency current is delivered through a probe, consisting of a partly insulated needle, with an active (unshielded, monopolar) tip. The tip may be of variable length, the most common being 3 cm, and may either be a single straight tip or expandable, containing multiple prongs or tines that when deployed form an umbrella-like appearance where the active portion of the needle is positioned. The probes are of variable design and have different mechanisms for providing feedback to the operator of the power being delivered, the temperature at the tip(s) and the resistance (impedance) of the adjacent tissues. The RF generator can also control the temperature at the tip(s), preventing charring of tissues, which can limit the ablation zone. The amount of vibration and subsequent heat production is relative to the distance from the unshielded tip, with the volume of tissue destruction produced dependent on the number of probes placed, their distribution and the size of the unshielded monopolar electrode.

For larger tumours, multiple needle placements may be made to produce overlapping areas of tissue destruction. After the procedure the probes are removed, with the probe tracts being ablated (cauterised) as the needles are withdrawn, reducing the incidence of tumour seeding and haemorrhage. Adjunctive interventional manoeuvres such as hydrodissection (instillation of collateral fluid to displace adjacent, temperature-sensitive structures), pre-embolisation or post-procedural chemoembolisation have extended the scope and applicability of these procedures.

The procedure may be performed under deep conscious sedation or general anaesthetic. The procedure may be performed either as a day case or requiring an overnight admission (the most common practice in the UK) with discharge the following day. Antibiotic prophylaxis is routinely administered before the procedure and continued for a variable period of 24 to 72 hours afterwards. Analgesia is required during the recovery period but may be self-administered as an outpatient and the post-procedural pain is usually limited in severity and duration, commonly requiring only non-steroidal anti-inflammatories.

There are recognised complications of the procedure, both generic and unique to the area being ablated – liver, lung or kidney. The risk of certain complications also varies according to the size and position of the lesion, its proximity to other structures and the experience of the operator. For the most part, RFA is an extremely successful method of providing focal tumour ablation and in skilled hands has a low and acceptable rate of complications. A multicentre study on over 2,000 patients undergoing hepatic RFA reported a mortality of less than 0.5%, and major and minor complication rates of 2% and 5% respectively.<sup>1</sup> Mortality was secondary to massive haemorrhage, bowel perforation, liver failure and septic shock. Major complications were haemorrhage, gallbladder perforation, bowel perforation and hepatic abscess. Pulmonary RFA has a higher complication rate, with complications requiring admission in over 10%, a pneumothorax incidence of 30% and a higher mortality rate of up to 4% in some reports.<sup>2</sup> Renal RFA appears safe, with most series reporting a zero mortality rate and a combined major and minor complication rate of less than 5%.<sup>3</sup>

# Requirements

## 1. Equipment

RFA probes and a radiofrequency generator are required. There are a number of different manufacturers, each having slightly different generators and probes. The generators have a variety of methods of enabling the operator to assess the adequacy of tissue damage being produced by the ablation treatment. The probes are also varied in design, some being water cooled and some measuring the local tip temperature whereas others measure the degree of impedance in order to determine treatment completion. The probe types are linked to the different generators. There is no evidence to suggest that any one particular probe is significantly better than any other.

**Recommendation:** The probes and generators chosen will in part be dependent on operator preference and the financial arrangement made by the institution and the supplier. It is often possible to negotiate arrangements on the cost and number of probes used, and the cost of the generator. It is probably beneficial to have more than one type of probe and generator available in any institution, both to enable competition among the equipment suppliers and to provide training using more than one probe. It is also possible that an operator may favour a particular type of probe for a particular lesion, but another probe for others.

## 2. Staff support

There are significant numbers of staff required to provide a successful and busy RFA practice. The service is most likely to run efficiently and successfully if a team of individuals, both medical and non-medical are involved.

Secretarial/clerical support is necessary to liaise with patients and referring clinicians, request scans performed elsewhere for review, book pretreatment and follow-up scans, arrange patient anaesthetic pre-assessment, book CT, MR or theatre sessions, retrieve medical notes and deal with correspondence. In institutions where there are large numbers of tertiary referrals, a clerical co-ordinator may be helpful in this regard. Facilities for the electronic transfer of images from referring centres will greatly aid the prompt initial assessment of tertiary referrals and accommodation into the local patient pathway.

Nursing staff are required, as with any form of interventional procedure. They may help with patient queries about the procedure, are essential to providing assistance during the procedure and may be involved in significant proportions of patient aftercare, including discharge and follow-up. Their role may vary among institutions. A busy service may consider the feasibility of a specialist nurse who develops expertise in this field and helps run the RFA service.

Radiographers familiar with both RFA and cross-sectional interventional procedures, particularly those performed with CT, are essential to enable accurate probe localisation.

Both cross-sectional and interventional radiologists perform RFA, and there are merits in each case. Independent of the specialisation, all individuals require adequate training. As far as possible, at least two consultants should be involved in service provision per centre. This enables joint discussion of more complex cases and allows continuation of service during leave or illness.

As procedures are performed under deep conscious sedation or general anaesthesia, an anaesthetist and an operating department assistant (ODA) are core team members. It is preferable to have a limited number of anaesthetists involved, so that they are familiar with the procedure, including patient positioning within CT or MRI, the potential complications, and the facilities available within the radiology department. The Royal College of Radiologists' guidelines on sedation and anaesthesia provide information on requirements for their safe provision.<sup>4</sup>

**Recommendation:** It is likely that the precise nature of staffing required by each RFA service will vary dependent on both the mix and number of cases. However, it is desirable that individuals are recruited into the service on a substantive rather than *ad hoc* basis so that they may become familiar with the patient pathways and facilities available and thus provide a timely and high-quality service. The numbers of staff and their time related to the service is likely to increase as the numbers of referrals and cases increase. The exact numbers of staff and their involved time is not prescriptive, but one case per fortnight when starting the service requires:

1. Consultant staff – equivalent to two programmed activities (PAs) per week
2. Secretarial/clerical – four hours per week
3. Nursing staff – four hours per fortnight
4. Anaesthetist and ODA – 4–6 hours per fortnight.

As the referral numbers and the length of time that the service has been provided increase, significantly more time is required than on a pro rata basis. A service providing weekly RFA for two patients requires at least one half-time consultant entirely devoted to service provision as a minimum and similar additional support. (This must also acknowledge the cumulative, post-procedural imaging burden, as image-guided ablation (IGA) is inherently a non-extirpative technique.)

### 3. Sessional/logistic support

Patients need to be seen as outpatients before the procedure either by the radiologist or a team member to explain the risks and benefits and to discuss any patient concerns. This may provide an opportunity for further imaging and assessment within the department. Patients requiring general anaesthesia will require an anaesthetic assessment. Access to pre-assessment clinics will greatly aid in the co-ordination of preoperative investigations and facilitate patient pathways, as day-case or overnight stay procedures.

The patients may be transferred after the procedure to a day-case bed – either within the radiology department or elsewhere within the hospital. Adequate day-case or overnight bed facilities are necessary, as are nursing staff familiar with potential interventional complications. Admission under a named clinician is necessary to provide overnight medical cover, and formal arrangements for this provision are needed prior to admission. The patient should be seen by a team member and carefully examined for any procedural complications before discharge.

Arrangements for outpatient follow-up are necessary where patients will need to be seen either by the referring clinician or by an RFA team member. There must be clear communication between the referring team and the RFA team regarding the procedure that has been performed and the follow-up that is required. Follow-up imaging may be performed either at the RFA centre or at the local referring centre and made available to the performing radiologist for assessment of treatment success, disease relapse or local recurrence amenable to further ablation. The local cancer network needs to ensure that clear guidelines exist for the management and follow-up of these patients.

**Recommendation:** To provide a comprehensive service, it will be necessary to negotiate access to a full range of pre- and post-procedure facilities. Units with a specialist interest in single organ ablation may not require some facilities. The lead radiologist for RFA should ensure that there are network guidelines for RFA referral and follow-up.

### 4. Time support

The provision of a successful RFA service is time-consuming. Ideally, radiologists who perform RFA should attend all the relevant multidisciplinary team meetings (MDTs) – liver/colorectal, lung, urology and bone – and be able to discuss the relative merits of image-guided ablation alongside other standard therapies. As this is unlikely to be achievable in all but a few centres, familiarity with the indications and success rates of RFA in these MDTs by an attending or chairing radiologist is appropriate. Clear guidelines should be disseminated across the cancer network regarding the referral of cases for RFA to the tertiary centre (see earlier). Following on from potential case selection, it is essential that all these patients are discussed at a MDT, even if it does not include all those involved in treating that particular tumour type. This is of critical importance in liver and lung RFA, as the role of chemotherapy, surgical resection and RFA frequently requires detailed discussion in relation to risks and benefits, the timing of the intervention and the potential if necessary for combined surgical and interventional procedures.

The provision of these inherently image-guided procedures has significant implications for cross-sectional imaging facilities. Departments undertaking this work will have to set aside time for dedicated CT and, eventually, MR sessions. Increasingly complex cases will require a four-hour CT session to carry out approximately two cases.

**Recommendation:** Timetabling in job plans to allow for outpatient consultation for discussing risks and benefits and consenting are necessary. Time for reviewing the patient after the procedure, at discharge and potentially at follow-up appointments is necessary. Time for follow-up imaging interpretation may be necessary.

### 5. Training

There are no formalised requirements for training, but it is recommended that a period of secondment at a unit providing the service occurs. This may be on a case-by-case basis if the trainee is a consultant at another institution, or may be for a block attachment at specialist registrar (SpR) level. As with all other radiological procedures, there is no guaranteed level of competence provided by observing and then performing a certain number of examinations. The number of examinations necessary to achieve competence will depend upon the trainee's core experience and competence either as a consultant or an SpR, but a minimum number of observed and then performed examinations is recommended. This will also vary depending on the service to be offered – hepatic, renal, lung, bone or a combination of them. For a consultant with significant previous experience of

targeted interventional procedures, a minimum of two live cases at a centre with appropriate experience should be observed.

A number of postgraduate training courses are provided by subspecialty societies such as the Cardiovascular and Interventional Radiological Society of Europe (CIRSE) and the European Society of Gastrointestinal and Abdominal Radiology (ESGAR). Post-competence training is also necessary and this is best achieved by performing a minimum number of ablations per year and auditing the results. The unit's outcomes should be made available to patients and referring clinicians. Attendance at continuing professional development (CPD) lectures and courses will also ensure that advances in the techniques available will be incorporated into local practice.

**Recommendation:** Initial training, familiarity with equipment and post-competence training are likely to become part of any revalidation process of radiologists offering a RFA service. All those involved in RFA should keep a database of referrals, procedures and outcomes.

## **6. Cancer Reform Strategy and extended waiting time standards**

As of December 2008, the extended waiting time standards in the Cancer Reform Strategy<sup>5</sup> came into force. For all subsequent treatments for patients with cancer, there is a 31-day deadline from the decision to treat and commencement of treatment. For RFA, most treatment decisions will be made at the MDT and it is at this point that the 31-day clock will start. To accommodate new patients, it would be difficult to meet the standard with a sessional frequency of less than one per week. Such a service will have important implications for cross-sectional imaging and should now start to be factored into CT and MR provision in centres deemed appropriate to provide IGA.

# Case selection

## **1. The National Institute for Health and Clinical Excellence (NICE)**

There is guidance available on the use of RFA for lung,<sup>6</sup> renal,<sup>7</sup> hepatocellular carcinoma (HCC)<sup>8</sup> and hepatic colorectal metastases<sup>9</sup> on the NICE website for clinicians and the general public. The guidance is supportive of the provision of RFA for these patients, but aside from HCC, recommends that RFA is performed in the context of appropriate clinical governance procedures, research and audit.

## **2. MDT**

All cases should be discussed at an appropriate MDT; this is clearly good practice and is mandatory from the NICE guidance. As discussed earlier, relevant expertise at MDTs is necessary. It is probable that patients suitable for ablative therapy are not referred because this is not considered during the discussion on therapeutic options or because the radiologist(s) that perform RFA are not present and able to suggest the treatment. As such, an increase in awareness of the scope and role of RFA is necessary among the radiological and clinical community. Guidelines regarding referring patients for RFA should be disseminated across cancer networks through the relevant site-specific groups.

# Service provision

## 1. Referrals

Direct referrals from physicians, surgeons and oncologists following outpatient consultations, referrals following an MDT discussion, general practitioner referral, and direct patient referrals may all occur. All these referrals should be channelled via the appropriate MDT. Direct tertiary referrals to radiologists from other centres also occur and should be reviewed once again at the tertiary MDT. The primary care trusts (PCTs) and commissioning groups need to be aware of these services, appropriate provision and costings.

## 2. Numbers of centres

The numbers of patients and procedures necessary to achieve competence have been discussed earlier. The numbers of patients referred into each current unit currently providing RFA is unknown, as is the potential number of patients that might benefit from the procedure. It is probable that RFA should be limited to centres that are designated for the specialist treatment of those tumours. This allows discussion of potential combination therapies, such as partial hepatic metastectomy and RFA, neoadjuvant chemotherapy and RFA, combined (chemo) embolisation and RFA, and so on.

It is likely that the numbers of patients that would benefit from ablation of hepatic metastases will exceed all other referrals. At present, it is estimated that up to 50% of patients with colorectal metastatic disease have liver-only metastases.<sup>10</sup> Approximately 20% of these patients are thought to be suitable for hepatic resection,<sup>11</sup> but the numbers of patients unsuitable for resection but potential candidates for RFA is unknown. The incidence of colorectal cancer in the UK is approximately 37,000 per year.<sup>12</sup> Nearly 14,000 of them would synchronously have, or metachronously develop metastatic disease.<sup>11</sup> Only about 10% of those with metastases undergo liver resection.<sup>11</sup> A conservative estimate would suggest that another 10% of these cases may be suitable for ablative therapy often as an adjunct to chemotherapy. RFA is also being used in conjunction with resection to extend the number of patients treated with curative intent. Additionally 50–60% of surgically treated patients will have disease relapse,<sup>11</sup> with the majority of these being local hepatic relapse; these patients may also be suitable for RFA.

Another consideration is the potential to retreat patients, further increasing the number requiring treatment. Perhaps the biggest potential increase in patients suitable for hepatic ablative therapy is due to the advent of the newer chemotherapeutic agents. These may make up to 30–40% of patients with organ-confined hepatic metastases previously thought untreatable for cure, suitable for either surgery or ablative therapy. Additionally, there is the potential for debulking hepatic metastases with RFA either pre- or post-chemotherapy, again significantly increasing the numbers of patients suitable for treatment. The recently reported CLOCC Trial (Chemotherapy + Local Ablation Versus Chemotherapy) – a randomised phase II study of local treatment of liver metastases by radiofrequency combined with chemotherapy versus chemotherapy alone in patients with unresectable colorectal liver metastases<sup>13</sup> – has just reported an interim outcome. This trial randomised 119 patients into two arms and has just reported one-year progression-free survival (PFS). The PFS in the RFA arm was significantly superior to the non-RFA chemotherapy-alone arm. If the CLOCC results are translated into standard clinical practice given the recent evidence on the numbers of patients that might benefit from RFA, the potential number of ablative therapies required for hepatic disease alone may be in the order of 7,000 to 10,000 patients annually.

As the incidence of cirrhosis rises in the UK,<sup>14</sup> the numbers developing hepatocellular carcinoma and those referred for RFA will increase. The number of patients suitable for renal ablation is also significant, with some centres increasingly ablating small (<4 cm) renal tumours as the primary procedure or in patients unfit for surgical resection. Up to a 100% successful ablation rate has been reported in patients with small renal tumours,<sup>15</sup> with up to a 90% successful ablation rate in larger tumours,<sup>15</sup> although recent reports in large series suggest the overall success may be less than this.<sup>16</sup> The impact of RFA on overall survival in patients with small renal tumours is less readily assessed than for hepatic or pulmonary RFA because of the potentially indolent nature of some small renal cancers, but where complete ablation has been achieved a five-year survival of 100% has been reported.<sup>16</sup>

It is also likely that the number of thoracic ablations is expected to increase significantly due to the increasingly aggressive treatment of paucimetastatic disease and inoperable non-small cell lung cancer. A recently published study (RAPTURE)<sup>17</sup> reported a greater than 50% five-year survival post-RFA for patients with colorectal pulmonary metastases. A further increase is likely as the role of IGA in the palliation of bone metastases expands. To treat this number of patients requires a significant expansion in both the numbers of centres providing ablative therapy and the numbers being performed in each centre.

**Recommendation:** Each cancer network should be encouraged to identify patient pathways for RFA within each tumour type, and preferably develop RFA services within the network, with the initial service provision from a centre already providing hepatic or thoracic surgery.

### 3. Baseline and follow-up imaging

Before treatment, each patient should have appropriate recent baseline imaging. Assuming the treatment is to be provided as a curative procedure, a multi-slice CT of the chest, abdomen and pelvis should be performed using an agreed scanning protocol. If this does not identify significant extra-hepatic metastases in patients being considered for RFA for colorectal hepatic metastases, a PET-CT should be performed. This should also be considered in patients for pulmonary ablative therapy, but is unnecessary in patients with HCC and renal cancer.

There is no defined accepted follow-up scanning protocol after RFA. A baseline scan performed shortly after the procedure is advisable and then scans at pre-agreed time intervals should be performed either at the referring institute or at the centre, dependent upon local agreement and likely tumour biology. MR may play an increasing role in this context.

**Recommendation:** The cancer network should agree and disseminate pre- and post-treatment imaging protocols.

### 4. Patient information

Written and online information should be provided for each of the types of procedures to be performed. This should be available in outpatients, with referring clinicians and local radiologists familiar with the information included. Patients should have easy access to a key worker who they can contact with any queries or requests for further information. Patients who are discharged after the procedure should have clear guidance about possible problems and what they should do in such a case.

**Recommendation:** Each centre should provide written and online information on each procedure.

# Audit and research

## 1. Audits

Each unit must regularly audit its own practice. The audit should include the number of patients considered for RFA and declined, as well as those accepted. The following parameters should be assessed:

1. The patient pathway
2. Complications – major and minor
3. The incidence of incomplete treatment and local relapse
4. Survival – disease-free and overall
5. Patient satisfaction.

The results of these audits should be made available to referring clinicians, patients, the trust clinical governance committees, and the cancer network.

## 2. Research

There are a number of unresolved questions regarding the use of IGA. It would be desirable that large centres, performing more than one case per week, were involved in active research, with co-ordination between centres to further research goals. Serious consideration should be given to establishing large multicentre randomised clinical trials to assess the role of RFA in clinical scenarios where the evidence in the literature at present is scanty and clinical equipoise exists. In future, participation of patients within such trials could be considered as an endpoint for audit.

# References

1. Livraghi T, Solbiati L, Meloni MF, Gazelle GS, Halpern EF, Goldberg SN. Treatment of focal liver tumours with percutaneous radio-frequency ablation: complications encountered in a multicentre study. *Radiology* 2003; **226**: 441–451.
2. Simon CJ, Dupuy DE, DiPetrillo TA *et al.* Pulmonary radiofrequency ablation: long-term safety and efficacy in 153 patients. *Radiology* 2007; **243**: 268–275.
3. Gervais DA, McGovern FJ, Arellano RS, McDougal WS, Mueller PR. Radiofrequency ablation of renal cell carcinoma: part 1, indications, results, and role in patient management over a 6 year period and ablation of 100 tumours. *Am J Roentgenol* 2005; **185**: 64–71.
4. The Royal College of Radiologists. *Safe Sedation, Analgesia and Anaesthesia within the Radiology Department*. London: The Royal College of Radiologists, 2003.
5. Department of Health. *Cancer Reform Strategy*. London: DH, 2007.  
[www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/dh\\_081006](http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/dh_081006) (last accessed 19/11/09)
6. National Institute for Health and Clinical Excellence. *Percutaneous radiofrequency ablation for primary and secondary lung cancers*. London: NICE, 2006.
7. National Institute for Clinical Excellence. *Percutaneous radiofrequency ablation of renal cancer*. London: NICE, 2004.
8. National Institute for Clinical Excellence. *Radiofrequency ablation of hepatocellular carcinoma*. London: NICE, 2003.
9. National Institute for Clinical Excellence. *Radiofrequency ablation for the treatment of colorectal metastases in the liver*. London: NICE, 2004.
10. American Cancer Society. *Cancer facts and figures*. Washington, DC: American Cancer Society, 1999: 1–8.
11. Simmonds PC, Primrose JN, Colquitt JL, Garden OJ, Poston GJ, Rees M. Surgical resection of hepatic metastases: a systematic review of published studies. *Br J Cancer* 2006; **94**: 982–999.
12. [http://info.cancerresearchuk.org/cancerstats/types/bowel/incidence/#age and sex](http://info.cancerresearchuk.org/cancerstats/types/bowel/incidence/#age%20and%20sex) (last accessed 19/11/09)
13. Ruers T, Van Coevorden F, Pierie J *et al.* Radiofrequency ablation (RFA) combined with chemotherapy for unresectable colorectal liver metastases (CRC LM): Interim results of a randomised phase II study of the EORTC-NCRI CCSG-ALM Intergroup 40004 (CLOCC). *Ann Surg Oncol* 2009; **16**(Suppl 1): 3.
14. Thompson Coon J, Rogers G, Hewson P *et al.* Surveillance of cirrhosis for hepatocellular carcinoma: systematic review and economic analysis. *Health Technol Assess* 2007; **11**: 34.
15. Gervais DA, McGovern FJ, Arellano RS, Scott McDougall W, Mueller PR. Radiofrequency ablation of renal cell carcinoma: part 1, indications, results, and role in patient management over a 6 year period and ablation of 100 tumours. *Am J Roentgenol* 2005; **185**: 64–71.
16. Kunkle DA, Uzzo RG. Cryoablation or radiofrequency ablation of the small renal mass: a meta-analysis. *Cancer* 2008; **113**: 2671–2680.
17. Lencioni R, Crocetti L, Cioni R *et al.* Response to radiofrequency ablation of pulmonary tumours: a prospective, intention-to-treat, multicentre clinical trial (the RAPTURE study). *Lancet Oncology* 2008; **9**: 621–628.

Citation details:

The Royal College of Radiologists. *Image-guided ablation*. London: The Royal College of Radiologists, 2009.

Ref No. BFCR(09)14 © The Royal College of Radiologists, December 2009

For permission to reproduce any of the content contained herein, please email: [permissions@rcr.ac.uk](mailto:permissions@rcr.ac.uk)

This material has been produced by The Royal College of Radiologists (RCR) for use internally within the National Health Service in the United Kingdom. It is provided for use by appropriately qualified professionals, and the making of any decision regarding the applicability and suitability of the material in any particular circumstance is subject to the user's professional judgement.

While every reasonable care has been taken to ensure the accuracy of the material, RCR cannot accept any responsibility for any action taken, or not taken, on the basis of it. As publisher, RCR shall not be liable to any person for any loss or damage, which may arise from the use of any of the material. The RCR does not exclude or limit liability for death or personal injury to the extent only that the same arises as a result of the negligence of RCR, its employees, Officers, members and Fellows, or any other person contributing to the formulation of the material.