European Society of Radiology

MAKING CANCER VISIBLE

THE ROLE OF IMAGING IN ONCOLOGY

INTERNATIONAL DAY OF RADIOLOGY

AN INITIATIVE OF THE ESR, ACR AND RSNA

Published by the
ESR – European Society of Radiology

In cooperation with
ESOI – European Society of Oncologic Imaging
October 2012

Coordination:
ESR Office, Neutorgasse 9, 1010 Vienna, Austria
Phone: (+ 43 1) 533 40 64-0
Fax: (+ 43 1) 533 40 64-441
E-Mail: communications@myESR.org
www.myESR.org

Managing Editor: Julia Patuzzi
Editors: Simon Lee, Michael Crean
Contributing Writers: Michael Crean (Chapter 5), Simon Lee (Chapter 3), Mélisande Rouger (Chapter 1+4), David Zizka (Chapter 2)
Art Direction & Layout: Robert Punz
Photo Credits: see page 94

The logo for the International Day of Radiology was been created with the help of the MR Center of Excellence in Vienna, Austria.
We would like to thank Prof. Siegfried Trattnig and Ms. Claudia Kronnerwetter for their valuable help.

Making Cancer Visible: the Role of Imaging in Oncology

An Introduction

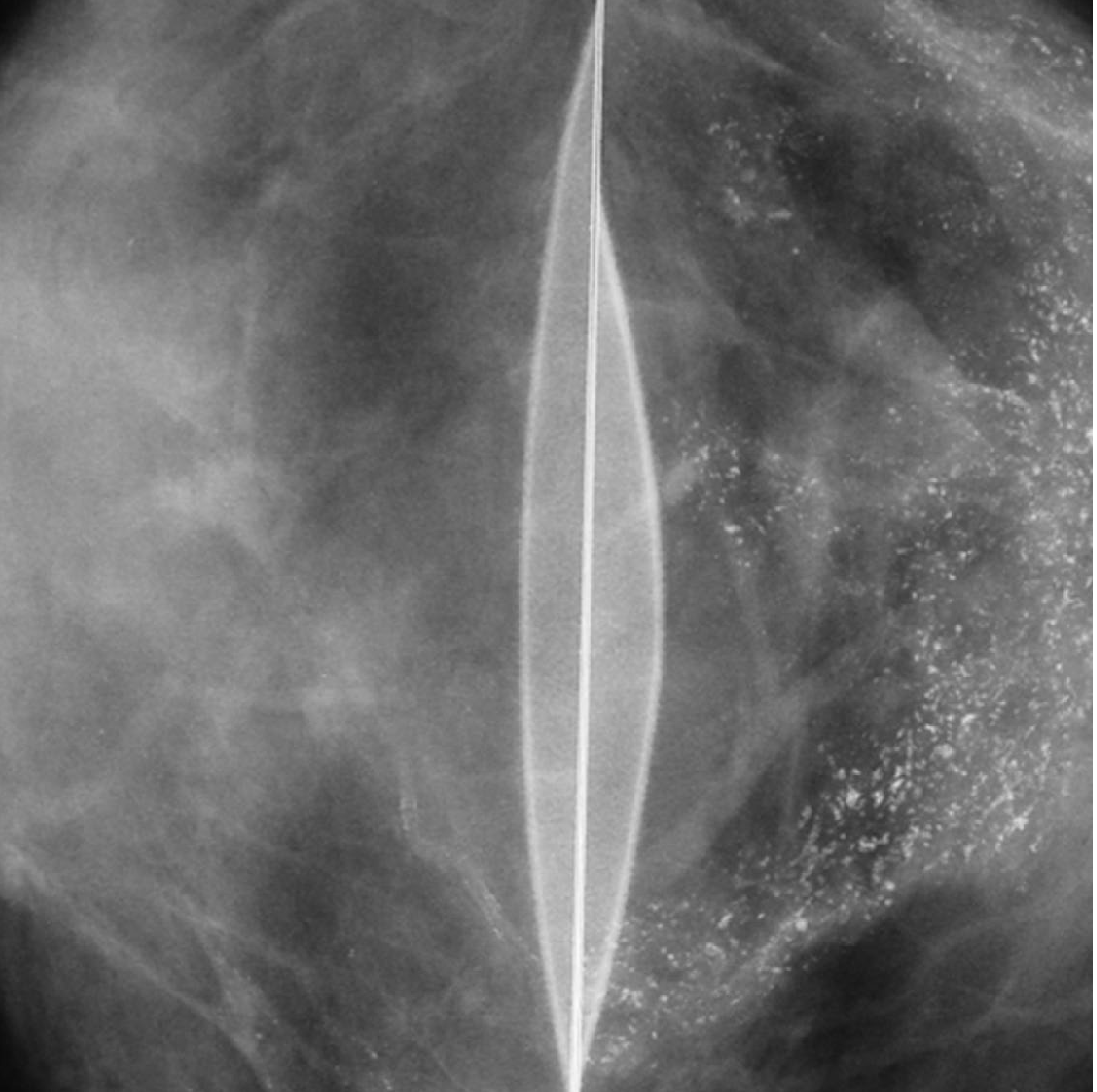
Cancer, in all of its more-than-200 forms, is one of the leading causes of death worldwide. According to the World Health Organisation, the disease accounted for around 13% of all deaths in 2008. Due to its high incidence, most people know something about the disease and, inevitably, the majority also know someone who has been afflicted by it. But its prevalence also makes cancer a very high priority for research and healthcare investment. Aside from the continuing search for a cure, huge global efforts are being made to improve the prevention, detection, and treatment of cancer, and a very large proportion of this progress is being made in the field of medical imaging.

Although oncology is the branch of medicine that traditionally deals with cancer, modern cancer care is a multidisciplinary undertaking, and specialists in medical imaging – whether they are radiologists or practitioners of nuclear medicine – are essential members of the team. The technological advances made in imaging equipment and the development of specific techniques for every stage of cancer care mean that the contribution of medical imaging, as well as the expertise of those who practise it, is indispensable.

This booklet, which has been produced especially for the first International Day of Radiology, aims to highlight the essential contribution imaging makes to five major steps in the cancer care chain: screening and prevention; detection; staging; treatment and therapy; and follow-up.

The whole booklet has been written with the generous assistance of 15 experts in oncologic imaging, from every continent, each of whom has provided their valuable input via short interviews. This material has been put together with the layperson in mind, but as an aid to the newcomer to radiology and medical imaging, we have included a glossary of terms at the back of the booklet.

We hope that this publication will provide some useful insights into the role of radiology and medical imaging in cancer care, and we sincerely hope it provides a few reasons to celebrate the International Day of Radiology with us on November 8.



Prevention & Screening

1. THE VALUE OF SCREENING IN CANCER CARE
2. NATIONAL SCREENING PROGRAMMES: OBJECTIVES AND REALITY
3. PATIENT INFORMATION
4. THINGS TO KEEP IN MIND BEFORE AN EXAMINATION IS CARRIED OUT
5. FUTURE DEVELOPMENTS

THE VALUE OF **SCREENING IN CANCER CARE**

Radiology's role is central to cancer management, with a wide choice of tools and techniques available for the detection, staging and treatment of the disease. But what is less well known is the value of medical imaging in recognising early manifestations of cancer and small clinically undetectable tumours before they become clinically apparent; a capacity that pushes radiology to the fore of oncologic care.

Medical experts agree that most cancers can be dealt with effectively if detected early. In this respect, imaging is, second only to lab tests, when it comes to the most valuable tools cancer care teams have at their disposal. In particular, different radiological tests have become very helpful in screening as they can show precancerous lesions before they become malignant and cause symptoms.

Early detection and prevention of disease has become crucial in the fight against cancer, especially in people at higher risk of developing malignancy, a part of the general population that will continue to grow worldwide in the decades to come.

> "Of course, there is no guarantee that radiology can prevent cancer before it is there, but it is of tremendous help in detecting pre-cancerous situations like colonic polyps and liver cirrhotic nodules. If we detect a tumour early, it may make treatment much simpler and cheaper and may even save lives."
>
> **Prof. Yves Menu, France**

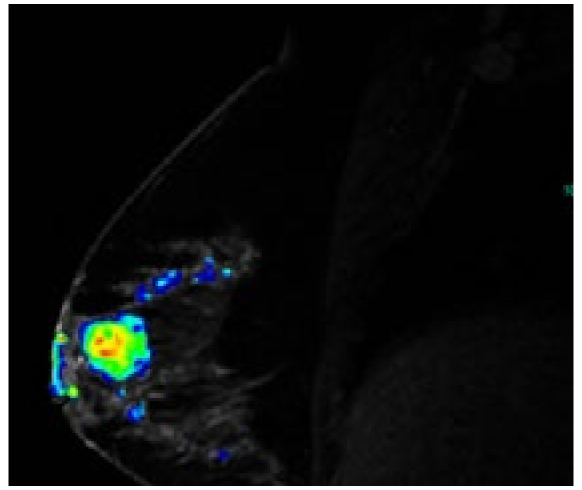
There are many ways for radiologists to identify the early signs of an individual developing cancer. Of the various tools available, those that use x-ray technology, such as mammography for breast cancer screening, are standard examinations. Recently, multidetector computed tomography (CT), a computerised imaging tool which is used to create 3D images based on x-rays, has shown its strength in applications such as colorectal cancer screening. Multidetector CT is now being used much more frequently in the detection of pre-malignant lesions, so-called polyps, in the large bowel, the discovery – followed by endoscopic resection – of which may significantly improve patient prognosis by prompting appropriate management.

The benefits of screening have been proven repeatedly since its introduction. Mammography screening has helped reduce breast cancer mortality by 30%, according to a recent study, which was conducted over almost three decades[1].

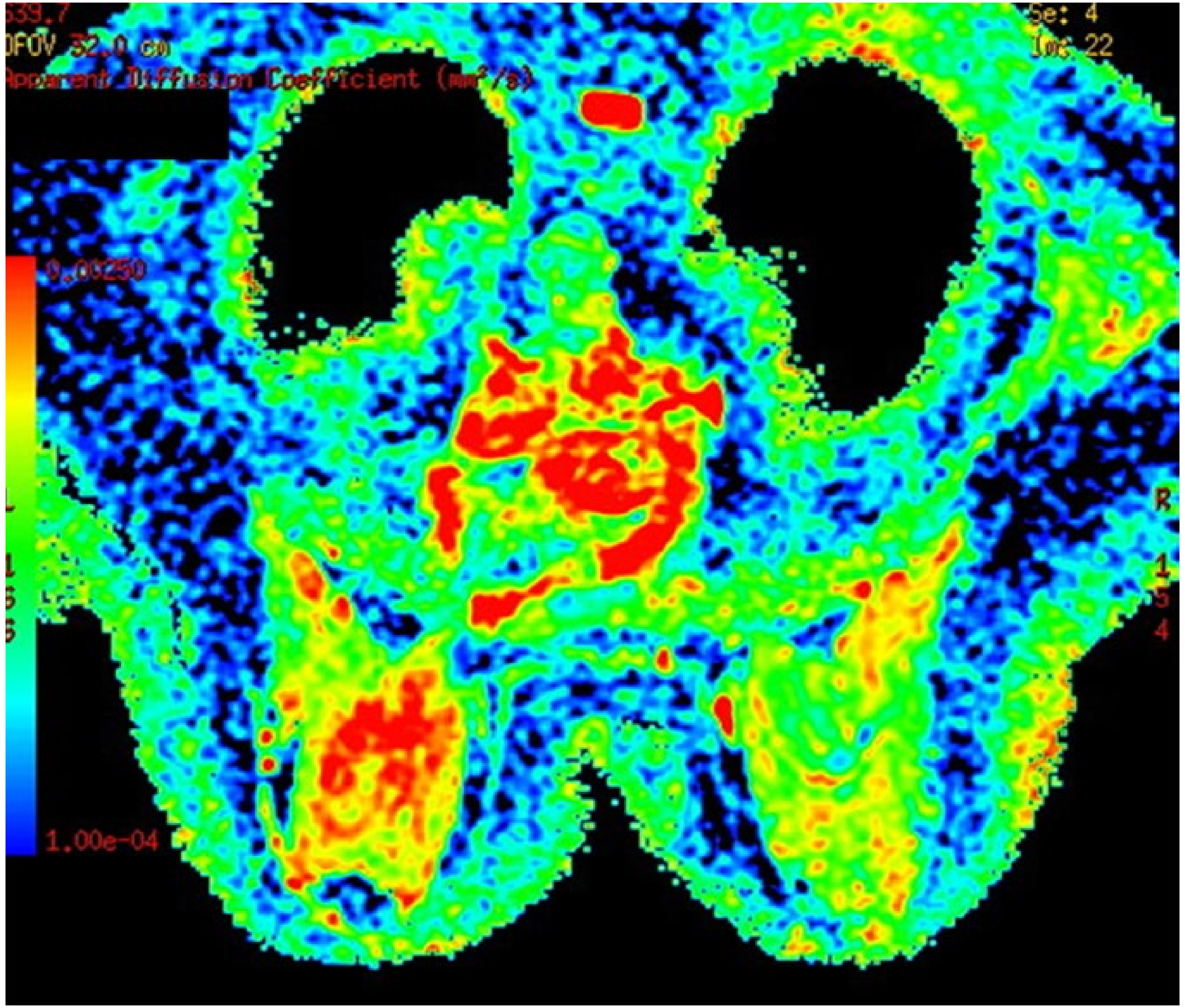
A recent National Lung Screening Trial (NLST) in the United States showed a reduction of 20% in lung cancer mortality among heavy smokers who were screened with low-dose spiral CT versus those screened with traditional chest x-ray.

> "This adds to existing successful imaging screening studies such as breast and colon. Without question, early detection of disease is greatly improved with imaging."
>
> **Dr. Reginald Munden, USA**

Dynamic Contrast-Enhanced MR image of breast cancer



[1] The study 'Swedish Two-County Trial' was published in 2011 in *Radiology* by Dr. László Tabár et al. The longest study ever conducted, it demonstrated that, 29 years after their first mammogram, women who were invited to get routine screening had a significant reduction in breast cancer mortality compared to those who received usual care.



NATIONAL SCREENING PROGRAMMES: **OBJECTIVES AND REALITY**

Most countries acknowledge the importance of running national screening programmes for certain groups of patients. However, today, the only widespread screening programmes are for breast cancer in women usually aged roughly between 40 and 74, who represent the group with the highest risk of developing cancer.

> "Large series seem to prove the benefit of such a screening, at least in a carefully selected population."
>
> **Prof. Yves Menu, France**

Screening practices vary considerably from one country to another. While Korea offers screening on a national level for stomach, liver, colorectal, breast and uterine cervix cancer, the most common types in that country, China and South Africa, for example, do not yet have any established national screening programmes. Most countries in America and Europe operate screening programmes for breast and cervical cancer, and many of those who have not already launched nationwide programmes for colorectal cancer are planning to introduce them soon. Lung cancer is also under evaluation as a possible subject of screening in many countries.

Setting up a national screening programme is a complex task, partly because it is difficult to define precise target groups with age limits, similar clinical histories, and various other characteristics. Guidelines for screening are determined locally and based on the resources of healthcare systems, the health concerns of the population, and cultural attitudes and priorities.

High rates of under-reported disease present another challenge in collecting clear and reliable figures, while restricted access to the latest technology remains a problem in many parts of the world. The absence of adequate tools for detecting early or precancerous conditions is all the more alarming in poorer countries, where cancer incidence is expected to increase by as much as 90% by 2030, according to a recent study[2].

> "In most developing countries, access to screening is extremely limited or even non-existent. Given that cancer incidence is expected to rise dramatically in some of these countries in the coming decades, the global medical community should work together to define minimum screening recommendations for all countries and to provide the necessary resources – including equipment and training – for essential screening programmes."
>
> **Prof. Hedvig Hricak, USA**

[2] The study 'Global cancer transitions according to the Human Development Index (2008–2030): a population-based study' was led by Dr. Freddie Bray of the International Agency for Research on Cancer (IARC) and published in *The Lancet Oncology* in June 2012.

PATIENT **INFORMATION**

Without such global guidelines or nationwide screening programmes, it is all the more important to provide clear recommendations to patients. Some people are more at risk than others due to their clinical history or family background, and doctors can advise them on how to proceed to avoid any future complications.

> "People who have high risk factors, such as a family history of particular cancers and some related gene carriers, should be screened."
>
> **Prof. Feng Feng, China**

It is generally accepted that people aged over 55, with a smoking history of one pack per day over 30 years, and former smokers, who have quit within the last 15 years, should be screened for lung cancer. For women with a lifetime cancer risk of 20% or greater, for instance women with a genetic risk, a breast examination with magnetic resonance imaging (MRI) is recommended. People with liver cirrhosis and/or hepatitis B or C virus should be screened to detect any signs of liver cancer.

People can obtain information about screening from their general practitioners, gynaecologists, urologists, and any other specialist, who should be able to advise when to screen and for what. Some patients may also benefit from their companies' medical insurance, which in some countries may cover the annual health-check for their employees over a certain age. The success of screening depends entirely on how well-informed the public is and on the health policies of each country.

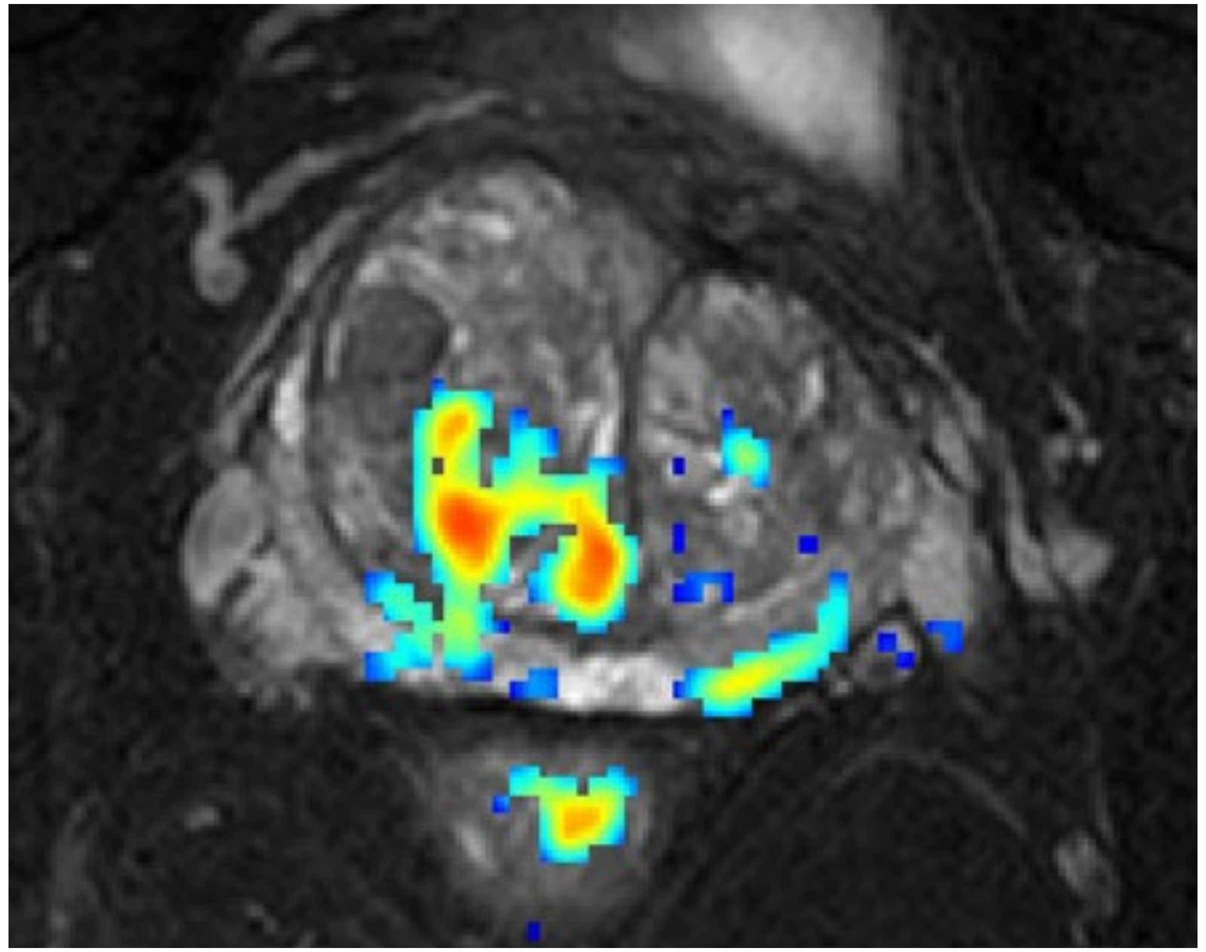
> "Providing the public with complete information is really a key issue for the success of a screening campaign. Having the patient as a partner makes everything easier."
>
> **Prof. Yves Menu, France**

Public awareness campaigns play a major role in this dialogue, and the participation of institutional partners is highly desirable. Healthcare stakeholders and cancer patient societies should be incorporated into these campaigns.

Information is also key to improving public healthcare. The more informed the public is, the likelier they are to push their governments to take action.

> "A lot depends on the educational level of the population. Unfortunately, in developing countries, there are still great challenges to achieving a satisfactory level of understanding of these issues. The population needs to be informed about the importance of imaging in cancer screening programmes, in order for them to be able to demand health authorities to set up such programmes."
>
> **Prof. Marcos Duarte Guimaraes, Brazil**

Diffusion cellularity map reflects the probability of cancer in the central prostate gland.



THINGS TO KEEP IN MIND **BEFORE AN EXAMINATION IS CARRIED OUT**

Cancer screening undoubtedly brings benefits, when it leads to the identification of cancer before it poses a real danger and requires intensive and often expensive treatment. But one should also be aware of the risks that are associated with imaging examinations.

Mammography, for instance, involves a small amount of ionising radiation, which can have a potentially carcinogenic effect. Because it also uses x-ray technology, CT is not a risk free procedure either. However, radiation risks remain very low and must be weighed against the benefits brought by the examination.

> "Disadvantages are minor compared to the lives saved by the technology. Most radiological tests used for early detection of disease have no or minimal side effects that are greatly outweighed by the benefits."
>
> **Prof. Anno Graser, Germany**

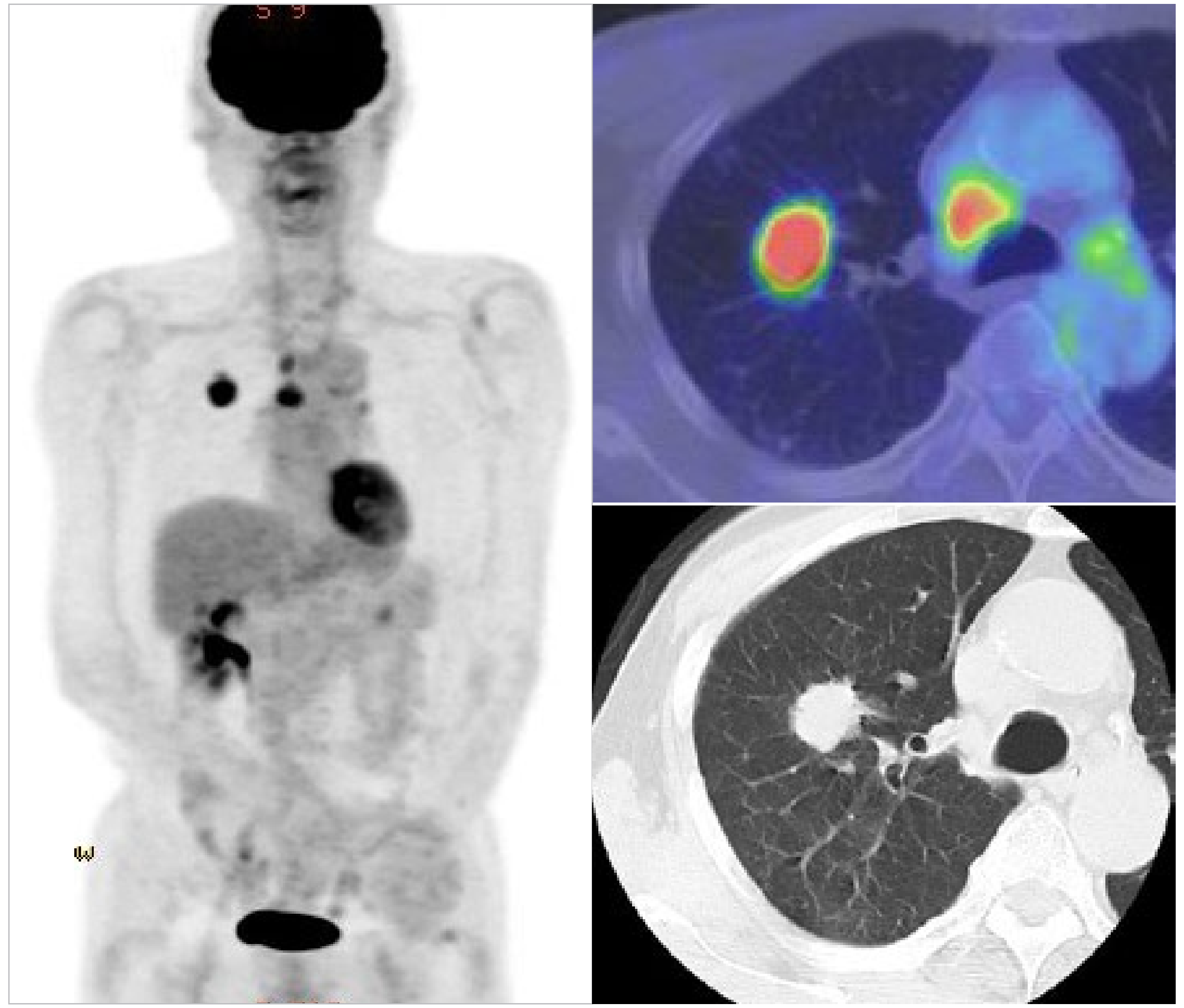
Some examinations, like mammography, may also cause discomfort to patients, because they will have a device pressed firmly against their bodies. The use of contrast products, media swallowed or injected into the body to enhance the contrast of an image, may also cause allergies and kidney dysfunction in sensitive patients. On the other hand, ultrasound examinations used in ovarian cancer screening, for example, have no side effects at all. As for multidetector CT colonography, it causes much less discomfort than conventional colonoscopy in screening for colon cancer, and can be carried out much more rapidly.

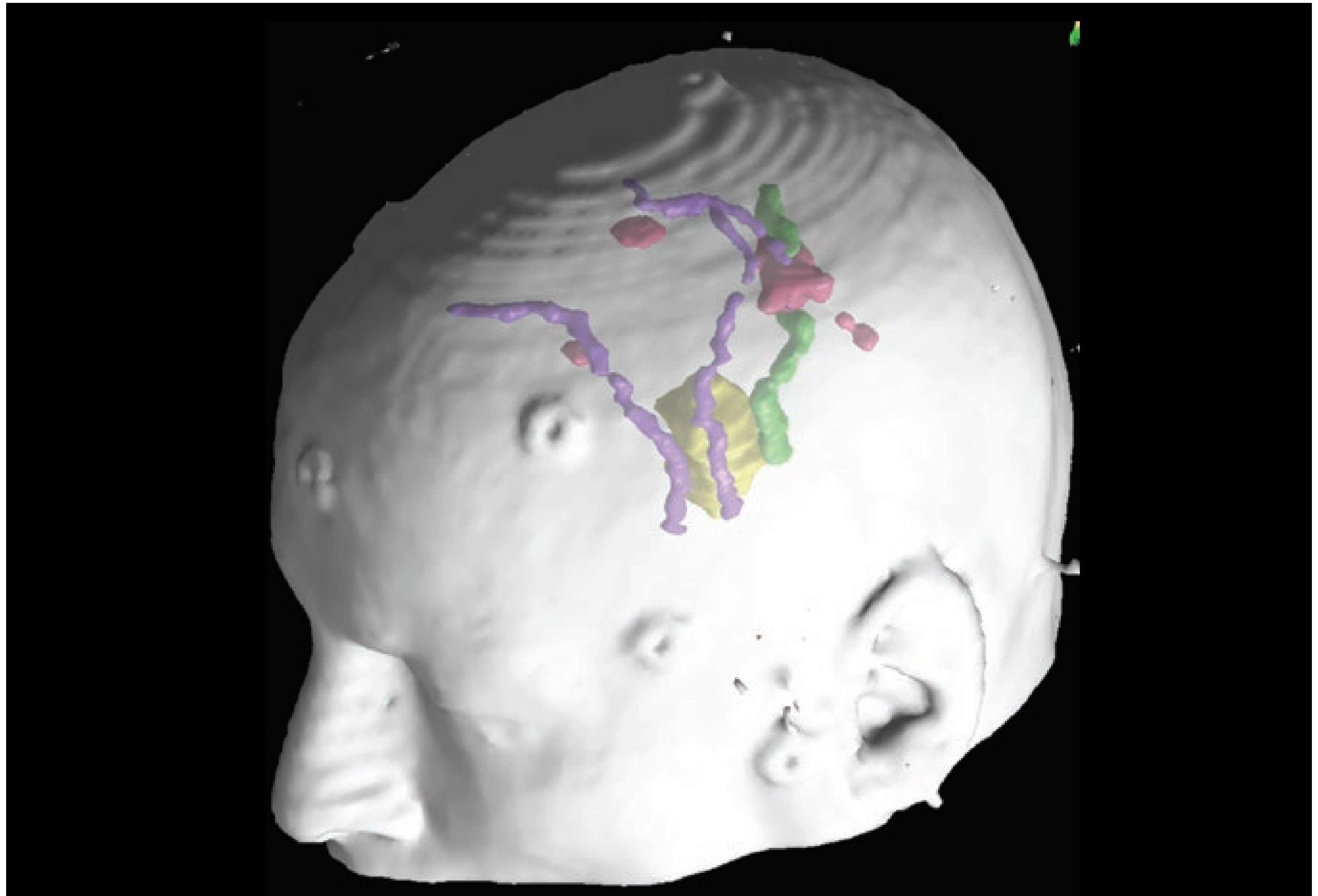
Finally, one should not underestimate the risk of false positive diagnosis and the series of costly examinations it can trigger. A false positive result indicates that a person has a given condition when they do not. For instance, a cancer test might return positive when the person is actually healthy.

> "False positive diagnosis may result in over-investigation of what ultimately turns out to be a benign condition. This can in turn result in unnecessary anxiety in the patient and unnecessary costs."
>
> **Dr. Adriana Dieguez, Argentina**

The best option for patients is to discuss all these issues directly with their doctors, who should inform them of all the possible risks, as well as the benefits, before deciding to undergo screening tests. Patients should know that screening is not perfect; it may not detect every cancer, but it can detect cancer early enough to achieve remission.

^{18}F-fluorodeoxyglucose (FDG) PET-CT of lung cancer with mediastinal lymph node metastases





A 3-dimensional image from a neurosurgical navigational system, which allows the neurosurgeon to see functional information during the operation. The tumour is in yellow. The motor cortex (the part of the brain that controls motor function) is in red. Purple indicates the large veins overlying the surface of the brain.

FUTURE DEVELOPMENTS

Imaging techniques have significantly improved in recent decades. As technologies are constantly being refined, imaging modalities will become even more accurate and reliable in the future. Low-dose chest spiral CT in lung cancer screening is very promising. But there are still enormous challenges and questions to be answered before this technique can be approved for use around the world. One of the main problems remains the significant disparity in access to and use of tools for prevention and early detection of cancer.

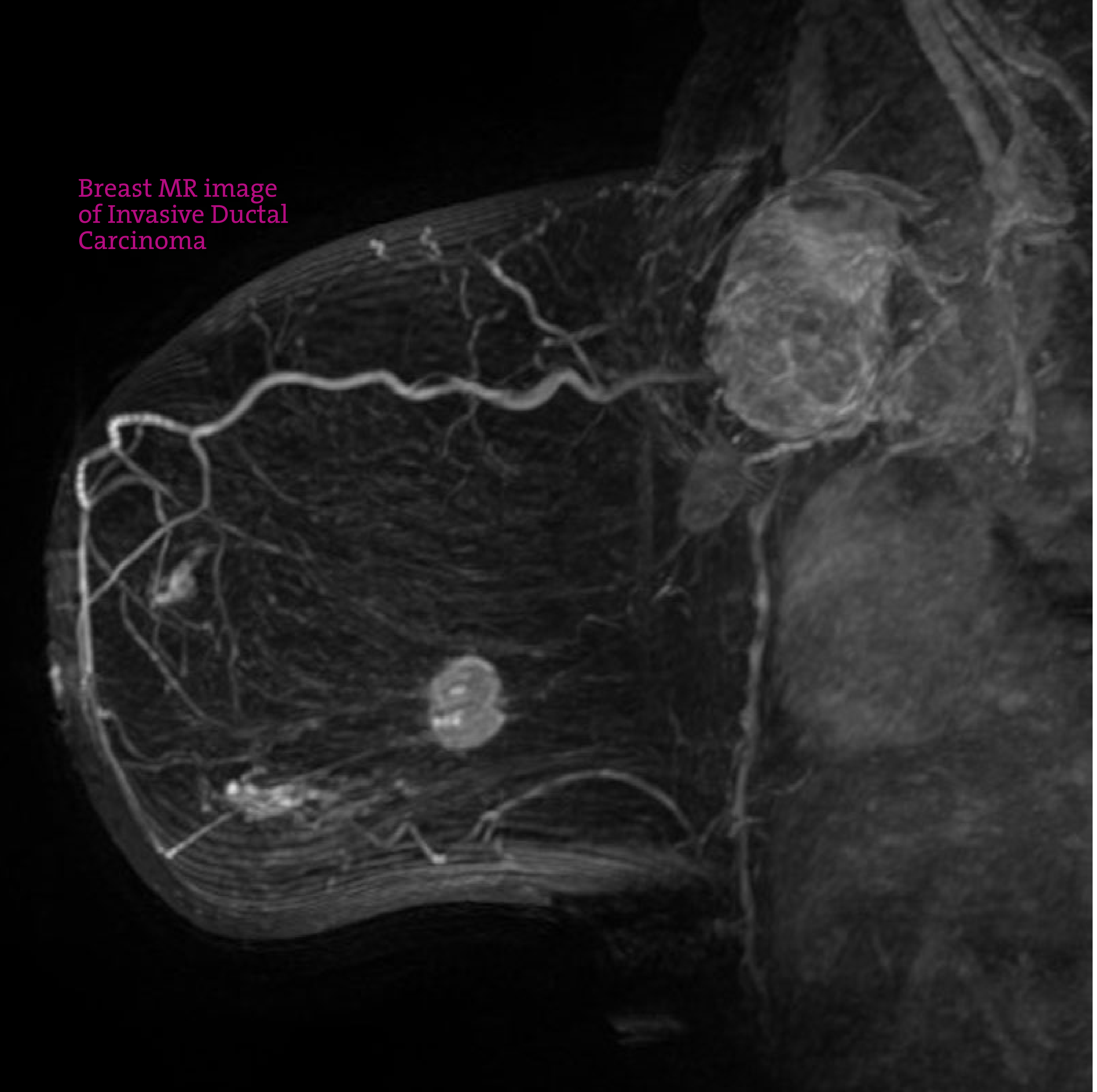
> "It is desirable to develop strategies to enable new technologies to be implemented universally in order to reduce mortality."
>
> **Dr. Adriana Dieguez, Argentina**

Radiologists are increasingly using radiation dose reduction strategies, which minimise the potential risks of radiation in x-ray-based imaging modalities without compromising image quality. Computer-aided detection and diagnosis systems can reduce the rate of missed cancers and may also help to characterise early lesions. Researchers are also working on ways to identify high-risk subjects, based on molecular or genetic studies, which may enhance screening effectiveness.

Cooperation with other medical specialties is key to these achievements. Radiologists already work in multidisciplinary teams to treat cancer patients. Close collaboration with other specialists, for instance biologists, physicists and doctors of nuclear medicine is fundamental to the development of new screening tools. As is the case in many other areas of medicine, the current trend in screening is toward personalisation, to find out the individual's risk of cancer, based on very specific biological tests.

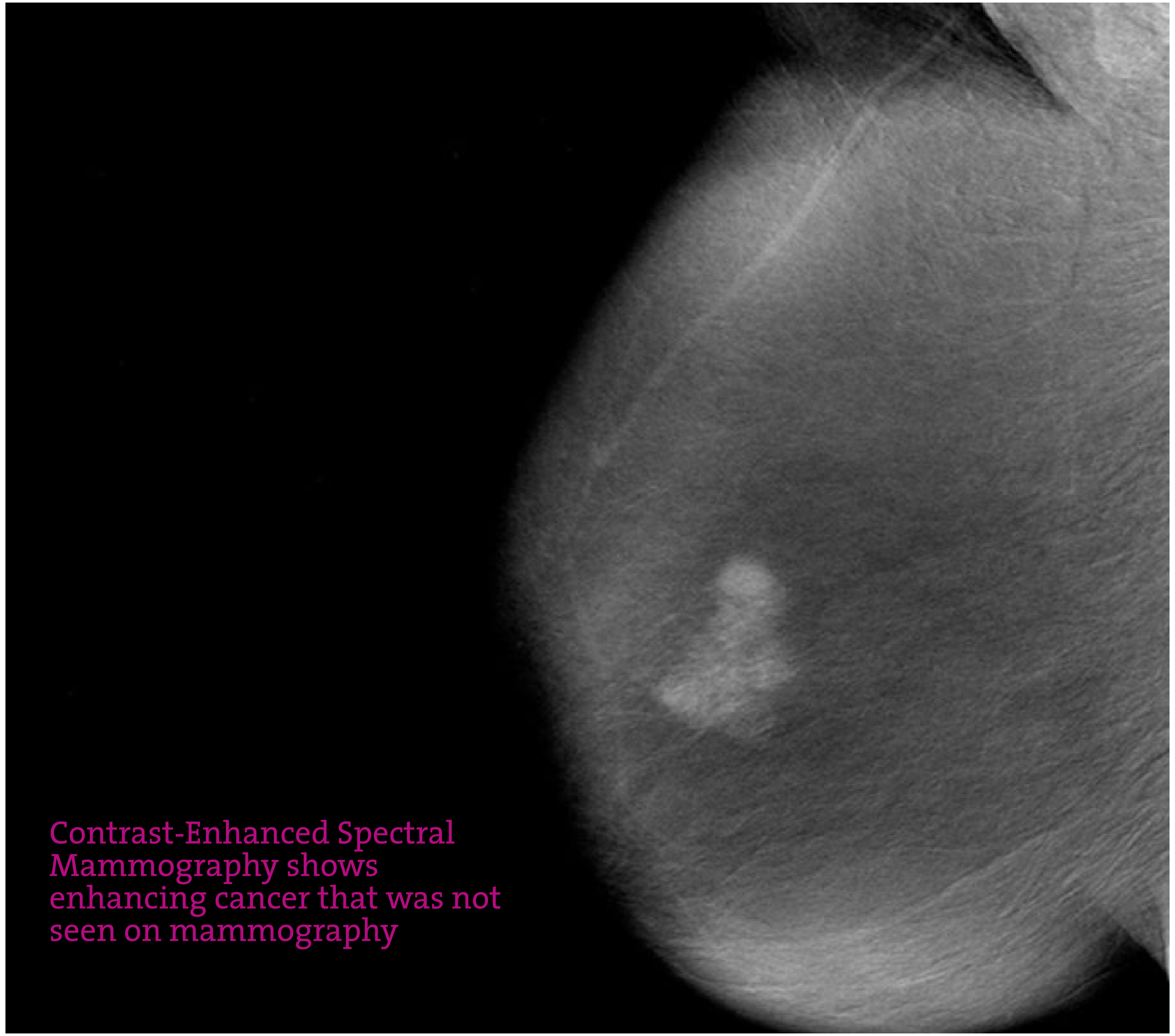
> "We all know that some people are more predisposed to some cancers, and we should maintain our progress in the ability to propose to the individual a screening programme that is tailored, rather than a 'mass product'."
>
> **Prof. Yves Menu, France**

In addition to the benefits brought by imaging, diet and obesity management, as well as environmental and lifestyle modifications, may also help to prevent cancer in the future.



Breast MR image
of Invasive Ductal
Carcinoma

Detection



Contrast-Enhanced Spectral Mammography shows enhancing cancer that was not seen on mammography

MEDICAL IMAGING IN THE **DETECTION OF CANCER**

Imaging plays a major role in the detection of cancer as it provides a detailed insight into the exact location and extent of the disease. It can also provide detailed information about structural or cancer-related changes. Emerging methods of molecular imaging, which combine traditional imaging technology and nuclear medicine techniques, can also be used to obtain more detailed information about abnormalities, including their distinct metabolism.

There are various ways to detect cancer using imaging methods. Cancer may be detected incidentally, when an examination is carried out for other reasons, or there may be clear symptoms and the patient may undergo imaging to confirm, locate, and determine the extent of the disease. Another possibility is of course the detection of a malignancy while participating in a screening programme.

> "Certainly radiology is by far the best method for cancer detection in the majority of cancers. However, the vast majority of tumours are only apparent with an advanced test, especially at the initial stage, and radiology is certainly the major player."
>
> **Prof. Yves Menu, France**

Modern medical technology offers a wide range of imaging methods to imaging specialists. Well known methods used for the detection of cancer are ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI) and mammography, the latter being used specifically to detect breast cancer.

> "The technique of choice depends on the type and site of the cancer. All of these modalities provide cross-sectional anatomical images. US and CT are generally less expensive and more widely available than MRI and are therefore used more frequently around the world."
>
> **Prof. Hedvig Hricak, USA**

In many cases cancer is identified based on the discovery of abnormalities in the appearance of soft tissue and bone. But there are also functional imaging techniques, which detect physiological or functional changes, such as specific changes in blood flow that can also signify the presence of cancer.

A very promising set of imaging techniques are available to radiologists through the methods of molecular imaging, which differs from traditional imaging in that biomarker probes are used to target specific areas or suspicious findings. In general, a biomarker is anything that can be used as an indicator of disease or changes in the human body, which interacts chemically with its surroundings to produce an effect that can then be seen on the screen. In comparison to other methods which show changes in size, density or water content, the radiologist can observe molecular changes, which opens up a completely new field of possibilities such as earlier detection and better understanding of tumour development. One of the most promising molecular imaging techniques is positron emission tomography (PET), which is most often combined with CT (PET-CT) and used to track probes in order to detect metastatic disease.

When it comes to the characterisation of a finding, or the differentiation between a malignant or benign abnormality, it is sometimes difficult to reach a final diagnosis. To avoid unnecessary invasive procedures and save the patient further discomfort, a comparison of various images, often obtained through different methods, is the first step towards a final diagnosis. If a definite diagnosis still cannot be made, a biopsy, where small parts of the abnormality are collected for further examination, is necessary.

Side-effects may occur and vary depending on the method used and the area of the body to be examined. The use of contrast agents may cause allergies and may pose risks to patients with renal insufficiency. Techniques such as US and MRI do not entail any radiation exposure and are generally considered to be very safe. In some situations however, MRI is not recommended, for instance in patients with a pacemaker or other metallic implant, because of the magnetic field used during the examination. Methods like x-ray and CT, on the other hand, expose the patient to ionising radiation. Radiologists always use the lowest radiation dose possible to get the desired results and modern imaging devices are constantly being improved to generate higher resolution images while significantly decreasing the amount of radiation and exposure time.

> "Effects on the patient can be considered as related to discomfort during the test, use of contrast agents, irradiation and directly invasive tests such as biopsies. Radiation effects are from ionising radiation from x-ray and CT. Effects are proportional to the dose of radiation and cumulative effects of multiple examinations although these are seldom relevant in daily practice."
>
> **Dr. Jean de Villiers, South Africa**

THE ROLE AND THE SKILLS OF THE RADIOLOGIST

The radiologist is likely to be the first person to detect a tumour based on either clear symptoms or previous suspicions. Imaging specialists also detect cancer during routine screening and are the most experienced physicians in choosing from a wide range of available imaging techniques in order to get the best results. When a tumour or an abnormality is detected, the first task of the radiologist is to identify the exact location of the tumour and the extent of the disease. After the detection of cancer, the radiologist interprets the cross-sectional images of the patient, makes the diagnosis and determines the stage and extent of the disease based on their findings.

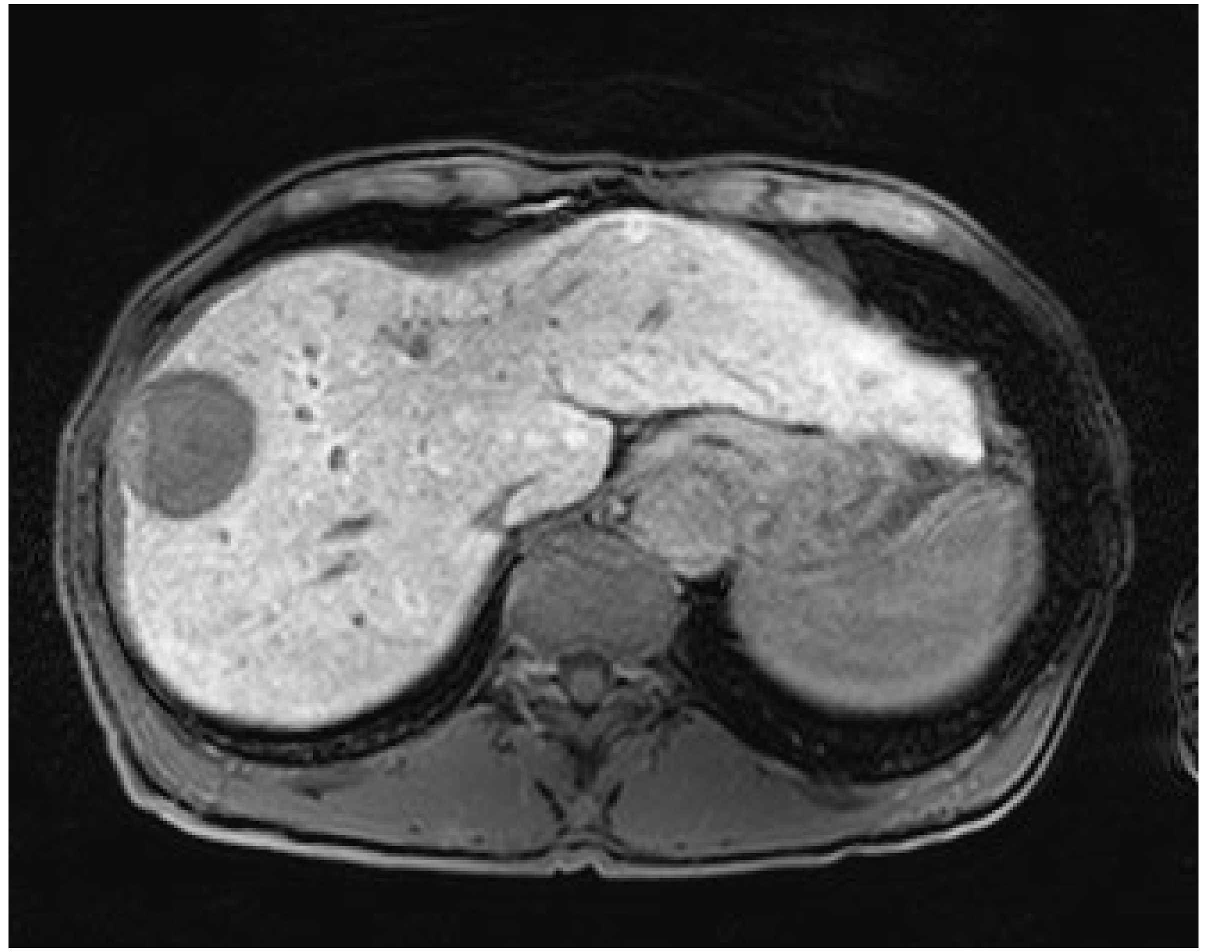
> "Image interpretation is the most visible contribution of radiologists. Diagnosis by expert radiologists is based on the extensive knowledge of anatomy, normal variations, pathology and technical principles of the imaging modality."
>
> **Prof. Hiroshi Honda, Japan**

A radiologist is not only an expert in the field of imaging techniques, but also an expert in understanding the patterns and appearance of cancer in various body parts and organs as well as ways of local and distant spread of different tumours, so-called metastases.

When it comes to cancer, patient care is a team effort and not the work of a single doctor. A multidisciplinary approach and good teamwork between the various physicians are crucial to the successful care of cancer patients from detection to treatment and follow-up. The role of the radiologist is not limited to the phase between detection and diagnosis but extends further, as radiology will also be involved in the choice of therapy, its monitoring, delivery, and follow-up. In hospitals especially, a multidisciplinary approach to the fight against cancer is very common and radiologists frequently work in a team together with other specialists.

> "A lot of communication takes place with the clinical oncologists and surgeons, usually in the context of regular multidisciplinary committee meetings. However, it is good practice to communicate with colleagues who have referred patients for examinations and, obviously, are in charge of the patient. This communication can be by telephone, e-mail or videoconference."
>
> **Dr. Adriana Dieguez, Argentina**

Detection of hepatocellular carcinoma



Characterisation of equivocal ultrasound findings (not shown) with CT. CT of the kidney shows a cystic structure in the left kidney (white arrow). However, this is not a simple cyst. CT demonstrates a solid nodule (green arrow), which is suspicious for a cystic cancer.

THE COMMUNICATION FLOW

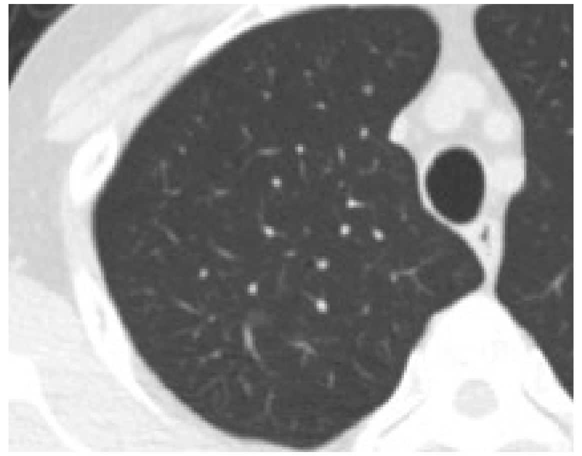
When the final diagnosis is reached and clarified, the next step is to inform the patient of their condition and the further steps and treatment options available. At this stage, the role and the involvement of the radiologist vary and are strongly dependent upon the local situation. In most cases it is referring physicians who will inform the patient about the results, as they are generally the people who have the most detailed knowledge of the patient's medical history. There are also cases, where the final diagnosis can only be reached by performing a pathological test, which excludes the participation of a radiologist. But the conventional background role of the radiologist is changing slightly as the multidisciplinary approach and patients' demands make the radiologist more and more involved. When working in multidisciplinary teams, the attending physician often requests that the radiologist be present when the patient is informed of a finding, so that specific questions regarding imaging can be answered by a specialist.

The radiologist is in many cases the first person to detect a tumour, but rarely the one who informs the patient. But the radiologist is still left with a degree of personal responsibility as the patient has to be advised to see their attending physician quickly to discuss their diagnosis and further options. He should make it clear to the patient that they should seek further treatment and see their doctor. In these situations, patients might also ask the radiologist directly for clear information.

"For instance, if a cancer is detected, the patient should be very clearly encouraged to consult his referring clinician very soon in order to organise the medical strategy. More and more the patients ask for clearly shared comprehensive information. However, this is not a simple situation, because it may change the patient's life, so the way the information is communicated should be considered very carefully."

Prof. Yves Menu, France

INFORMING THE PUBLIC



Computed tomography image of the chest using low radiation dose

With imaging being one of the major players in the fight against cancer, it is imperative that the public be well informed about its benefits and possibilities. The early detection of cancer, its prognosis and detailed information about the extent of the disease wouldn't be available to patients without medical imaging. All further treatment decisions are based on these findings.

There is also a need to inform the public about the wide range of imaging techniques available and which are the best diagnostic tests for a specific cancer or condition. More recently developed methods such as PET-CT are not well known to patients, but bring crucial benefits to the field of oncologic imaging.

Information on the availability of the different methods, whether they are available at all or only in specialised hospital departments, would make it easier for patients to consider their options when they have to undergo a specific procedure. It is also in the public's best interests to be aware of the specific costs of imaging and whether a referral is needed if they want to see a specialist or undergo a specific imaging examination.

Besides all the information on the benefits of modern imaging, the public should also be made aware of the possible disadvantages and side effects which go hand in hand with some techniques. Some methods expose the human body to larger amounts of radiation than others and some such as ultrasound and MRI use no radiation at all. It is important for patients to be aware of those facts in order to understand why the radiologist has to decide in each individual case which method is the most appropriate. This is particularly important for patients with special conditions, who may for instance be allergic to contrast agents or have metal implants, in the case of MRI examination. Pregnancy also limits the use of some methods.

> "The population should be informed about the importance of imaging in cancer detection. Thus the population will be able to require that health authorities take action aimed at implementing cancer detection."

Prof. Marcos Duarte Guimaraes, Brazil

FUTURE **DEVELOPMENTS**

Medical imaging strongly depends on technology, so progress and further developments in the field of imaging technology are vital to the progress of the discipline itself. Over the last 40 years, there have been major innovations in the field of medical imaging, such as CT and MRI, which currently achieve a high level of diagnostic accuracy and spatial resolution when combined with the methods of molecular imaging, which is for many radiologists the most promising tool for the future.

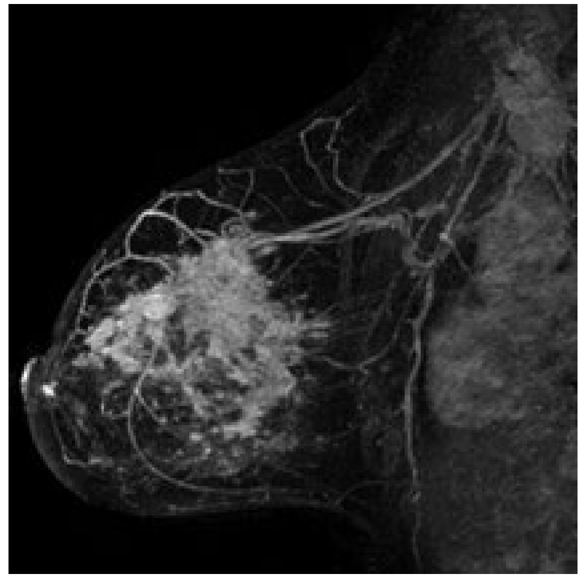
The very early stages of cancer and other illnesses should then become detectable using customised biomarkers which can detect the smallest traces of the disease. The use of radiolabelled glucose in combination with PET, which is able to produce a 3D image of a functional process in the body, has become an integral part of cancer diagnosis. As tumours or inflammation use up high levels of glucose, the radiologist can easily track the location and spread of the disease.

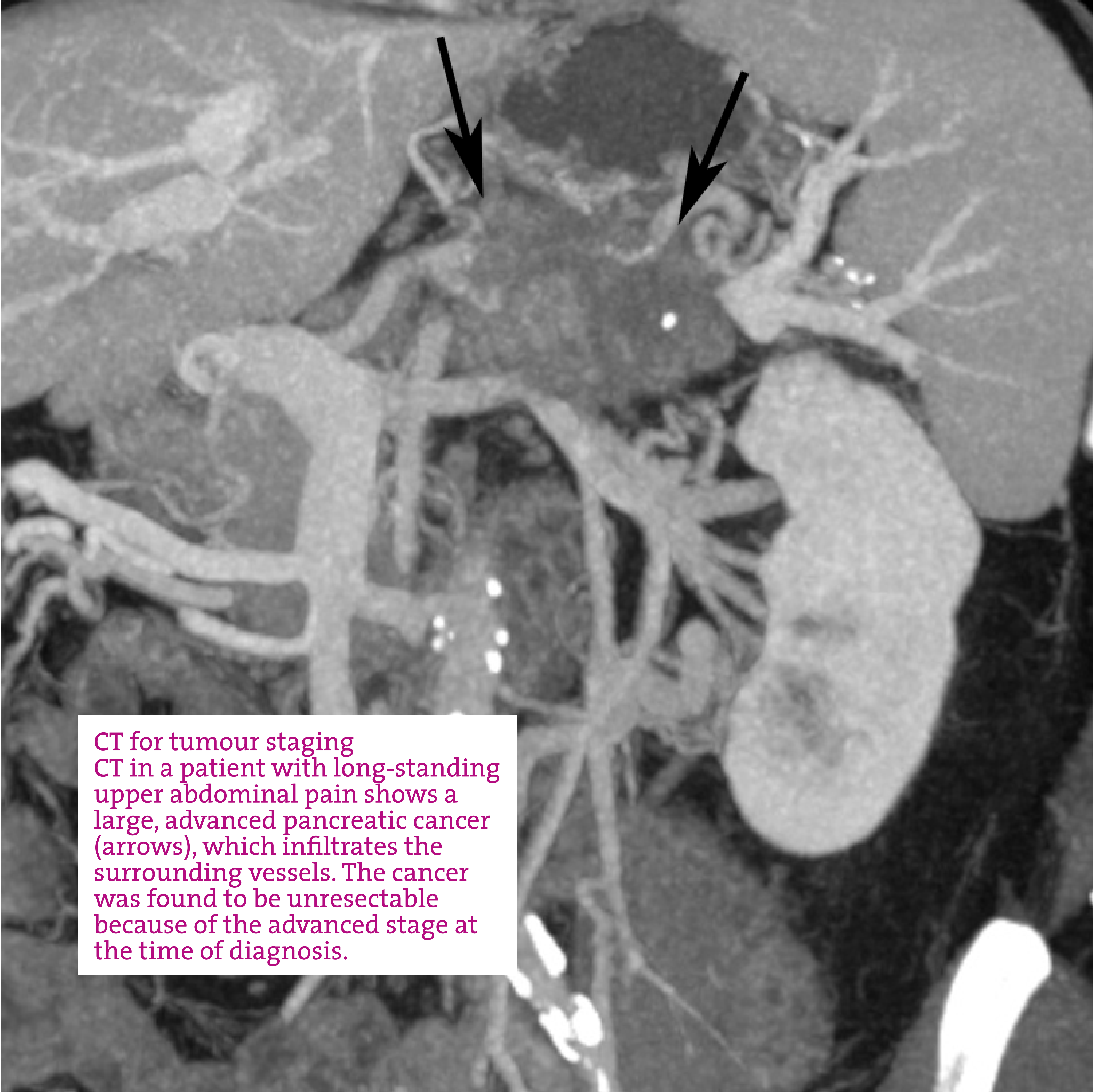
But it is not only newly developed methods that bring about improvements in cancer detection; established methods such as MRI also have a lot to offer. At the moment most MR devices operate at a magnetic field-strength of 1.5 and 3 Tesla, but in experiments strengths of up to 11 Tesla have been achieved and provide extremely high quality images. Diffusion-weighted imaging, which allows the mapping of the diffusion process of molecules, has already shown some very positive results, and will certainly see further developments that will aid understanding of the function, structure and evolution of tissues like cancer when treatment is administered.

It is of course hard to predict how new methods or devices will influence oncologic imaging and when patients will benefit from it. What can be said for sure is that imaging will become an even more powerful cancer detection tool in the future especially when biomarkers and molecular methods have been developed to their full potential.

> “PET-MR is a cutting-edge imaging modality and has been released by some vendors very recently. Compared to PET-CT, PET-MR provides a better background image with improved soft tissue contrast without radiation exposure. Moreover, integration of molecular and functional information generated from PET and MR could provide useful information in characterising the cancer.”
>
> **Prof. Hiroshi Honda, Japan**

Breast MR image of Invasive Lobular Carcinoma





CT for tumour staging
CT in a patient with long-standing upper abdominal pain shows a large, advanced pancreatic cancer (arrows), which infiltrates the surrounding vessels. The cancer was found to be unresectable because of the advanced stage at the time of diagnosis.

Staging

THE IMPORTANCE **OF STAGING**

There are many clinical factors that might raise the initial suspicion of cancer, and there are various methods used to confirm its presence in one form or another. The actual diagnosis of cancer is generally made through laboratory tests of a tissue sample collected through biopsy or surgery, the need for which is usually determined by blood tests, imaging, or both. So, imaging alone cannot provide definite diagnosis, but it very often helps doctors to reach their conclusion.

As the previous chapter explained, radiology provides vital tools for detecting and characterising tumours that have been evidenced via other methods, but it is also extremely useful in taking the next step. Being able to visualise the exact location of a suspected tumour allows doctors to closely examine the surrounding area, providing a first impression of whether or not any potential cancer may have spread, and if so, how far. Not only does this mean doctors can visually pick the best point in that area for the biopsy sample to be taken from, but it also provides the first hints as to the 'stage' of what may later be confirmed as cancer.

"Once a histologic diagnosis is made, imaging is the key diagnostic tool used to stage the cancer – that is, to determine exactly where the primary tumour is located and how far the cancer has spread. For some tumours, imaging findings are still supplemented by findings from surgery – but with the continuous advancement of cross-sectional imaging and the development of molecular imaging, staging laparotomy is becoming obsolete. Accurate staging is essential in order to select the appropriate treatment. Thus, by staging cancer, radiologists and other imaging specialists significantly influence cancer care."

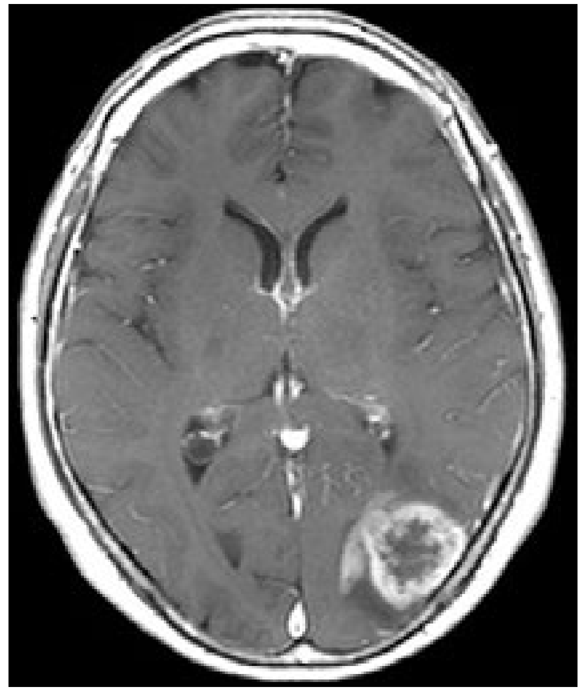
Prof. Hedvig Hricak, USA

As Prof. Hricak says, as soon as cancer is diagnosed, the most important thing to establish, which will determine the first steps of treatment – if not the entire treatment plan – is the precise extent of the cancer. Doctors will only know how to proceed by finding out exactly where cancer is in the original site (the primary tumour), whether it has spread to other parts of the body (the process known as 'metastasis'), and how large any tumours are. In this sense, staging is essentially the reconnaissance, which informs exactly how the 'battle plan' of treatment will be drawn up. Imaging is by far the most effective method to accurately stage cancer, and this is where the radiologist's skill, and experience of medical images, plays a very important part.

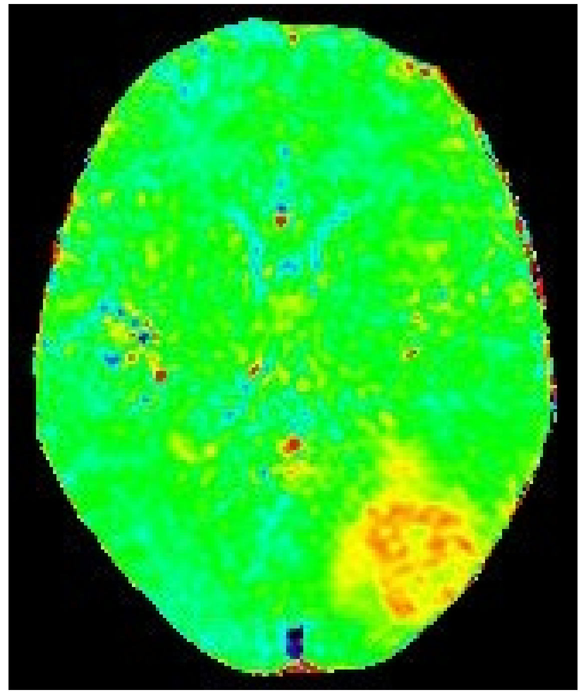
"Accurate staging is widely based on imaging. No other test allows for the depiction of both the primary tumour and its potential metastases. The prognosis of any given malignant condition depends on the initial stage at the time of diagnosis."

Prof. Anno Graser, Germany

Chemical exchange saturation transfer (CEST) imaging of a malignant brain tumor
Post-contrast T1-weighted image



THE RADIOLOGIST **TAKES CENTRE STAGE**



Chemical exchange saturation transfer (CEST) imaging of a malignant brain tumor
CEST image

The broad range of radiological tools and techniques available means radiologists can choose how to examine the body when staging cancer. The decision of which method to use can be influenced by various factors, such as the area of the body where the primary tumour is located, the areas to which cancer is most likely to spread, the sensitivity of the patient to radiation (influenced by age, physical condition, pregnancy, etc.) and, in some cases, the cost of the examination.

CT, PET-CT and, increasingly, MRI are perhaps the most commonly used methods employed in staging, particularly where a whole-body exam is required, but other techniques such as ultrasound, x-ray, and mammography are also commonly used. Aside from these methods, all of which are used to look inside the body from outside, doctors may also occasionally use endoscopy in the course of staging, which involves the insertion of an endoscope (a very small tube containing a light and camera) into the body.

No single method is guaranteed to spot everything, but the big advantage of having so many options to choose from is that they can often be used in combination to provide a more comprehensive picture.

> “In order to answer different questions, the radiologist can use all imaging techniques. But it is important to understand that there is no single perfect examination. In most cases, a combination of examinations is the appropriate strategy, even if computed tomography is the usual starting point.”
>
> **Prof. Yves Menu, France**

While complete staging relies on a combination of clinical findings, including blood tests, radiology provides the central and pivotal staging process, so the radiologist’s role at this point in the cancer care continuum is absolutely essential. As well as managing and operating the equipment used for staging and diagnosis, and selecting the methods used to carry out the examinations, the radiologist is also the person who will analyse and interpret the resulting images, with reference to important clinical knowledge about the patient’s current condition and medical history. The radiologist is therefore relied upon not only to detect already evident findings, but to know to where a given tumour may spread and to confirm or exclude the presence of local and distant metastases (the new sites of spread) through detailed analysis of these locations.

> “The radiologist has a fundamental understanding of the strengths and weaknesses of the imaging tools available and which imaging modalities are best suited for the investigation of particular tumour types. Particular cancers are best appreciated with certain types of investigations and a radiologist is best situated to know which is the most appropriate investigation to use.”
>
> **Prof. Andrew Little, Australia**

The radiologist’s expert analysis will be an integral factor in the decision about the course of action to be taken, but the decisions are usually made by a multidisciplinary team of doctors, responsible for the management of each cancer patient. Images obtained in the examinations will be presented and commented on by the radiologist, before being discussed by the team, usually including oncologists and pathologists. Frequently, new questions may be raised, due to new events or biological findings, and very commonly, the radiologist will return to previous examinations with the same or another imaging tool, in order to characterise images or to ensure that nothing was missed.

THE COMMUNICATION CHAIN

There are usually many people involved in the management of an individual case of cancer, some of whom the patient will have close contact with and some of whom remain very much 'behind the scenes'. Most healthcare institutions take a multidisciplinary approach to cancer care, meaning that the management of each patient is the responsibility of a team of doctors from various branches of medicine, all of whom work together closely to achieve the best possible results. At every stage of a patient's progress, meetings usually take place that draw on the expertise of oncologists (cancer specialists), pathologists (specialists in disease processes), radiation oncologists (specialists in treating cancer with radiation), and radiologists, as well as numerous other physicians, including those who specialise in the particular body regions affected.

"At a local level good communication with all members of the multidisciplinary team managing a patient is key to quality care. It is now routine in many countries for the initial diagnosis, imaging staging and potential management strategies for cancer patients to be discussed in a multidisciplinary team meeting. This ensures that there is good communication between all parties."

Prof. Vicky Goh, United Kingdom

Individual team members are involved to varying degrees in the different steps of cancer care, but communication is still vital. For the radiologist, this means compiling clear, detailed and accurate reports on examination findings for the team, as well as providing recommendations and coordination of follow-up (covered in chapter five of this booklet). Although patients may not necessarily hear directly from radiologists, their involvement in meetings, and particularly through frequent contact with the referring clinician, is an important factor in cancer management.

When it comes to informing the patient of the actual diagnosis, this is done by the oncologist or referring physician in the majority of cases, although occasionally the radiologist will be involved. This varies from country to country, but in general the radiologist will only be consulted when the patient has a particular question.

"In China, patients receive their medical imaging reports from the department of radiology, and they will see their physicians/surgeons with the reports. Occasionally, the patient will consult the radiologist directly and the radiologist will provide the necessary explanations."

Prof. Feng Feng, China

"Depending on local clinical practice, the radiologist either talks to the patient directly, or to the referring physician. In Germany, for example, most private radiology centres offer direct patient interviews and discussion of findings after the imaging. In most hospitals, however, that is impossible to provide and findings will be communicated to the patient during clinical rounds on the ward."

Prof. Anno Graser, Germany

LOOKING **FORWARD**

Due to the nature of the tasks involved, many of the advances being made in radiology to benefit cancer staging are the same as, or similar to, those benefitting detection and characterisation (described in the previous chapter). Incremental improvements in the many technical components of today's common imaging equipment mean that progress is always being made and that the resolution and clarity of images are on the rise. But new developments also include the additional features that are being added to existing technology, such as functional imaging: the ability to visualise processes in the body, such as blood flow and other functional (or physiological) processes.

Arguably, the most significant advances being made are related to molecular imaging, which is used to observe molecular changes on a cellular level, and specifically positron emission tomography (PET), which is usually used in combination with high quality CT or MR scans. PET is an especially sensitive imaging tool, which relies on the unusually high rate of metabolic activity that occurs in cancer tissue to produce three-dimensional images of particular functional processes. The combination of PET with CT or MR provides far superior images, which help the radiologist to accurately localise the active cancer tissue to a particular site or organ.

Molecular imaging in general is an extremely promising field, which benefits all the stages of cancer management where images are involved, i.e. diagnosis, staging, treatment evaluation, and follow-up. The most important feature of these tests is that they combine, in a single scan, morphological (anatomical), physiological (functional) and metabolic information. This means that doctors can obtain an unprecedented level of detail about the nature of cancer tissue, even to the extent that fine differences can be detected between individual tumours in a single patient, which could prove to be invaluable when it comes to planning therapy.

> "Not only can the same type of cancer behave differently in different patients, but even within a single patient, metastatic tumours arising from the same cancer may behave differently. In fact, even different regions within a single tumour may have their own distinct molecular characteristics. Because molecular imaging can distinguish differences in these characteristics within and between tumours, the role of imaging specialists in diagnosing, characterising, and staging cancer, as well as determining the appropriate treatment, is likely to become even more pronounced with progress in molecular imaging and targeted therapy."

Prof. Hedvig Hricak, USA

This image depicts a multitined radiofrequency ablation electrode in stage 1a primary lung cancer. The electrode kills the cancer with extreme heat. The patient is treated as an outpatient. The body removes the dead tissue leaving behind a scar.

Treatment & Therapy

1. TREATMENT MONITORING WITH IMAGING: SAVING TIME
2. THE GROWING USE OF IMAGE-GUIDED THERAPIES
3. INTERVENTIONAL RADIOLOGY AND MINIMALLY INVASIVE TREATMENTS
4. FUTURE DEVELOPMENTS

TREATMENT MONITORING WITH IMAGING: **SAVING TIME**

Once cancer has been localised and staged, doctors can proceed with treatment. Here, as in every stage of oncologic care, imaging is of fundamental importance. Imaging techniques can be used to monitor therapy, which allows doctors to gauge the success of the therapeutic plan from the beginning.

Being able to check the effectiveness of a treatment early on means a change in course can be made as soon as it becomes necessary, which is a crucial timesaver in the battle against cancer and a factor in improving quality of life during and after treatment. Imaging techniques can show if the selected therapy is proving effective in a patient and, if not, can help doctors to choose a more suitable strategy. Whether radiation therapy, chemotherapy, or both, are carried out, imaging can measure their effectiveness by showing how the tumour responds to them.

Various response criteria models have been developed for this purpose, of which the most commonly used is the RECIST (Response Evaluation Criteria In Solid Tumours) model; a set of published rules that define when cancer patients improve (response), stay the same (stabilisation) or worsen (progression). An initial scan is taken before the treatment starts, against which later scans will be compared. Various imaging techniques are then used once therapy commences, to determine its effect. When the course of treatment ends, a final examination is performed to assess whether the response of the cancer to treatment has been complete, partial or stable. Information about treatment response is crucial for doctors, as they can use it to plan the next steps, i.e. whether the patient needs further treatment or, in the best cases, follow-up care, if tumours have been destroyed.

Treatment response is traditionally monitored by measuring the dimensions of the primary tumour and the dimensions of a number of lymph nodes and abnormalities, and comparing those dimensions with the original pre-treatment images. In addition, certain imaging tools can show tumour metabolism, increasingly important information in treatment planning.

Functional and molecular imaging are increasingly popular in cancer management. These techniques use contrast products or biomarkers, which are substances that are usually swallowed or injected and used to highlight certain body tissues or biological molecules. When viewed with imaging tools such as CT, MRI and positron emission tomography (PET), they can show cellular activity and molecular processes in organisms, including tumours. Once doctors know the nature of a tumour and how it interacts with the rest of the body, they can more easily define which therapy is most likely to be effective.

> “Imaging is used to assess response to treatment largely using tumour size and/or recurrence. It is also used to monitor possible side effects of therapy and therapeutic interventions. Conventional imaging, such as x-ray, ultrasound (US), computed tomography (CT) and magnetic resonance imaging (MRI) utilise measurements to assess response or progression. Response is typically classified as being ‘progressive disease’, ‘stable disease’, ‘partial response’ or ‘complete response’ to treatment. Functional and molecular imaging will include assessment of tumour metabolism and thereby predict response to a particular therapy.”
>
> **Dr. Jean de Villiers, South Africa**

THE GROWING USE **OF IMAGE-GUIDED THERAPIES**

Another role of imaging in cancer treatment is to facilitate the delivery of therapy. Radiation (radiotherapy) or chemical agents (chemotherapy) are very frequently used in treatment, and the medical team wants to be as sure as possible that they hit their targets without harming the surrounding organs or tissues. These treatments used to be applied to the whole body, but many are now performed locally, to destroy just the tumour and minimise any complications. These therapies require a very high level of precision, and oncologic physicians, whether they are radiotherapists, surgeons or nuclear medicine physicians, increasingly rely on personnel with specific imaging skills to guide them during their interventions.

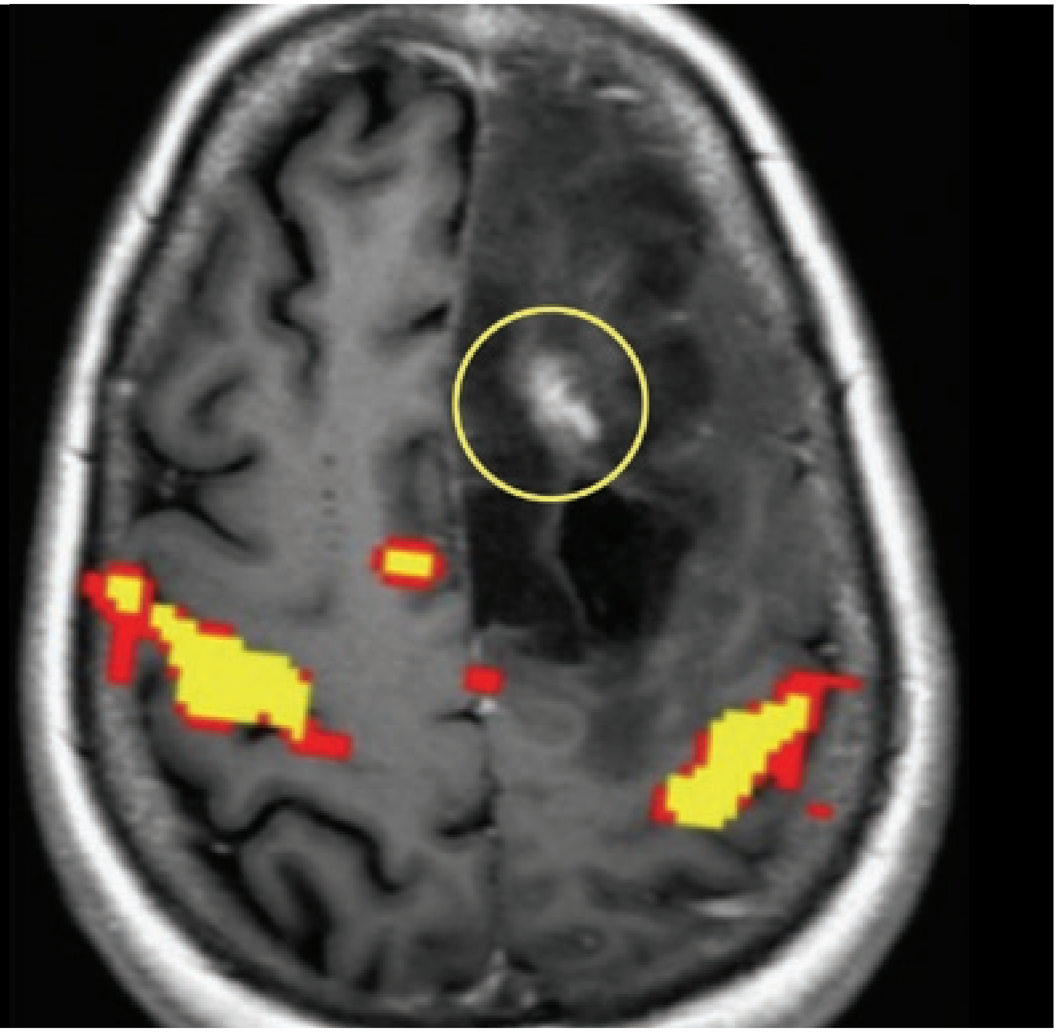
> "Imaging is used to guide the treatment of cancer in a variety of ways. Radiation oncologists use imaging to determine the location of the cancer and properly position the radiation beam. Nuclear medicine physicians use imaging to track the activity of radiopharmaceuticals in the body and determine whether they are reaching their target accurately and in sufficient quantity. Also, imaging equipment is now installed in many surgical operating rooms."
>
> **Prof. Hedvig Hricak, USA**

> "Image-guided surgery based on preoperative CT and MRI has become popular especially in brain surgery, and is widely used for the resection of brain tumours. Planning of radiation therapy is also based on CT images, so that the tumour receives sufficient doses of radiation while controlling the dosage to preserve critical organs. Image-guided therapy can improve treatment outcome and reduce the risk of complications."
>
> **Prof. Hiroshi Honda, Japan**

There are many examples of how CT or MRI can be used to guide treatment. Neurosurgeons commonly use whole-brain 3D images to plan surgery in detail, and surgeons increasingly use 3D images during their interventions in liver surgery. After surgery, CT images enable physicians to make sure that the tumour is gone. In radiation therapy, image guidance is also more and more commonly used to improve safety.

So radiologists are responsible for treatment monitoring and they help deliver therapy as accurately and safely as possible. In addition, they sometimes perform the treatment themselves. These activities have actually given rise to a whole branch of radiology: interventional radiology.

INTERVENTIONAL RADIOLOGY AND **MINIMALLY INVASIVE TREATMENTS**



A 2-dimensional image of a brain tumour (circled) and the parts of the brain that control motion of the hand (seen in yellow and orange). This information allows the neurosurgeon to assess the relationship between the tumour and the motor cortex and plan a safer operation.

In recent years, a growing number of image-guided therapies have widened the range of cancer treatment options. Interventional radiology, a subspecialty of radiology, has been developing since the early 1970s and many innovative image-guided techniques have been established, especially with regard to cancer treatment. These techniques are minimally invasive, meaning that they can be performed through a tiny incision and therefore involve minimal physical stress. The advantage of these techniques is that they pose little risk to the patient; much less than conventional surgery, which usually requires larger incisions. These techniques typically use ultrasound, x-ray, CT or MRI to guide the application of radiofrequencies (RF) or extreme temperatures, which cause the tumour to shrink. The treatment is delivered through a small tube or catheter, which is guided by a radiologist using real-time images, to destroy the tumour without damaging the surrounding tissues.

Image-guided therapeutic procedures may be used in many cases: brain, liver, lung or renal cancer patients are increasingly treated this way. As Professor Hricak points out, there are many different possible options, all of which may be used to treat different cancers. Embolisation consists of obstructing blood vessels that feed a tumour until it shrinks and dies. Embolisation is used to treat not only liver, but also bone and lung cancer. Catheters can also transport chemical agents to the site of the tumour, and release agents which will eat up the tumour. Radiologists may also administer radiation themselves, for instance in a treatment called selective internal radiation therapy (SIRT), by injecting tiny microspheres of radioactive material directly into the arteries that supply the tumour. Radiologists also commonly perform radiofrequency ablation, which uses electromagnetic (radio) waves combined with US or x-ray, to ablate lung and liver metastases as well as primary renal cancers.

The advantage of minimally invasive image-guided therapies is that they can reduce the risk of complications and shorten in-patient stays. They are also an excellent alternative to surgery for patients who are severely ill, refuse to have surgery, or whose cancer cannot be surgically removed. Physicians can recommend to patients which treatment they should undergo after considering all the information and gathering all the expertise on a case-by-case basis. The type of cancer, clinical history of the patient, and availability of resources will determine the choice of therapy.

"Instead of making a large incision, an interventional radiologist will typically use imaging to guide a catheter or needle to the treatment site to deliver a therapeutic agent. For example, in an approach called thermal ablation, imaging is used to guide a needle to a tumour and then extreme temperatures are applied via the needle to destroy the tumour. Thermal ablation may be used to treat cancers in the kidney, liver or lung, among other sites. In hepatic artery embolisation, a treatment for liver tumours, imaging is used to guide a catheter to the hepatic artery, and particles are then injected to block the flow of blood from the artery into the tumour; some doctors may also choose to inject a chemotherapeutic agent or particles that emit radiation."

Prof. Hedvig Hricak, USA

FUTURE **DEVELOPMENTS**

Research is booming in many areas of cancer imaging, including treatment imaging, and this should result in better monitoring options and more refined image-guided therapies within the next ten years, according to experts. Radiotherapy and surgical techniques are currently under the scope of researchers, as well as new chemotherapeutic agents and 'intelligent drugs' designed to target specific cells.

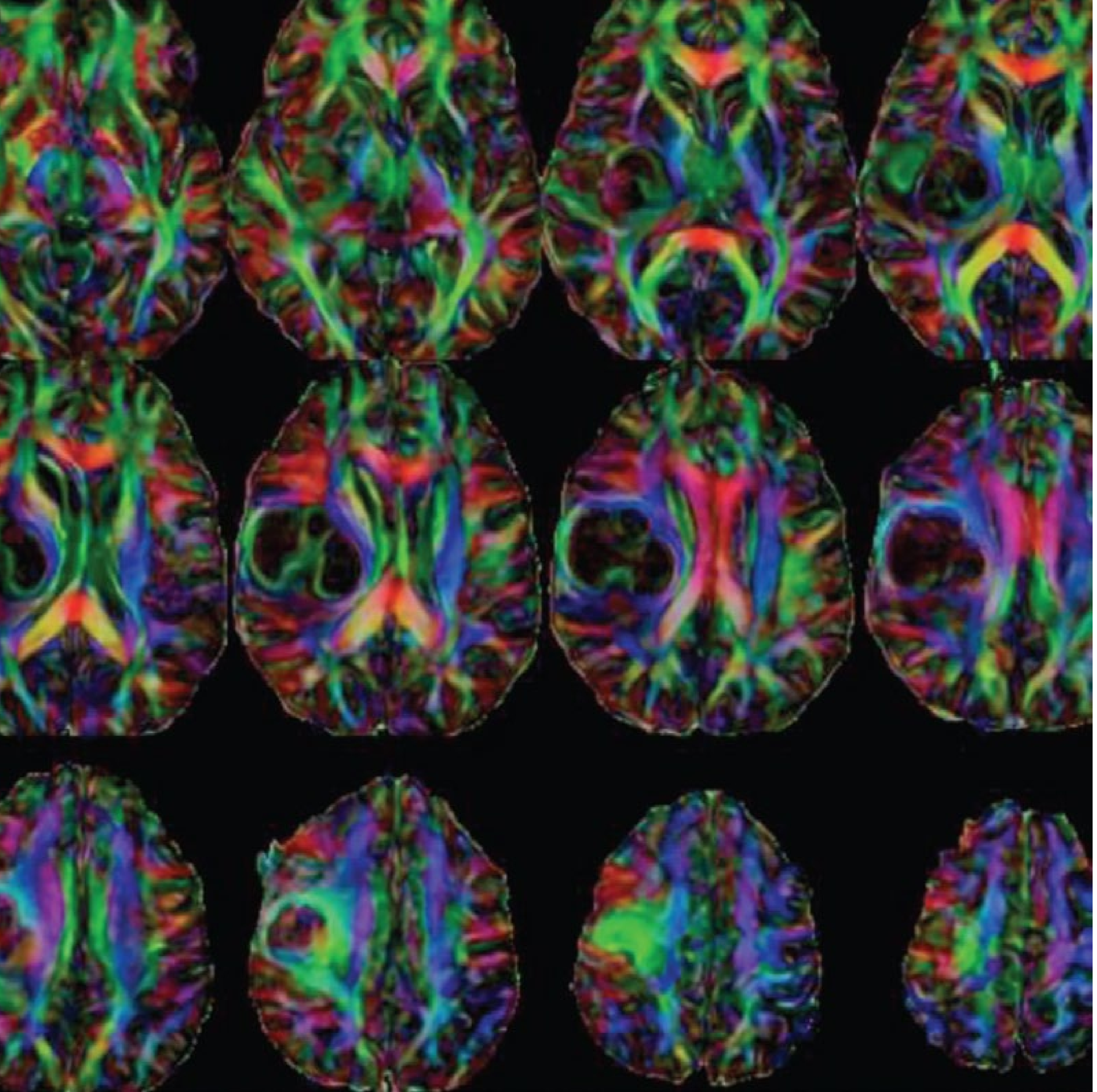
In particular, efforts to reduce the toxicity of therapeutic agents, improve the detection of cancer and assess therapy efficiency with PET should pay off.

> "The promising developments in cancer treatment that involve radiologists include the ability to selectively deliver therapeutic agents to target tissues and thereby reduce systemic toxicity. Patients with cancer will benefit from the new PET metabolites that target specific tissue and will improve the sensitivity and specificity of cancer detection and treatment response."
>
> **Prof. Andrew Little, Australia**

Further advances should also be expected in physical ablation and electroporation, a treatment that facilitates the introduction of a drug or a piece of coded-DNA into a cancerous cell by increasing the electrical conductivity and permeability of the cell membrane. Electroporation is typically guided by imaging techniques such as CT or MRI, first to create 3D images of the tumour before treatment and then to place the electrodes during the procedure.

In addition, the development of sophisticated nano-particles and probes should push the accuracy of treatment monitoring and guidance with imaging even further. Treatments should continue to be refined, as they have been in recent years, improving both life expectancy and quality of life for their recipients.

> "In general, current treatments are safer and more effective than in the past. The magnitude of benefits varies from tumour to tumour, but overall, stage by stage, patients are living longer today than in the past, in most locations. Also, quality of life has improved so much through the development of strategies that allow less aggressive treatments and extensive development of palliative therapies to control symptoms."
>
> **Dr. Adriana Dieguez, Argentina**



Follow-up Care

1. THE IMPORTANCE OF FOLLOW-UP CARE
2. TOOLS OF THE TRADE
3. THE RADIOLOGIST'S ROLE
4. WHAT THE PUBLIC SHOULD KNOW ABOUT IMAGING IN FOLLOW-UP CARE
5. FUTURE DEVELOPMENTS IN FOLLOW-UP CANCER IMAGING

THE IMPORTANCE OF **FOLLOW-UP CARE**

Cancer can be a particularly resilient disease. In fact, most medical professionals avoid using the term 'cure', due to the fact that many cancers are capable of recurring later on in life. Instead, physicians involved in cancer care prefer to talk of 'remission', having halted or reduced the spread of the disease. Some patients may experience partial remission, where there is a 50% reduction in tumour growth, or even complete remission, where the tumour and all manifestations of the cancer have disappeared. Though there is no definite cure, patients can, and often do, survive cancer and it is not always the case that the cancer remerges.

Because of the resilient and pervasive nature of cancer cells it is important that patients undergo regular checkups after they have been declared to be in remission. Follow-up care involves a series of regular examinations in order to monitor cancer remission and pinpoint any possible recurrence. Patients should undergo follow-up checks to ensure their cancer remains in remission because the earlier recurrence is spotted, the better the prognosis. This is where imaging plays one of its most important functions, as it can help physicians to non-invasively detect the state of the disease or its recurrence before symptoms appear. It is a cornerstone of follow-up cancer care.

> "Medical imaging is vitally important to monitoring therapy response and follow-up care of cancer patients. Imaging provides a non-invasive outpatient assessment for patients, which is accessible to the general community not only in major urban centres, but also in remote and rural communities. The digitisation of medical imaging examinations permits remote diagnosis and expert second opinions."
>
> **Prof. Andrew Little, Australia**

Medical imaging allows oncologists to make follow-up checks less uncomfortable or intrusive to patients and its efficiency ensures that patients can be monitored and informed of any complications in a timely fashion.

T1 mapping of a liver tumour

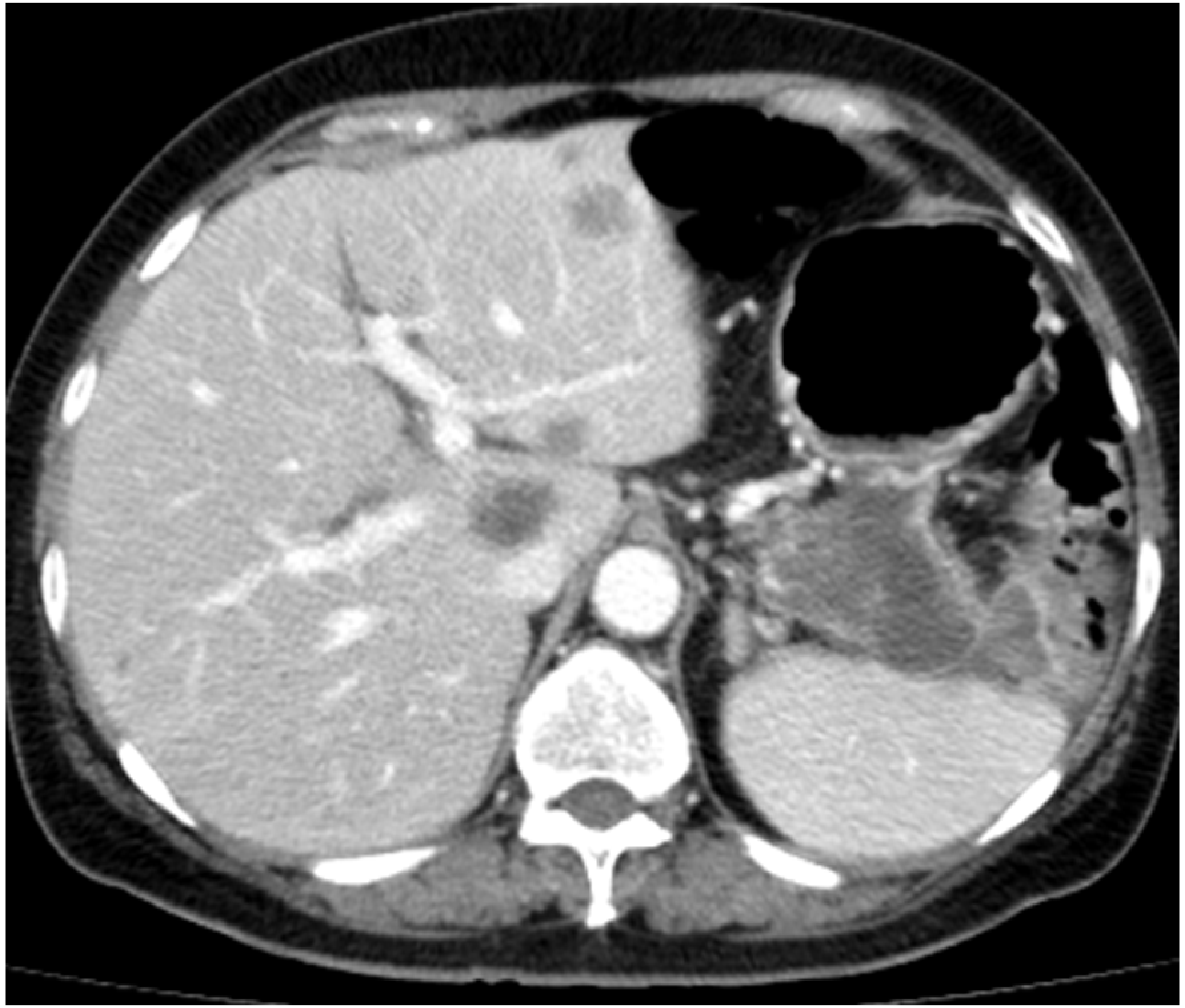
TOOLS OF THE TRADE

Much like during the preceding stages of cancer care, radiologists have an array of techniques and equipment at their disposal. Patients who undergo follow-up examinations are most likely to encounter computed tomography (CT), magnetic resonance imaging (MRI) or ultrasound (US).

Each technique is suited to assessing different forms of cancer. CT is probably the most common technique used for follow-up examinations. It is quite a versatile technology, allowing the radiologist to image most parts of the body quickly and with a high level of detail. Depending on the specific cancer, patients may encounter other techniques such as MRI and ultrasound.

Physicians and radiologists work together to decide on the most suitable technique, and factors such as the type of cancer, location, and previous treatment influence the choice of procedure. Many patients may have had CT or other ionising radiation scans during the detection, staging, or treatment stages, and in such cases the medical team may want to limit the patient's exposure to further radiation doses. However, the benefit of having the appropriate scan greatly outweighs the risks of exposure.

> "Ultrasonography is widely used to detect occurrence of lymph node and liver metastasis. CT is used to detect local recurrence, as well as metastases in lymph nodes and distant organs. It is also used to detect late complications of chemotherapy and radiotherapy. MRI is used for similar purposes, but is more useful in detecting brain and bone metastasis."
>
> **Prof. Hiroshi Honda, Japan**



THE RADIOLOGIST'S **ROLE**

The radiologist is responsible for interpreting the images acquired through a range of techniques and then communicating their analysis to the patient's physician. This means the radiologist needs to understand more than just images; they must be familiar with oncologic medicine in order to distinguish the appearance of cancer from other diseases or anomalies. Given the radiologist's knowledge and experience of the imaging features of cancer and its recurrence, they are often the first to spot the early signs of cancer recurrence, making their role pivotal to the effectiveness of follow-up care.

Again, as is the case at earlier stages of cancer care, the radiologist operates as part of a medical team to give patients the best follow-up care and to ensure prompt detection of any possible complications. Imaging is not the only means used to detect possible complications. Patients are likely to undergo other exams, similar to those they had during the staging of their disease, such as biopsies or blood tests. However, radiologists provide a non-invasive means, with minimum discomfort to the patient, of assessing the need to carry out more invasive or uncomfortable procedures and can thus save patients a great deal of stress.

The radiologist works behind the scenes to provide treating physicians with indispensable information, helping them to make crucial decisions on further treatment or tests.

> "Radiologists contribute to post-cancer care by detecting recurrence. Early detection of recurrence requires deep knowledge about patterns of recurrence in each type of cancer. Another role of the radiologist is to diagnose complications as a result of treatment, which are often difficult to distinguish from recurrence."
>
> **Prof. Hiroshi Honda, Japan**

> "A multidisciplinary approach and the joint participation of other experts with the radiologist are essential."
>
> **Prof. Marcos Duarte Guimaraes, Brazil**

WHAT THE PUBLIC SHOULD KNOW ABOUT IMAGING IN FOLLOW-UP CANCER CARE

"They should know that imaging is the most important reference for the follow-up of treatment. At the same time, clinical information and, in some cases, biological data are important. The medical decision always relies on a multidisciplinary approach."

Prof. Yves Menu, France

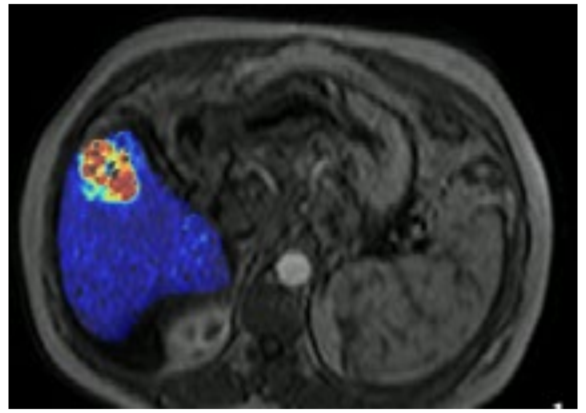
The general public are often made aware, through campaigns of various kinds, of screening programmes for certain cancers. While many people may have some idea of what an actual cancer diagnosis entails in terms of treatment and lifestyle changes, others may not be fully aware of what comes after the initial treatment.
During follow-up care, patients often need to undergo similar exams to those they experienced during diagnosis and staging in order to check for possible recurrence. The frequency of such checkups varies depending upon the type of cancer in question, the health of the patient, and their course of treatment. Generally speaking, checkups are scheduled for every three to four months for the first two to three years following treatment; after that, patients usually have appointments once or twice a year. Patients will not necessarily undergo imaging procedures during all of these appointments, but it is an option for the treating physician who can then consult with the radiologist as to the nature of any remaining tumours or signs of recurrence.

FOLLOW-UP
CARE
MAKING CANCER VISIBLE
THE ROLE OF IMAGING IN ONCOLOGY

"During remission, patients are examined more regularly in the early period after completion of therapy and then much less frequently when disease remission has been confirmed. For example, patients in established remission after breast cancer or some testicular cancers are usually only imaged on an annual basis."

Prof. Andrew Little, Australia

Permeability map of malignant liver tumours relates to aggressiveness.



Patients should always report any pain or symptoms to their physician; while in many cases this is due to normal factors it can prompt the oncologist to investigate further. Medical imaging on the other hand, can help detect recurrence or complications before they become symptomatic. Most techniques are quick and can detect complications, allowing physicians to work with the radiologist to identify any potential complications as early as possible, helping to ensure the very best possible prognosis.

FUTURE DEVELOPMENTS IN FOLLOW-UP CANCER IMAGING

Cancer is the subject of a great deal of research, much of which goes into developing methods of detection and treatment. However, many developments can also benefit patients already battling the disease.

Improvements within the field of medical imaging could have the potential to buy valuable time for patients by pinpointing a possible recurrence earlier than is currently possible.

Where cancer is concerned, sooner is always better and this is particularly true in terms of the initial detection of tumours and recurrence following treatment.

> "This is an important issue. Even if imaging provides useful information as it is, we would like it to be better. We are looking for methods that would not only tell us that the treatment is effective or not, but also tell us more quickly, and, if possible, even to predict it from the beginning. Imaging and other sciences are working hard on this issue, because it would save time and improve treatment effectiveness. Although not possible today, we know that some imaging methods have the potential to provide this information."
>
> **Prof. Yves Menu, France**

Some imaging tools, discussed in other chapters of this booklet, have some of this potential. Molecular imaging and technology like positron emission tomography (PET) could be used more widely to discern the precise metabolism of cancer tumours, giving oncologists more detailed information regarding the nature of the cancer. Treating physicians will be able to monitor individual tumours within a patient through such methods.

> "In the future, molecular imaging will likely be used to assess differences in treatment response within and between different tumour sites in individual patients."
>
> **Prof. Hedvig Hricak, USA**

The benefits imaging brings to cancer care at present are clear. It allows the physician, in cooperation with the radiologist, to discern signs of cancer, non-invasively and efficiently. While this ability by itself makes a huge impact on cancer care, it is constantly developing and new techniques to improve patient care should emerge in the years ahead.

About the Interviewees

Fergus V. Coakley
Portland/OR, United States

Fergus Coakley was recently appointed as chair of radiology at Oregon Health and Science University in Portland. He previously served as chief of abdominal imaging and vice- chair for clinical services in the department of radiology and biomedical imaging, the University of California, San Francisco. Past experience includes a fellowship and a year as faculty in Body Imaging at Memorial Sloan-Kettering Cancer Center, New York. Dr. Coakley is involved in the teaching of radiology at all levels, from medical students to postgraduate trainees. At UCSF, he obtained a T32 Training Grant from the NIH, which he secured in 2005 and was renewed through 2015. Dr. Coakley is widely published in peer-reviewed scientific journals and is a frequent lecturer and sought after expert in CT radiation dose, MR-guided high intensity focused ultrasound and MRI of prostate cancer.

Jean-Pierre de Villiers
Cape Town, South Africa

Jean Pierre de Villiers is a radiologist specialising in oncologic imaging and interventional radiology, working in private practice in Cape Town, South Africa. He received his undergraduate training at the University of Pretoria, from 1982 to 1987, and spent two years in general practice. He then completed his radiology residency at Grootte Schuur Hospital, Cape Town, followed by a fellowship at the University of Cape Town in 1996. Dr. de Villiers has spent twelve years working in private practice in South Africa, as well as two years working in oncologic radiology at St. Vincent's Hospital in Sydney, Australia.

Adriana Dieguez
Buenos Aires, Argentina

Adriana Dieguez is a practicing physician at the University of Buenos Aires, Argentina, where she graduated with honours and specialised in radiology. She is currently coordinator of the department of magnetic resonance and computed tomography in oncologic diseases and the department of teaching and research at the Diagnóstico Médico medical centre, Buenos Aires, Argentina. Dr. Dieguez is a member of the executive committee of the Argentine Society of Radiology and coordinator of its oncologic imaging section. She is also associate editor of the scientific journal of the Argentine Society of Radiology, *Revista Argentina de Radiologia.* Her interests focus on breast MRI and the staging of rectal cancer with MRI.

Marcos Duarte
São Paulo, Brazil

Marcos Duarte Guimaraes is a medical practitioner with a master's degree in oncology. He also contributes to the PhD programme of the AC Camargo Cancer Hospital, in São Paulo, Brazil. He is a member and coordinator of the cancer imaging section of the Brazilian College of Radiology (CBR). He has experience working with several radiological modalities including CT, PET-CT, thoracic and whole-body MRI, and image-guided percutaneous procedures. Dr. Duarte's research interests include the development of novel molecular imaging techniques and tools for early disease detection. He has published original manuscripts, has authored textbooks and is associate editor of the first Brazilian oncologic imaging textbook. He has also spoken at many courses, meetings and national conferences.

Feng Feng
Beijing, China

Feng Feng is professor of radiology at Peking Union Medical College (PUMC), and vice-chair of the department of radiology, PUMC Hospital. She is also physician-in-chief of radiology at the PUMCH, as well as a standing committee member of the Society of Tumour Imaging, which is affiliated with the Chinese Anti-Cancer Association. She serves as a member of the editorial board of the *Journal of Cancer Research,* and as a peer-reviewer for several Chinese medical journals, such as the *Chinese Medical Journal, Chinese Journal of Medical Imaging Technology,* and the *Chinese Journal of Radiology.* Dr. Feng's research interests include the diagnosis and monitoring of intracranial tumours, methods for early disease detection, and treatment evaluation. She has published more than 50 original papers in peer-reviewed journals and has authored two textbooks and four books on MRI, chest radiology and liver cancer.

Vicky Goh
London, United Kingdom

Vicky Goh is professor of clinical cancer imaging at King's College London, and honorary consultant radiologist at Guy's and St Thomas' Hospitals, London. She is currently vice-president of the European Society of Oncologic Imaging, a member of the European Society of Radiology Research Committee Board, a member of the European Society of Radiology Leadership Institute, a member of the European School of Radiology faculty and a member of the editorial board of *European Radiology.* Her research interests include the improvement of tumour characterisation with functional CT, MRI and PET-CT; multimodality assessment of treatment response; and development of novel prognostic and predictive tumour biomarkers for gastrointestinal, lung and renal cancers. Dr. Goh has published more than 80 original papers, reviews and book chapters to date. She was awarded the ESGAR Gold Award in 2010, for the best gastrointestinal imaging paper in *European Radiology,* 2009.

Jin Mo Goo
Seoul, Korea

Jin Mo Goo is professor of radiology and director of the chest x-ray section at Seoul National University Hospital, Seoul, Korea. He received his MD and PhD degrees from Seoul National University. He serves on the editorial boards of the *Korean Journal of Radiology, Investigative Radiology,* and the *American Journal of Roentgenology,* and has been a member of the Fleischner Society since 2012. His main research interests include the application of computer-aided diagnosis systems, quantitative analysis of imaging, and evaluation of ground-glass nodules in the lung. Dr. Goo has published more than 120 articles in English-language, peer-reviewed journals.

Anno Graser
Munich, Germany

Anno Graser is associate professor of clinical radiology and director of oncologic imaging at the University of Munich Medical Centre. He received his initial undergraduate training at the University of Munich, but he also studied at the Memorial Sloan-Kettering Cancer Center, New York, and the University of California, San Francisco. He then went on to complete his residency at the University of Munich before moving on to a research fellowship at New York University. He has published a number of peer-reviewed articles and has lectured at a variety of international conferences. Dr. Graser is president of the European Society of Oncologic Imaging and a long-time member of the European Society of Radiology.

Hiroshi Honda
Fukuoka, Japan

Hiroshi Honda is professor of radiology and chairman of the department of radiology at the Graduate School of Medical Sciences, Kyushu University, Japan. He will also be president of the Japan Radiological Society's Congress in 2013. Dr. Honda received his medical degree from Kyushu University, Japan, in 1979. He completed his radiology residency at Kyushu University and received board-certification in radiology. After working as an abdominal radiologist in Japan, he joined the radiology staff at the department of radiology, University of Iowa, U.S., for three years and then returned to Kyushu University in 1989. He has served as president of the Kyushu Radiology Society since 2002 and has been a member of the Board of the Japan Radiological Society (JRS) since 2003.

ABOUT THE
INTERVIEWEES

MAKING CANCER VISIBLE
THE ROLE OF IMAGING IN ONCOLOGY

Hedvig Hricak
New York/NY, United States

Hedvig Hricak is chairperson of the department of radiology at the Sloan-Kettering Cancer Center in New York, and professor of radiology at Weill Medical College, Cornell University, New York. She has published over 480 research reports, reviews and articles, plus 18 books and 133 book chapters. In total, her work has been cited over 16,000 times. She has been honoured with numerous awards including the Gold Medal of the European Society of Radiology, the Béclère Medal from the International Society of Radiology, the Moroccan Merit Medal from the International Society of Radiology, an honorary doctorate in medicine from the Ludwig Maximilians University of Munich, and the Order of the Croatian Morning Star of Katarina Zrinska, Presidential Award from Croatia. Dr. Hricak has been rated one of America's top radiologists by the Consumer Research Council and recognised as one of the top doctors in New York by *New York Magazine.* She was ranked number two in *Diagnostic Imaging's* 20 most influential radiologists of the past decade. She is also a past president of the Radiological Society of North America.

Andrew Little
Melbourne, Australia

Andrew Little is associate professor of radiology at St. Vincent's Hospital, Melbourne, Australia and a fellow of the Royal Australian & New Zealand College of Radiologists (RANZCR) and the Royal College of Radiologists, UK. He graduated from the University of Melbourne with a doctorate in medicine and a master's degree in surgery. He completed his postgraduate fellowship training in body imaging, non-vascular intervention and vascular/interventional radiology at The Middlesex Hospital, London and the University of Pittsburgh Medical Center. Dr. Little specialises in oncologic imaging and oncologic intervention, with research interests including hepatobiliary intervention and hepatic MR imaging. He has received numerous academic prizes, awards and fellowships including the DuPont Prize, the Siemens Medical Solutions Prize, the GE Medical Systems Prize and the RANZCR Rouse Travelling Fellowship. He is also the author of many publications.

Luis Martí-Bonmatí
Valencia, Spain

Luis Martí-Bonmatí is head of the MRI, CT and abdominal section of Doctor Peset University Hospital, Valencia and chief of radiology at Quirón Hospital, Valencia, Spain. His research interests include MR and CT of the liver, clinical applications of MRI, contrast agents, and image processing. He also serves as vice-president of the Spanish Society of Radiology (SERAM) and, in addition to his publications, he has served on the editorial boards of various peer-reviewed journals of radiology. Dr. Martí-Bonmatí is also an active member and the current chairman of the research committee of the European Society of Radiology.

Yves Menu
Paris, France

Yves Menu is professor of radiology and chairman of the department of radiology at Saint Antoine Hospital, Paris and head of the department of radiology and nuclear medicine at the Paris VI University Hospitals. A specialist in abdominal and oncologic imaging, he has lectured on gastrointestinal disease and the evaluation of tumour response at many international conferences. He is past president of the European Society for Gastrointestinal and Abdominal Radiology (ESGAR) and will be president of the 2015 annual ESGAR meeting in Paris. Dr. Menu was president of the European Congress of Radiology in 2011 and has been chairperson of the Professional Organisation Committee of the European Society of Radiology since 2011. He is an honorary member of the Radiological Society of North America and the recipient of many awards.

Reginald F. Munden
Houston/TX, United States

Reginald F. Munden is professor of diagnostic radiology at the MD Anderson Cancer Center, University of Texas. He initially studied biology at the University of South Carolina, before moving on to study medicine and dentistry at the Medical University of South Carolina, where he later completed his residency in diagnostic radiology. He received a fellowship in thoracic radiology from Harvard University, Boston, and earned a degree in business administration from Auburn University, Alabama. Dr. Munden has been actively involved in clinical imaging research and has published a large number of peer-reviewed articles. He is also an active member of many scientific societies and a long-time member of the Radiological Society of North America.

Wolfgang Schima
Vienna, Austria

Wolfgang Schima is head of radiology at the Goettlicher Heiland, Barmherzige Schwestern and Sankt Josef Hospitals, Vienna, Austria. He studied medicine at the University of Vienna, where he also completed his residency in radiology. He has written a number of peer-reviewed articles and is an active member of many international scientific societies. Dr. Schima's research interests include oncologic imaging and CT colonography. He is actively involved in the Austrian Roentgen Society and the European Board of Radiology. He is also a long-standing member of the European Society of Radiology.

Glossary

Ablation
A technique used to destroy or remove any abnormal tissue growths.

Adenoma
Benign tumours of glandular tissue such as colon mucosa (also known as colonic polyps), liver or thyroid. They can, in rare cases, become malignant over time, in which case they are referred to as adenocarcinomas.

Benign tumour
A tumour which lacks the ability to spread (metastasise) or invade the contiguous organs. In other words, it lacks the properties indicative of cancer.

Biomarkers:
An indicator of the presence, absence or progression of a specific disease. It can be identified through blood or urine samples, like antibodies for infections or glucose rate for diabetes. It can also be identified via imaging, like the level of enhancement of a tumour after intravenous injection of contrast media. A reliable biomarker is useful for evaluating the presence, recurrence or response to treatment in cases of cancer.

Biopsy
A medical test, in which a sample of cells or tissue is taken. There are a number of different biopsy procedures which are usually performed under optical guidance (like endoscopy or direct skin sample), imaging or surgical guidance, depending on the localisation of the tissue to be sampled. It may require a local or general anaesthesia. The tissue sample is then examined by a pathologist to determine the presence of disease.

Catheter
A tube that can be inserted into a body cavity, duct or vessel. It facilitates the drainage or introduction of fluids or gases. It can also provide access for surgical instruments.

Contraindication
A condition or factor which makes it inadvisable to carry out a specific medical treatment. There are absolute and relative contraindications: absolute meaning there are never any circumstances to justify the treatment, and relative meaning that in some circumstances the benefit of the treatment may outweigh the consequences. A penicillin allergy is an example of an absolute contraindication to the use of penicillin; while pregnancy is a relative contraindication to the use of ionising radiation scans, however in some cases the benefits of such scans can far outweigh the risks.

Contrast medium
An agent or substance introduced into the body (vessels or cavity) to enhance the contrast of fluids or structures within the body for imaging. Iodine (for CT and angiography) and gadolinium chelates (for MRI) are the two most common contrast media used in imaging. Contrast media are sometimes inserted into the digestive tract (oral or rectal administration). Barium and iodine are the most common digestive contrast media. In rare instances, contrast media can have adverse effects, like an allergic reaction. Renal damage can also occur, but only in cases of pre-existing kidney disease. For this reason, renal function sometimes needs to be evaluated before contrast media is injected.

Computed tomography (CT)
Also commonly referred to as x-ray computed tomography or computed axial tomography (CAT) and often wrongly called a 'scan' or 'scanner'. The term 'tomography' means 'slices' and refers to the acquisition and presentation of images as contiguous slices of tissue. This applies to CT and also ultrasound, MRI and nuclear medicine. In the case of CT, the attenuation of x-rays by the tissue is measured. Because more than one million calculations are made in less than a second, a very powerful computer is necessary to manage this information immediately. These 2D images, can be put together to provide 3D images. This is called post-processing, because it is carried out once the examination is finished.

CT colonography/virtual colonoscopy
A conventional colonoscopy involves the use of an endoscope to examine the large bowel and distal part of the small bowl. The endoscope is a flexible tube with a camera which is then, for the purposes of a colonoscopy, inserted via the anus.
A virtual colonoscopy is a non-invasive alternative to this procedure, using CT to produce a 3D image of the bowel. It is considerably more comfortable for the patient, because it does not require any anaesthesia. However, good preparation (colon cleansing) is necessary to obtain relevant images.

Diffusion-weighted imaging (DWI)
This MRI technique identifies the micro-movements of water molecules within the body. It is useful in many cases, like the early detection of stroke, or the detection/characterisation of tumours in various areas of the body.

Electroporation
A technique that increases the electrical conductivity and permeability of a cell plasma membrane, using an electrical field, in order to introduce a substance into the cell, such as a drug.

Embolisation
A technique which principle is used to obstruct vessels that are bleeding (for instance after a trauma or feeding a tumour). In cases of cancer, embolisation reduces the quantity of blood and therefore oxygen within the tumour, which halts its growth and may even destroy it. The obstruction of vessels is usually performed through a catheter inserted via the femoral artery under local anaesthesia. Embolisation is commonly associated with local administration of particle bearing antitumoural agents like chemotherapy or radiotherapeutic components. These are called 'chemoembolisation' or 'radioembolisation', respectively.

Endoscopy
A procedure which allows physicians to see inside the patient. Unlike radiological procedures, endoscopy is an invasive procedure which involves inserting a fibre optic cable with a camera, via a cavity. It sometimes requires general anaesthesia. It allows for the direct insertion of interventional tools in order to perform a biopsy or even the resection of small tumours like colonic polyps (see 'adenoma').

Ionising radiation
Radiation is a process where energetic particles or waves travel through space or a medium. There are two main types of radiation; ionising (radiography, CT, nuclear medicine, radiotherapy) and non-ionising (ultrasound, MRI). X-rays are ionising radiation used in radiography and CT. It is interesting to know that we are all exposed to ionising radiation from the atmosphere, higher for instance when travelling in the mountains. Because ionising radiation can be harmful, the doses used in radiological procedures are kept as low as possible, and any risks from radiation exposure are carefully weighed against the benefits of the scan before the examination. In radiotherapy, ionising radiation is used to destroy tumours. Low power, non-ionising radiation is generally harmless and is widely used in telecommunications.

Interventional Radiology
A medical subspecialty within radiology. Interventional radiology comprises all invasive diagnostic and/or therapeutic approaches. Using imaging guidance, the interventional radiologist performs biopsies; inserts stents or prostheses, to re-establish flow in obstructed vessels or bile ducts; treats tumours with ablation or embolisation; and removes foreign bodies, like broken catheters for instance. Interventional radiologists often perform routine diagnostic radiology procedures as well.

Laparotomy
A surgical procedure that involves making an incision in the abdominal wall in order to gain access to the abdominal cavity.

Laparoscopy
A surgical procedure that allows access to the abdominal cavity without an incision. Three holes are made in order to insufflate gas, insert a video camera and surgical tools. This technique is used for many surgical procedures today. However, because of more limited access, pre-surgical evaluation of disease is crucial and so imaging is instrumental with regard to surgical planning.

Liver cirrhotic nodules
Nodules or lumps that are symptomatic of liver cirrhosis and are formed when damaged tissue in the liver regenerates.

Magnetic resonance imaging (MRI)
A technique which uses a magnetic field to construct an image of a specific area of the body. This technique is particularly good for imaging the brain, bones, muscles, liver and bile ducts, pancreas, heart, and vessels. It provides high contrast between the different soft tissues. Unlike CT and x-rays, MRI does not use ionising radiation.

Malignant tumour
A tumour which has the ability to spread (metastasise) and/or to invade the contiguous organs. However, invasiveness is very different from one tumour to another. Some tumours develop mainly locally, while some others are often multifocal from the beginning. Even within the same organ, there might be very different types of malignant tumour. Therefore, the evolution observed in one person is usually not applicable to another, even if the same organ is involved. Malignant tumour is a synonym for cancer.

Mammography
A process that uses low energy x-rays to image the human breast. The aim is to detect breast cancer as early as possible by detecting masses or microcalcifications.

Metastasis
Refers to the spread of a disease from one part of the body to another. When a cancer has spread, it is said to have metastasised. The new tumours are referred to as metastases.

Modality
A term used within medical imaging to refer to particular imaging equipment or examination types, such as CT or MRI.

Medical Imaging
Refers to any process used to create images of the human body for medical purposes. It encompasses imaging techniques using both visible and invisible light and so covers a range of disciplines such as radiology, nuclear medicine, endoscopy, thermography, medical photography and microscopy.

Multi-Detector CT
Also known as multi-slice computed tomography, this method uses a two dimensional array of detectors to create images of multiple sections simultaneously, which greatly increases the speed of image acquisition.

Nano-particles
A term used in nanotechnology, it refers to an object with a size between 100 and 1 nanometres. One nanometre is equal to one billionth of a metre.

Nuclear Medicine
A medical specialty involving the use of radioactive substances to diagnose and treat disease. Nuclear medicine specialists use these radioactive substances or 'radiopharmaceuticals' to gauge the extent of a disease based on cellular function and metabolism, rather than on biological or structural changes within the body.

Optical imaging
An imaging technique which uses visible, infrared or ultraviolet light. Inferences can then be made based on the absorption or scattering of light within the body.

Over-investigation
In some cases patients may be referred for more examinations than is ultimately necessary. This can result from overly broad screening programmes leading to some patients being examined for conditions that may never cause any symptoms or complications.

Positron emission tomography (PET)
This imaging technique creates 3D images of functional processes taking place in the body by detecting the rays emitted by a positron emitting substance, which has been placed in the body. It is most commonly used in combination with CT (PET-CT) which allows for anatomical and metabolic imaging, so the radiologist can see what the structure looks like and what it is doing.

Polyps (colorectal)
A fleshy growth which develops on the lining of the colon or rectum. They are usually benign, but some types can become malignant. See the term 'adenoma'. Not all colonic polyps are adenoma. Only adenomas can develop into cancer over time.

Premalignant lesion
Refers to altered tissue where there is a greater chance of cancer developing than in the unaltered form. Identification of such a lesion allows preventive treatment.

Radiolabelling
Also known as isotopic labelling, this refers to the introduction of a radioactive substance into the body and tracking it through a metabolic pathway or cell.

Radiology
A medical speciality which uses imaging techniques such as x-ray radiography, CT, ultrasound, PET, and MRI to visualise and identify disease within the body.

RECIST
Response Evaluation Criteria in Solid Tumours is a set of published guidelines to help physicians define a cancer patient's status. It is used to indicate if a patient has improved (responded), stayed the same (stabilised) or worsened (progressed).

Renal insufficiency
A condition also known as renal failure or kidney failure. It is a condition in which the kidneys fail to adequately filter toxins and waste products from the blood.

Selective Internal Radiation Therapy (SIRT)
A type of radiation therapy for cancer that involves injecting tiny amounts of radioactive substance into the arteries which supply the tumour.

Serum alpha-fetoprotein
A plasma protein found within the human body. It is used as a biomarker to detect the presence of certain tumours.

Spiral CT
A type of computed tomography, where the x-ray source and detectors move in a helical (spiral) pattern around the patient in order to increase resolution.

Ultrasound
An imaging modality that uses ultrasonic waves. These waves are above the audible range of humans, but can be used to image tendons, muscles, joints, vessels and even organs for any signs of lesions.

X-ray
The oldest and most well known imaging modality, which uses x-rays to produce images of the body. It is a particularly useful technique as it is relatively cheap and can help detect a range of conditions.

Photo Credits

Page 6 Image provided by Hedvig Hricak, Elizabeth A. Morris and David D. Dershaw
Page 9 Image provided by Hedvig Hricak, Elizabeth A. Morris and David D. Dershaw
Page 10 Image provided by Hedvig Hricak, Elizabeth A. Morris and David D. Dershaw
Page 13 Image provided by Luis Martí-Bonmatí
Page 15 Image provided by Hiroshi Honda
Page 16 Image provided by Hedvig Hricak and Andrei Holodny, MSKCC
Page 18 Image provided by Hedvig Hricak, Elizabeth A. Morris and David D. Dershaw
Page 20 Image provided by Hedvig Hricak, Elizabeth A. Morris and David D. Dershaw
Page 25 Image provided by Hiroshi Honda
Page 26 Image provided by Wolfgang Schima
Page 28 Image provided by Hiroshi Honda
Page 31 Image provided by Hedvig Hricak, Elizabeth A. Morris and David D. Dershaw
Page 32 Image provided by Wolfgang Schima
Page 35 Image provided by Hiroshi Honda
Page 36 Image provided by Hiroshi Honda
Page 42 Image provided by Hedvig Hricak and Steve Solomon, MSKCC
Page 48 Image provided by Hedvig Hricak and Andrei Holodny, MSKCC
Page 52 Image provided by Hedvig Hricak and Andrei Holodny, MSKCC
Page 55 Image provided by Wolfgang Schima
Page 58 Image provided by Yves Menu
Page 61 Image provided by Luis Martí-Bonmatí

European Society of Radiology

Let's celebrate together

INTERNATIONAL DAY OF RADIOLOGY

NOVEMBER 8, 2012

WWW.IDOR2012.COM
WWW.INTERNATIONALDAYOFRADIOLOGY.COM

AN INITATIVE OF
THE EUROPEAN SOCIETY OF RADIOLOGY (ESR)
THE RADIOLOGICAL SOCIETY OF NORTH AMERICA (RSNA)
THE AMERICAN COLLEGE OF RADIOLOGY (ACR)

WWW.IDOR2012.COM
WWW.INTERNATIONALDAYOFRADIOLOGY.COM

MORE RADIOLOGY INFORMATION FOR PATIENTS:
PATIENTINFO.MYESR.ORG
WWW.RADIOLOGYINFO.ORG