

# SOMATOM Sessions

Radiation Therapy Supplement

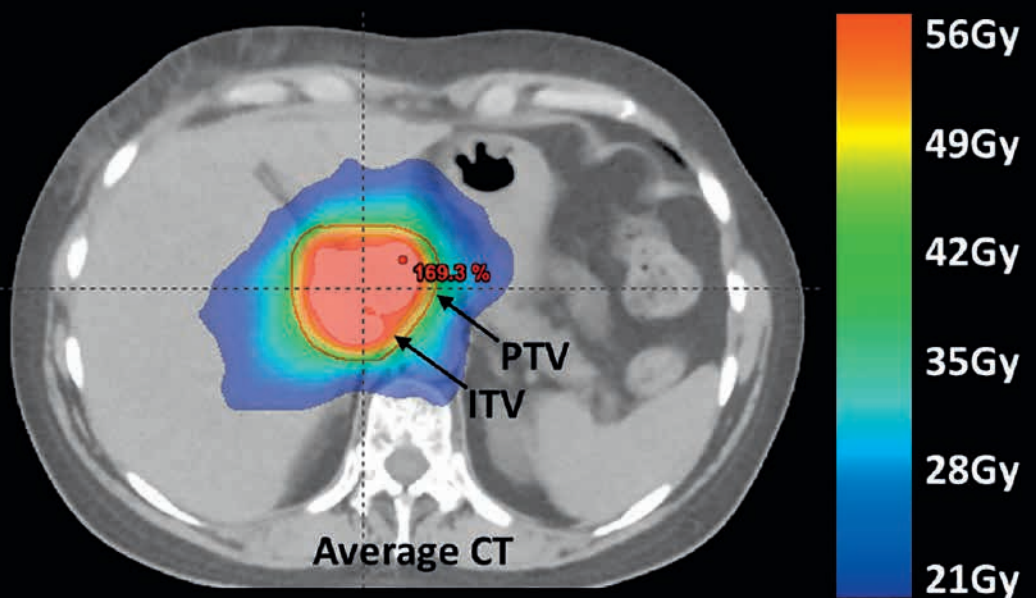
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**Chief Editors:**  
Monika Demuth PhD;  
Cécile Mohr PhD

**Project Management:**  
Sandra Kolb; Kerstin Kopp

**Responsible for Contents:**  
Gabriel Haras MD

**Editorial Board:**  
Monika Demuth PhD;  
Cécile Mohr PhD; Alexandre Ripert

**Authors of this issue:**  
Bär Esther, Department of Medical  
Physics in Radiation Oncology,  
DKFZ Heidelberg, Germany

Cisek Pawel, MD, Department of  
Brachytherapy of St John's Cancer  
Center in Lublin, Poland (COZL)  
Ćwikla Professor Jaroslaw, MD,  
Department of Brachytherapy of  
St John's Cancer Center in Lublin,  
Poland (COZL)

Hasuwald Henrik, MD, Department  
of Radiation Oncology, Heidelberg  
University, Germany

Kieszko Dariusz, MD, PhD, Depart-  
ment of Brachytherapy of St John's  
Cancer Center in Lublin, Poland  
(COZL)

Nowicki Miroslaw, MD, Department  
of Brachytherapy of St John's Cancer  
Center in Lublin, Poland (COZL)

**Journalists:**  
Robert L. Bard; Garry Barker;  
Jens Mattern; Martin Suter

**Photo Credits:**  
Jean-François Bérubé; Filip Ćwik;  
Darren Hauck; David McArthur

**Production and PrePress:**  
Norbert Moser, Kerstin Putzer,  
Siemens AG, Healthcare  
Reinhold Weigert,  
Typographie und mehr ...  
Schorfbaumstrasse 7,  
91052 Erlangen

**Proofreading and Translation:**  
Sheila Regan, uni-works.org

**Design and Editorial Consulting:**  
**Managing Editor:** Mathias Frisch

**Photo Editor:** Andrea Klee

**Layout:** Mathias Frisch,  
Irina Paschenko  
Independent Medien-Design,  
Munich, Germany In cooperation  
with Primafila AG, Zurich,  
Switzerland

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expertise with the readers of  
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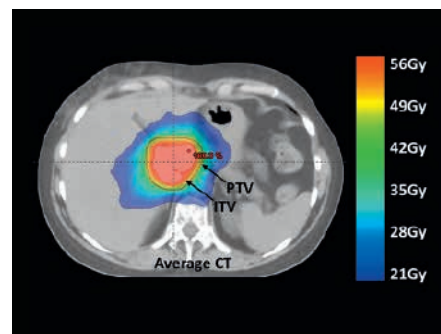
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Computed Tomography: diagnostic and therapeutic methods and their application  
as well as results and experience gained with corresponding systems and solutions.  
It introduces from case to case new principles and procedures and discusses their  
clinical potential.

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## Cover



For a patient with a solitary liver metastasis  
from breast cancer neither surgical resection  
nor radiofrequency ablation of the metastasis  
was an option due to location and size of the  
lesion.

A Stereotactic Body Radiation Therapy (SBRT)  
of the liver metastases was conducted sup-  
ported by a SOMATOM Definition AS Open  
4D-CT scanner. (Dose distribution in color-  
wash from 21 to 56 Gy.)

*Courtesy of Radiotherapy and Radio-Oncology  
Department, University Medical Center  
Hamburg-Eppendorf, Germany*

December 2014

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in a Breast Cancer Patient

## Dear Reader,



This Radiation Therapy Supplement of SOMATOM Sessions presents new ways of using CT in the therapeutic arena and demonstrates the leading role Siemens plays in helping physicians further improve patient care, especially as regards radiation therapy. Computed tomography is now used widely in radiation therapy (RT) for simulation purposes. CT provides patient-specific density distribution, the prerequisite for dose calculation, as well as 3D images of a quality that enables precise contouring of tumor and organs-at-risk. These are fundamental for confident planning of the right radiation therapy approach.

Such RT requirements of CTs are well understood. At Siemens, we listen to you as our customers and continuously strive to provide optimal solutions tailored to your needs in our SOMATOM portfolio. RT demands high image quality with minimal artifacts for confident contouring and the right set of positioning accessories – all integrated into a smooth workflow.

With the advent of novel treatment techniques such as stereotactic ablative radiotherapy (SABR) and stereotactic body radiotherapy (SBRT), the requirements regarding CT simulators are evolving. We already have answers to these recent developments. Our SOMATOM Definition AS Open – RT Pro edition, for example, has been optimized to meet these specific needs: From

the ability to achieve excellent image quality for all oncology patients, whether obese or with metal stabilization, prostheses, or dental implants (illustrated well by the German Cancer Center case study using iterative metal artifact reduction iMAR<sup>1</sup>) – to evaluate tumor motion precisely using 4D CT. And all this supported by smooth integration into the IT infrastructure of RT or radiology departments.

Beyond conventional external beam RT, computed tomography also has an important role to play in specialties like brachytherapy and particle therapy. Modern CTs such as those in the SOMATOM CT sliding gantry family bring high-quality 3D, 4D, and low-dose imaging to the treatment room and support your clinical and workflow needs. Today, you can learn how Dr. Dariusz Kieszko and the team at St. John's Cancer Center in Lublin, Poland, have successfully used their "CT-on-rails" in a wide range of brachytherapy cases. Another promising avenue is the potential of Dual Energy CT. Dr. David Roberge from CHUM, Canada, shares his views on potential new applications in RT, such as accessing functional lung information.

As you can see, CT in radiation therapy has a long and exciting journey ahead. We hope you enjoy reading this radiation therapy supplement. As always, we would

appreciate your feedback and look forward to continue to work with you to help bring the benefits of computed tomography to even more patients around the world.

**Gabriel Haras, MD**  
Head of Business Segment  
Radiation Oncology,  
Imaging and Therapy Systems  
Division, Siemens Healthcare,  
Forchheim, Germany

<sup>1</sup> This product is 510(k) pending. Not available for sale in the U.S. Contact your local Siemens organization for further details.

iMAR is designed to yield images with a reduced level of metal artifacts compared to conventional reconstruction if the underlying CT data is distorted by metal being present in the scanned object. The exact amount of metal artifact reduction and the corresponding improvement in image quality achievable depends on a number of factors, including composition and size of the metal part within the object, the patient size, anatomical location and clinical practice. It is recommended, to perform iMAR reconstruction in addition to conventional reconstruction.

The products/features here mentioned are not commercially available in all countries. Due to regulatory reasons their future availability cannot be guaranteed. Please contact your local Siemens organization for further details.

# High-Quality Radiation Oncology Care in Australia

From the beginning, the founders of Australia's GenesisCare saw that their goals of better patient care, superior technology, higher standards, and growth as a private oncology and cardiovascular provider required more than just good equipment. It needed a strong and dedicated partner with top class technology and ongoing research and development, plus an unstinting cooperation that would support them through their journey.

Text: Garry Barker, Photos: David McArthur



As the General Manager of Radiation Oncology Victoria, Aldo Rolfo from GenesisCare expects more than just good products from a healthcare provider.

When GenesisCare, Australia's largest radiation oncology group, went shopping for state-of-the-art CT scanners they were looking not only for one of the world's best technology and after-sales support,

but a partner. "We wanted to have a relationship, not just a transaction," says Aldo Rolfo, General Manager of Radiation Oncology Victoria, the Melbourne-based southeastern arm of the nation-

wide group. They chose Siemens because "we believed we could work together to implement the right solution and to look at opportunities around product development to improve our imaging."



## Technological and human factors

"We just felt that Siemens was the right fit to be able to do that," he says. "They understood what we wanted to do and were able to help us do it. That was very important to us – good quality imaging, plus good people to work with."

## Strong communication

"No matter what challenge we have thrown out, Siemens has delivered the solution. Siemens' SOMATOM is now our exclusive platform for CT scanning for radiation therapy across Australia. Their engineers and project management team come out and look at the requirements. We sit down together and formulate a project plan. There is really strong communication all the way through the process," Rolfo says.

"Siemens can take care of everything from construction through to certification. That's the kind of service we are after – almost a turnkey in some instances and in others where we had an existing room, less so, but there was a real flexibility around where we would get those CT scanners from the factory to our treatment rooms in a very short time and get them up and running quickly. I think in one installation at Footscray it was completed in three days, which is pretty phenomenal."

Aldo Rolfo likes to tell the story of a recent installation in Queensland that, he says, shows the knowledge, resourcefulness, and cooperation of Siemens' engineers and technicians. A big SOMATOM scanner had to be lifted to the eighth floor of a building. "Not many vendors would relish that," he says. "But Siemens did and were really good. Initially they were going to haul it up by crane on the outside of the building, necessitating the removal and replacement of a big window; very time-consuming and expensive. In the event they used the freight lift. That's a good feature of the Siemens equipment; it's big but it can be separated." In the Queensland build-

ing, the lift had a capacity of just three tons, and by separating the scanner into several pieces, each of them was under the maximal weight limit." Some vendors wouldn't have done that. It was a good outcome for us. We had none of the safety or construction issues that would have been involved if we had craned it up outside the building."

## Adding a fourth dimension

In the end, providing state-of-the-art treatment relies on technology. "One of the solutions we are talking about is a motion management approach which combines CT 4D scanning capabilities with RPM<sup>1</sup>," Rolfo says. "We are working closely with Siemens at the moment to introduce it in our practice." Currently, the SOMATOM



The Ringwood Radiation Oncology Centre is one of the 23 sites of GenesisCare and provides radiation therapy and care in particular to patients in the Melbourne area.

## GenesisCare Snapshot



■ Cancer Care   ■ Both Heart Care and Cancer Care   ■ Heart Care, Cancer Care and Sleep Care

In the last 12 months, GenesisCare Radiation Oncology Practices provided over 300,000 treatments across 23 sites and 45 linear accelerators by over 1,400 highly competent and professional staff.

<sup>1</sup> RPM is a trademark of Varian Medical Systems.

scanners are used to produce a 3D dataset of images used by the radiation therapy operators to aim their X-ray beams with precision that can be as fine as a single millimeter. SOMATOM scanners have built-in 4D capabilities, and when connected/combined, RPM adds a fourth dimension, time, to cope with, for example, a patient's breathing. We are moving quickly to four-dimensional datasets," Rolfo says. "We want to see what happens in movement – when a tumor is under movement from respiration or positional change, so now we are scanning with time and can track what happens as the diaphragm or the chest goes up and down."

"Every tumor site, and every patient is a different technical challenge that we solve through this planning process. We rely on high quality imaging to be able to visualize tiny tumors and there is no doubt that we have been seeing some really good image quality coming from the Siemens platform that we have implemented. Very clear and detailed images such as we are now getting enables our doctors to see small tissue structures and



*"Every tumor site, and every patient is a different technical challenge."*

Aldo Rolfo, General Manager,  
Radiation Oncology Victoria,  
Melbourne, Australia

design the treatment and do the irradiation very successfully."

### Finding solutions ...

GenesisCare is relatively new in oncology in Australia. It was founded ten years ago by Dan Collins, a businessman and analyst, who developed a passionate interest in healthcare but also many concerns about it as he watched his father's suffering and death from amyloidosis. Back in 2003, Collins had limited knowledge of the healthcare industry, but what he had seen and assessed through his business experience and acumen told him that the system

needed reform, needed an efficient businesslike approach, and better standards.

He believed a different operating model was needed, one that fostered alignment among the key stakeholders – patients and their referrers, doctors, professionals, and hospitals. And he saw that attention needed to be focused on how care was funded.

### ... for cancer and cardiovascular disease

Ten years ago, as Dan Collins began the journey that would culminate in the creation of GenesisCare, standards of care varied widely across Australia. Some patients were not accessing care at all; doctors and patients were unable to use known guidelines to make decisions. Collins saw waste, duplication, and funding models that were at risk. He set about finding solutions for the two principal disease burdens in the nation – cancer and cardiovascular disease.

That led him to Geoff Holt, MD, Head of HeartCare Partners in Brisbane, a practice of seven cardiologists that was leading the way in Australia towards group practice, sub-specialization, expert training and the use of networked electronic medical records rather than the cumbersome paper-based system then in general use. They formed a partnership, planned what they felt was necessary to do, and set about bringing



GenesisCare has deployed a variety of SOMATOM scanners across its locations, from SOMATOM Emotion to SOMATOM Definition AS Open.

together like-minded doctors to expand access to care, improve standards, and share best practice.

Today, the group's two divisions – CancerCare and HeartCare – operate strictly to the best international protocols. In the past 12 months, they have provided more than 300,000 cancer treatments and over 400,000 cardiovascular treatments. The group has more than 1,300 employees working in 102 locations.

### 1,000 cancer patients per day

In radiation oncology GenesisCare has 23 sites in Victoria, NSW, Queensland, South Australia, and Western Australia – with others being planned. They make up 25 percent of the total resource in Australia and together deal with more than 1,000 cancer patients a day.

"We operate to the standards that are followed in the US and Europe," Rolfo says. "We subscribe to all the protocols coming out of the US and Europe, so the treatment delivered in our centers matches that delivered in New York, Los Angeles or any of the major centers in Europe."

### Passion, accuracy, and patient comfort

Team spirit is strong among the professional staff. "We are very precise creatures here," says Karen Hailey, one of the Senior Imaging Planners at the busy Ringwood centre in the east of metropolitan Melbourne. Karen has worked in



Precision is of paramount importance in radiation therapy and reproducible positioning is ensured, from the beginning of the process, with the ability to use similar positioning accessories on SOMATOM scanners as on the linacs.

oncology and scanning for 30 years, starting her training, as did her boss, Aldo Rolfo, at the renowned Peter MacCallum Cancer Centre in Melbourne. It was clear as she explained the very fine tolerances that could be achieved with the SOMATOM scanner, and the high standards required in oncology patient care that she and her colleagues were dedicated and passionate about their work. "I can work to a fraction of a millimeter and do it day after day," she says. But every detail is checked and rechecked. Two operators work together on each scan to make sure data collected is absolutely correct. "The accuracy of the CT 3D data we record for the doctors determines the accuracy of the X-ray beam during treatment on the linac," she says.

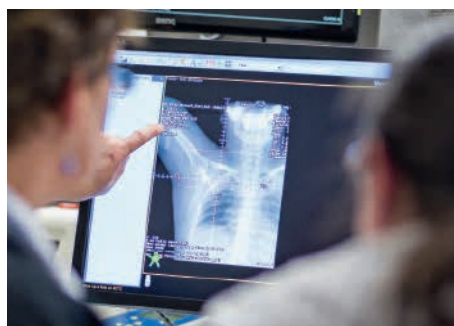
Accuracy and patient comfort are paramount, Rolfo says. "Patients undergoing radiation treatment have to have a scan of their treatment area precisely in the treatment position. Images are taken and exported to a dedicated treatment planning software solution where we model how the radiation behaves around the tumor or the area we are aiming to irradiate," Rolfo says.

"On nearly all sites we have an exclusive Siemens platform in place. There is no doubt that we have been seeing some really good image quality and definition coming from the Siemens platform we have implemented."

**Garry Barker**, specializes in business, technology, and healthcare. He has worked in Australia, New York, and Southeast Asia for the *Melbourne Herald*, and was Group Foreign Editor for the *Herald* and *Weekly Times* before being posted to London as Bureau Chief for Europe and the Middle East. He is currently Technology Editor of *The Age*, Melbourne's premier morning newspaper.

The statements by Siemens customers described herein are based on results that were achieved in the customer's unique setting. Since there is no "typical" hospital and many variables exist (e.g. hospital size, case mix, level of IT adoption) there can be no guarantee that other customers will achieve the same result.

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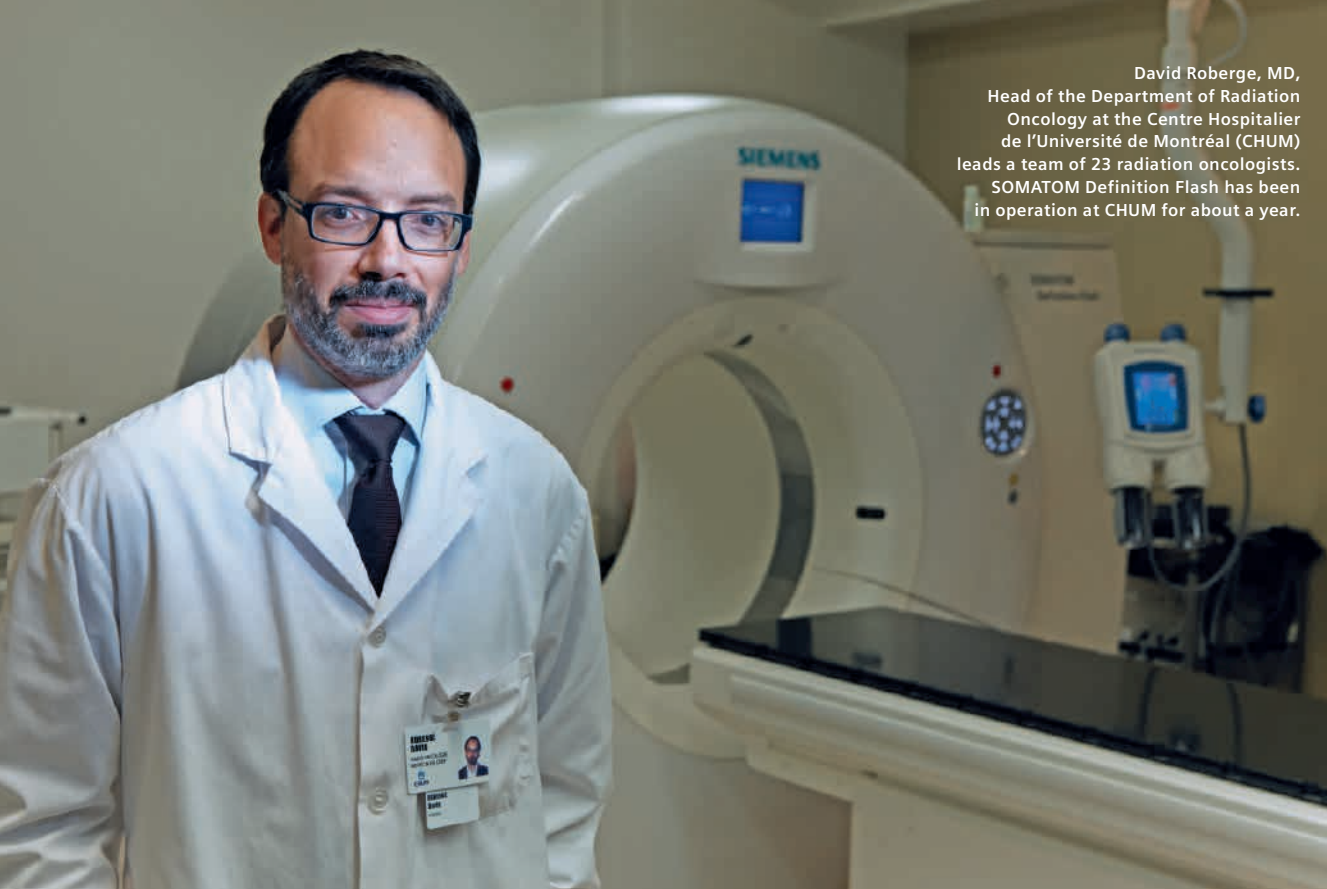


The team imports the SOMATOM images in the Eclipse™ treatment planning system (Varian Medical Systems) where the treatment plan is devised.

### Further Information

[www.siemens.com/  
imaging-for-RT](http://www.siemens.com/imaging-for-RT)





David Roberge, MD,  
Head of the Department of Radiation  
Oncology at the Centre Hospitalier  
de l'Université de Montréal (CHUM)  
leads a team of 23 radiation oncologists.  
SOMATOM Definition Flash has been  
in operation at CHUM for about a year.

# Big Steps Towards Dual Energy Simulation

In oncology, Dual Energy CT yields excellent results not only for diagnostic purposes. David Roberge, MD, at the University of Montréal in Canada, optimizes radiation therapy by utilizing Siemens's big bore scanners with Dual Energy capabilities.

Text: Martin Suter, Photos: Jean-Francois Bérubé

Energy seems to be what David Roberge is all about. Below the desk of the fast-talking oncologist, a wastebasket overflows with empty coffee capsules. He consumes "rarely less than three" cups a day, Roberge confesses. Yet stress is not what drives the Head of the Department of Radiation Oncology at the Centre Hospitalier de l'Université de Montréal (CHUM).

Rather, Roberge is animated by Dual Energy. The 41-year-old French-Canadian is convinced that using computer tomography scanners with Dual Energy capabilities can improve radiation treatment of cancer patients. Together with the 23 radiation oncologists in his department he has embarked on an ambitious Dual Energy CT research program. "The whole

work that will hopefully produce benefits because Dual Energy is just starting right now," he says. Barely suppressing his pride, he adds: "We are pioneers."

Dual Energy scanners take two images at different energy levels of typically 80 kV and 140 kV. They are routinely used in clinical settings to improve the visualization of conditions like musculoskeletal



injuries, gout, arteriosclerosis, stroke, pulmonary embolism, brain hemorrhage, and cardiovascular disease. "Take a kidney stone," Roberge explains, "it will tell you the composition of the stone, and this helps you find the disease that creates the stone."

### Taking technology a step further

When it comes to cancer, the advantages of acquiring two different CT images have been proven for the diagnosis of a variety of tumors, mainly those in soft tissue. Lesions in the liver or the pancreas are more clearly identifiable as benign or cancerous because they look different at various CT energy levels.

David Roberge and his team take the technology a step further: They believe Dual Energy CT images allow them to more precisely simulate external and internal radiation therapy as well as to improve dose calculation. To prove the concept – and offer patients better treatment – the department purchased three state-of-the-art Siemens CT scanners. One of them, the Dual Source SOMATOM Definition Flash, has two separate X-ray tubes capable of producing two images at different energy levels in one go. The other two scanners, both SOMATOM Definition AS Open, run two consecutive scans to acquire Dual Energy data.

### Radiation therapy simulations

Both Siemens radiation therapy tailored scanners boast wide bores of 78 cm for the SOMATOM Definition Flash and 80 cm for the SOMATOM Definition AS Open. This makes them ideally usable as radiation therapy simulators. In order to plan for radiation treatment, patients are positioned exactly as they will be on the table of the linear accelerator. "For instance, breast cancer patients must be scanned with one arm up," says Roberge. "Plus we need to see all of the tissue, not only the tumor. We need a bigger

image. Also, we need a flat table enabling a reproducible position and lasers for reference marks."

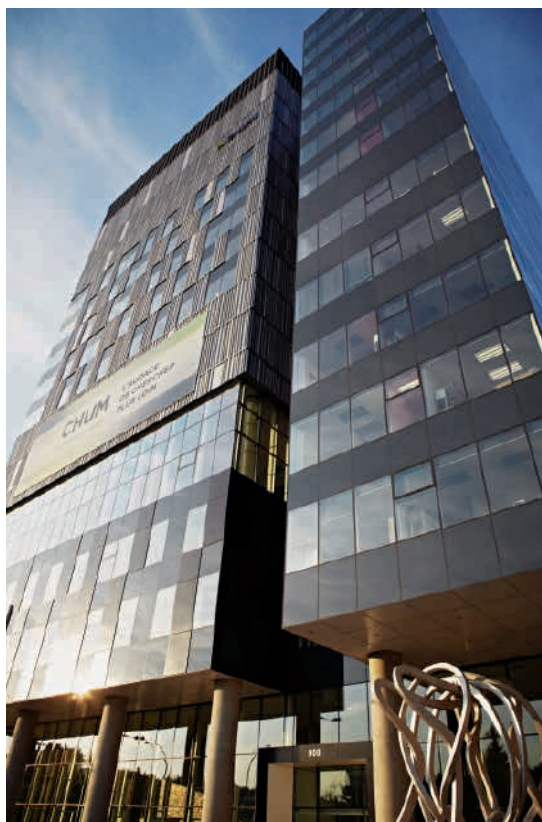
David Roberge cannot show the two single-source scanners, because they are yet to be installed at a new facility of the CHUM. A private consortium is in the process of building three glass towers near Montréal's Quartier Latin. The government-run hospital as the tenant will move in gradually, and the most services, including radiotherapy, will be operational 2016, the final project (including an auditorium, offices and all of the clinic space) will be operational in 2020. For its interior design, Roberge made sure the scanning and radiation equipment will be mounted in a workflow-optimizing layout, with CT scanners, MRI scanners, and injection rooms all in a row.

The Dual Source scanner, however, has been in operation in CHUM's

*"In many cases, we think the amount of iodine correlates with the function. So we have a project looking at a lung with a Dual Energy scan and quantifying the lung contribution due to the contrast perfusion."*

David Roberge, MD,  
Head of the Department  
of Radiation Oncology,  
Centre Hospitalier de  
l'Université de Montréal, Canada

old building for about a year. The brick architecture of the Hôpital Notre Dame at the east end of the Parc Lafontaine looks as plain from the outside as it is impractical on the inside. The Radiation Oncology



Centre Hospitalier de l'Université de Montréal (CHUM) is located in the center of Montréal and near by the river Saint-Laurent.

*“When we got that device we were getting something that was uncommon, that has possibilities for the future, that we can use to innovate with, that gives us research opportunities.”*

David Roberge, MD,  
Head of the Department  
of Radiation Oncology,  
Centre Hospitalier de l'Université  
de Montréal, Montréal, Canada

Department has gone through serial expansions and has had to function over three levels, requiring time-consuming patient travel between floors. It is expected that the new building will simplify procedures considerably.

### True enthusiasm

The present locality cannot diminish Roberge's enthusiasm for the Dual Source Dual Energy scanner. Its purchase became one of his

priorities after he took over the department four years ago. Born in Montréal, David Roberge became interested in radiation therapy in medical school, when his grandmother was suffering from Hodgkin's Disease. The fascination has never left, and he passed it on to his colleagues at CHUM: Roberge could convince his fellow radiation oncologists to each contribute about 10,000 Canadian Dollars of their private funds to the hefty purchase price of the SOMATOM Definition Flash.

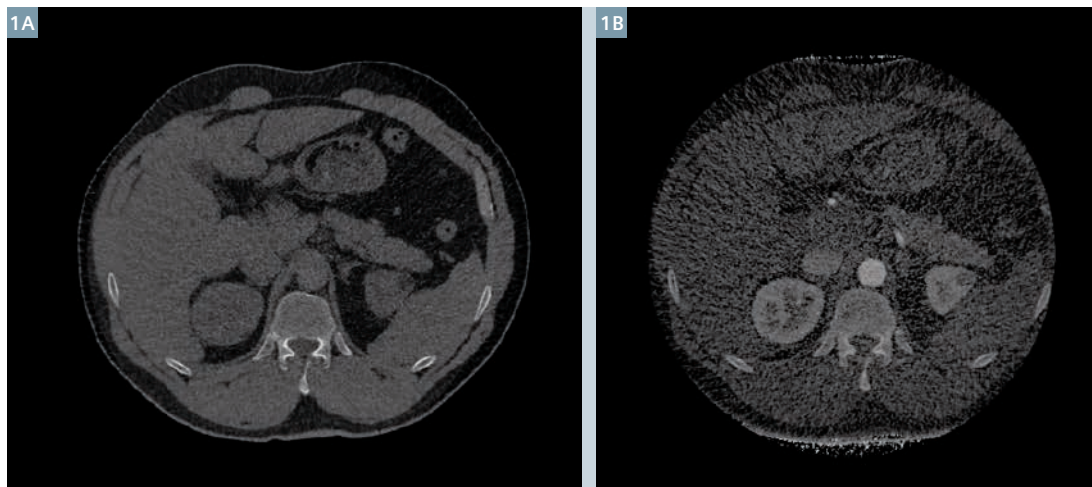
In Canada's socialized medical system the doctors do not expect to increase profits, he says. “But there is a feeling that it will help the image of the institution to have this equipment. It also helps when we ask patients for money to support the institution.” The idea is to make CHUM better known outside of Québec. The Dual Source Dual Energy scanner is “a large piece of equipment that was bought with goals beyond giving the best care for patients,” Roberge explains. “When we got that device we were getting something that was uncommon, that has possibilities for the future, that we can use to inno-

vate with, that gives us research opportunities.”

### Tailored treatment of tissue

Most of the benefits of Dual Energy CT's can be achieved with either of the two scanner types. Acquiring two scans at unequal energy levels helps reduce metal artifacts, those X-ray shadows cast by implants. Another promising area of research is the tailored treatment of tissue based on functional information. “Usually we think of healthy tissue on a volume basis,” Roberge says. He takes the example of the lung, where radiation treatment is considered safe if it does not affect more than, say, a certain percent of the organ's 1,000 cubic centimeters. In that regard, lungs, kidneys, or livers “are considered a piece of meat.”

But in reality not all parts of the lung are equally active. “If patients have been smoking for many years and they have underlying lung disease, some parts of the lung might be contributing more to the respiratory function and some less,” David Roberge explains. The aim is to irradiate the different areas of the lung unequally and, if possible, avoid as much as possible treat-



1 Dual Energy CT can provide patient-specific tissue information such as effective electron density ( $\rho_{\text{eff}}$  Fig. 1A) and effective Atomic Number ( $Z_{\text{eff}}$  Fig. 1B).



For the radiation oncology team, fast acquisition offers the unique chance to scan organs in motion.

ment beams going through healthy and functionally active parts. This is where Dual Energy comes in. "It allows us to automatically quantify the iodine that is in the contrast material," says Roberge. "In many cases we think the amount of iodine correlates with the function. So we have a project looking at a lung with a Dual Energy scan and quantifying lung function based on contrast."

### Potential to open up new approaches in radiation therapy

As Roberge explains, Dual Energy can improve image quality with iodine contrast. "But to calculate the dose we must look at the body without contrast. We typically did one scan without contrast and then injected contrast and did it again. And we used one to define the target and one to calculate the dose. We hope to come up with a methodology to use the Dual Energy to do the scan just once with the contrast and to use software to remove the contrast for the dose calculation." As a result, the second scan would be unnecessary. "It will mean less radiation dose for the patient, and it is also faster."

"Exact dosing is particularly important with brachytherapy, because often larger doses are delivered internally than externally," Roberge says. "If we can better define the tissues and their electron density, that is, how much radiation tissue can absorb, with Dual Energy, maybe it will have an impact in brachytherapy dose calculation." Dual Energy promises even better results for proton therapy, he believes. "But there is currently no proton therapy in my neck of the woods." Canada's healthcare system affords only one proton accelerator in Vancouver. In the United States, 13 of the very expensive machines are in use.

Again and again, Roberge returns to his SOMATOM Definition Flash. Its advantage beyond the Dual Energy capability is image quality and speed. Hélène Lama, a radiotherapy technician, is full of praise for the SOMATOM Definition Flash scanner. "Acquisition of the image is faster and the definition of the image is really, really good," she says. Patients can be intimidated by the large size of the machine. "Some are claustrophobic. Then we talk to them and explain that the machine is there to help them."

For the radiation oncologist, fast acquisition offers the unique chance to scan organs in motion. "We have seen things we did not imagine," says Roberge. "For example, CT scans where you see someone swallowing, displayed in a video." Looking into the future, the caring father of a young daughter can visualize highly specific radiation treatments of critical organs such as the pulsating heart. Aided by fast Dual Energy CT images, the therapeutic radiation could eventually be applied "only at one point in the heart's cycle, for instance at maximum dilation."

But Roberge knows that such innovations take time. "Proving the concept can be achieved soon, but the clinical proof will only be possible later." The slow rhythm of research does not discourage him, though. The additional information provided by Dual Energy CT, particularly with fast single sourcing, has already yielded the most important results for any physician, he says. "It has changed how we treat certain patients."

**Martin Suter**, based in New York City since 1993, is a correspondent for the *Swiss Sunday newspaper, Sonntags-Zeitung* and has written for a variety of major European publications on topics ranging from politics and technology to business and healthcare.

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### Further Information

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# Optimizing Cancer Care in America's Dairyland

Located in the heart of the Midwest United States, Wisconsin has long been considered as "America's Dairyland". So much so that Wisconsinites are lovingly referred to as "cheeseheads". Milwaukee, Wisconsin, is home to the Froedtert and the Medical College of Wisconsin Clinical Cancer Center. Allen Li, PhD, Professor of Radiation Oncology and Chief of Medical Physics, discusses clinical considerations of designing radiation therapy CT protocols to optimize cancer care to cheeseheads and non-cheeseheads alike.

Text: Robert L. Bard, Photos: Darren Hauck



Allen Li, PhD, Professor of Radiation Oncology and Chief of Medical physics at the Froedtert & the Medical College Clinical Cancer Center, Milwaukee, WI, USA

Different tumors in different areas of the body have unique characteristics. In radiation therapy, these need to be considered in balancing sufficient dose to obtain the best local tumor control while limiting the patient's healthy tissue to radiation exposure. Furthermore, each patient is unique and brings additional challenges to clinicians who have the task of treating their cancer. CT imaging is the foundation for devising a radiation therapy treatment plan, and proper contouring on the basis of the images helps to clearly distinguish the targets from the normal, healthy surrounding structures and potential organs-at-risk. Li describes the process of contouring on CT images as "delineating the target and the normal structures." He adds, "Contouring is important because any error will be carried forward through the patient's treatment plan and we want to reduce any uncertainty with good image quality."

In some cases, particularly in lung and pancreatic cancers, proper contouring involves accounting for motion during the respiratory cycle. The normal lungs and tumor often have different density and would be very easy to image if not for breathing movement. Li adds, "If you are



unable to remove the respiratory artifact in the radiation treatment of pancreatic cancers then a potential consequence is the duodenum may be injured from the radiation treatment because of its proximity to the pancreas.”

### Optimizing image quality as a sound basis for treatment

The SOMATOM Definition AS Open is equipped with a set of hardware and software features which permits excellent images of the pancreas and lungs despite motion during the respiratory cycle. Allen Li remarked that he uses a 4D CT protocol for image acquisition of sarcomas metastasized to the lung, where advanced motion correction eliminates breathing artifacts and reduces noise.”

Dedicated approaches based on tailored feature sets of CT scanners are of paramount importance to provide quality care with confidence, in a wide range of clinical cases. For example, radiation therapy of the pancreas puts a healthy duodenum at risk because the duodenum is in close proximity to the pancreas and non-optimized CT is less able to deal with motion, often leading to images with artifacts. As a result, boundaries of the diseased pancreas and the duodenum are less clear on CT planning images and therefore contoured less precisely; this can put the healthy and sensitive structure at risk of exposure during treatment.

Li explains, “Thanks to the ability of adequately modulating the CT tube current according to clinical needs, imaging of the pancreas has improved with the ability to go against the established protocol by having the ability to adapt dose as needed, which is new.”

Proximity of targets and organs-at-risk is also a challenge in contouring of prostate and head and neck patients. In such cases, the body areas typically contain healthy tissues that are soft and small, and thus vulnerable to harm from even low levels of radiation delivered

during treatment. In the case of prostate patients, Li explains that the neighboring bladder and rectum – to be protected during therapy – are composed of similar tissues to the prostate, which is to be treated thus high-quality CT images and precise contouring is required to clearly differentiate these structures and plan the best treatment possible. Further CT protocol optimizations are also required as tumor types are also very diverse. So, in addition to visualizing target and healthy tissue, clinicians need the ability to tune CT imaging according to the clinical case. This is possible with the SOMATOM Definition AS Open and is a primary reason why Li chose Siemens.

### Supporting operational needs

The Froedtert & the Medical College Clinical Cancer Center is a bustling state-of-the-art facility filled with eager faculty and staff to help patients and families afflicted with cancer. The halls of Froedtert prominently display salvaged architectural features of the previous hospital to preserve a connection between the old and new. In this clinic, as in many others where space can be sparse, the SOMATOM Definition AS Open was an excellent choice as it is

very efficient in terms of clinical space: It fits into a very small CT suite with a footprint of only 18 square meters (59 sq ft) and a system design that needs only 24 square meters (78 sq ft). Additionally, the scanner can fit into many existing infrastructures because it can be cooled by either air or water. The water cooling is quite advantageous in radiation therapy, as patients typically get marking on the skin and no unpleasant draughts of cold air is blown on them during the process.



The Froedtert & the Medical College Clinical Cancer Center of Wisconsin is the largest cancer treatment hospital in the Midwestern United States.

*“Contouring is important because any error will be carried forward through the patient’s treatment plan and we want to reduce any uncertainty with good image quality.”*

Allen Li, PhD, Professor of Radiation Oncology and Chief of Medical Physics at the Froedtert & the Medical College Clinical Cancer Center, Milwaukee, WI, USA



The SOMATOM Definition AS Open with Sliding Gantry can be installed in a linac bunker and provides high image quality for precise position verification.

Efficient imaging is an obvious advantage to patients as it can help attenuate their inherent stress. All patients benefit from faster scanning, but some may benefit significantly with the new technology. Many radiation therapy patients are very sick, frail, and distressed and are likely to benefit the most from efficient imaging. Additionally, all pediatric imaging is likely to be improved because of children's inherent energy and difficulty remaining still. The faster imaging is due in part to the SOMATOM Definition AS Open's fast rotation speed and reconstruction power. Lastly, operating the CT scanner has become easier and less time consuming for the staff: It is not uncommon that certain CT scan-

ners have X-ray tubes that require warm-up before being able to scan the patient and cooling, for example following 4D CT acquisitions, causing delays. With the direct anode cooling technology of the Straton tube, SOMATOM Definition AS Open eliminates these issues and the wasted time that it caused – thereby streamlining usage of the equipment.

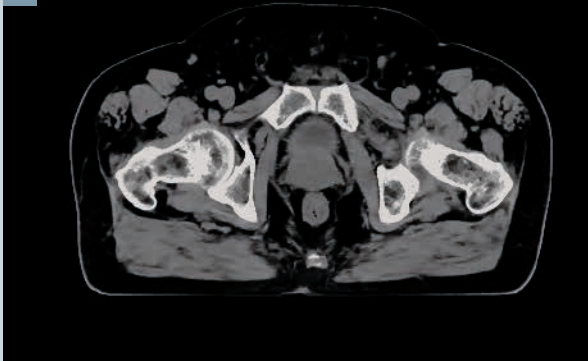
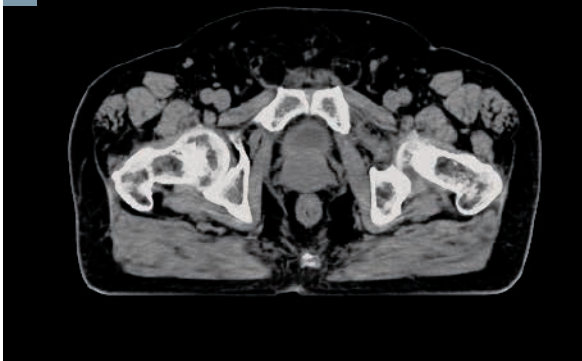
### Meeting individual patient needs during radiation therapy

Allen Li explains that some patients may have to hold an uncomfortable position during imaging, as scanning needs to be in the same position as during treatment on the

linear accelerator. For example, patients with breast cancer must pose with the arm up and away from the target breast which some find uncomfortable. Therefore, imaging needs to be fast while visualizing the entire anatomy, especially the body outline, which permits dose calculation and treatment planning. With older technology, both the speed and field-of-view were limiting. Now, Li explains, "With the SOMATOM Definition AS Open the images can be reconstructed" if the anatomy extends beyond the scan field-of-view. This is possible thanks to the extended field-of-view and HD FoV features, which permit users to view and use images for precise treatment planning, covering anatomical areas larger than previously possible. The extended field-of-view is particularly useful in imaging of obese and sarcoma patients referred to radiation therapy. Combined with these useful functionalities, the spacious scanner that accommodates positioning aids, such as a breast board is an excellent choice for radiation therapy planning.

In addition, Li's colleagues in radiology have made arrangements to scan their obese patients with the radiation oncology department's equipment because of its capabilities and superior weight limit of 212 kilograms (300 kilograms optional). Obese patients may no longer be excluded because of scanner limitations. Time-consuming special care and handling between CT technologists and obese patients has been eliminated or minimized and larger patients can undergo treatment feeling more comfortable and less self conscious.

Last but not least, Li explains that there are many opportunities to improve the quality of the images – which can be compromised, for example in large patients. Li explained that the iterative reconstruction algorithm, SAFIRE<sup>1</sup> (Sinogram Affirmed Iterative Reconstruction) is helpful for selected cases and reduces noise – thereby increasing image conspicuity for



**1** Prostate cancer patient underwent CT-guided radiation therapy. CT was acquired immediately prior to each delivery of radiation therapy. Protocol optimized images (Fig. 1A: Filtered back projection, Fig. 1B: SAFIRE).

further delineation. In addition, he also says, “The big benefit of SAFIRE is that it does not take much time.”

In closing, Allen Li says that he believes designing protocols for radiation therapy using the SOMATOM Definition AS Open is easy once the user grasps an appreciation for the relationship between the tube

current and voltage – and takes advantage of the special scanner features. Furthermore, Li believes that “image acquisition is very intuitive” and that there are additional, lesser known benefits to his new system. For example, Li adds, “Routine QA for physics is easy to operate,” and he also believes the learning curve is low

for therapists who operate the system, in particular for those who may not have a radiology background.

**Robert L. Bard** is a freelance medical writer certified by the American Medical Writer's Association who also conducts clinical research at the University of Michigan's Division of Cardiovascular Medicine.

## The Froedtert & the Medical College of Wisconsin Clinical Cancer Center

Located in the heart of the Midwestern United States in Milwaukee, Wisconsin, the Froedtert & the Medical College of Wisconsin Clinical Cancer Center is the largest cancer treatment hospital in the Midwestern United States. Recent successes in the surgical removal and radiation therapy of pancreatic cancers have resulted in patient referrals from all over the world. The Clinical Cancer Center is focused on streamlining the cancer experience for both patients and their families. The facility provides “one-stop shopping” where patients can have all their medical needs addressed. All oncologists are highly specialized since they are not just cancer specialists,

but rather cancer specialists for one particular area of the body. The Clinical Cancer Center provides a multidisciplinary team approach of specialists who provide cancer treatment, including medical physicist Allen Li, PhD.

Allen Li is Professor of Radiation Oncology and Chief of Medical Physics at the Froedtert & the Medical College of Wisconsin Clinical Cancer Center. Li also serves as the Director of the College's Physics Residency Program and he works closely with clinicians to provide high quality radiation therapy care – from imaging to treatment delivery – to the cancer center's patients.

<sup>1</sup> In clinical practice, the use of SAFIRE may reduce CT patient dose depending on the clinical task, patient size, anatomical location, and clinical practice. A consultation with a radiologist and a physicist should be made to determine the appropriate dose to obtain diagnostic image quality for the particular clinical task. The following test method was used to determine a 54 to 60% dose reduction when using the SAFIRE reconstruction software. Noise, CT numbers, homogeneity, low-contrast resolution and high contrast resolution were assessed in a Gammex 438 phantom. Low dose data reconstructed with SAFIRE showed the same image quality compared to full dose data based on this test. Data on file.

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# Image-Guided Brachytherapy: New Perspectives in Poland

While the Polish healthcare system has not caught up with the speed of the rising economy, the Ministry of Health has invested in prevention and treatment of cancer in the last few decades. This has positively impacted especially the less prosperous east of the country. Today, a hospital like the St John's Cancer Centre in Lublin, close to the Ukrainian border, can offer a wider range of high-quality brachytherapy treatments to its patients.

Text: Jens Mattern, Photos: Filip Ćwik

"It started with the permission for a new building for our hospital," explains Dariusz Kieszko, MD, Deputy Director of Brachytherapy at St John's Cancer Centre in Lublin. Knowing of the advantages of a CT with sliding gantry that enables imaging and treatment to be com-

bined in one room, he asked to build a theater of 50 square meters, an unusually large suite for a Polish hospital. Today, the staff of the brachytherapy department is highly satisfied with its decision and the purchase made in 2011 – for many reasons. While brachy-

therapy treatments were very limited in Lublin before, being used primarily for gynecological cases and sometimes for lung cancer, the department can now additionally treat breast cancer, advanced skin cancer, and liver cancer.

## Issues of time ...

Since the existing CT at St John's Cancer Centre was permanently occupied by the demands of external beam radiation therapy, the brachytherapy department used an analog X-ray C-arm apparatus to visualize patient anatomy and implants – a time-intensive procedure.

As the need for 3D images became quite apparent, a further key time-related issue was the transport of the patient from the brachytherapy suite, where implants were set up, to the imaging room, where CT images were acquired. "Today, with the Siemens SOMATOM CT scanner with Sliding Gantry directly located in our theater, we save an hour with each patient," Kieszko says.

## ... and of precise use of HDR dose

Today, a 54-year-old woman is here for treatment, which is led by assistant radiation oncologist Pawel Cisek. The patient has breast cancer and metastases in the stump of the



Pawel Cizek and the Lublin team have finalized an image-guided brachytherapy treatment and the patient will go to the post-surgery recovery room. In many cases, the patient can go home on the same day of the intervention.





Dariusz Kieszko, MD, PhD (right) and Pawel Cisek, MD (left) are radiation oncologists specialized in image-guided brachytherapy. In addition to treating many diseases such as breast cancer and skin cancer, they continuously develop their techniques and recently started treating liver cancer patients.

vagina have to be treated. The uterus has been removed previously, and the metastasis probably came from the ovary. Since her cancer has metastasized, she also receives chemotherapy as part of her treatment regimen.

A few days earlier, a CT scan of the vagina was made. On the day of the treatment, four titanium applicators were inserted by the physician and a new CT image was made with the implants in place. The patient lost some blood during the insertion, but the specially designed rails of the CT are sealed against fluids, ideal for a surgical environment.

In the computer room next to the brachytherapy suite, Pawel Cisek uses the images to analyze the position of the needles in the tumor relative to the anatomy. He marks critical structures to be spared during treatment in yellow – in this case, urinary bladder, large intestine, and rectum – for the physicist and sends him the images.

The radiation oncologist discusses the dose and the duration of irradiation with the physicist and shows

him the visualized critical structures. “There is not much tolerance of variation for the dose,” says Cisek.

After the plan is finished, treatment is performed. Later applicators are removed and the patient can recover in a special post-surgery room, freeing up the operating theater for another patient. After a rest, the patient can go home the same day.

“We have been using high dose rate brachytherapy (HDR) since 2006,” explains Dariusz Kieszko. The more traditional low dose rate brachytherapy (LDR) treatment, which uses seeds implanted for a longer time in the body of the patient, typically necessitates hospitalization, thereby requiring more staff and typically incurring higher costs. Now, HDR is supported by the 3D accuracy and image quality of the in-room CT.

The 54-year-old woman would not have been treated with brachytherapy previously. “Too risky,” Kieszko says, “because we wouldn’t have known exactly where the needles are.” Also, the delicate

organs in the surrounding area could not have been seen with a 2D conventional X-ray image. Nowadays, treatment like hers is routine.

### The cost factor

The faster procedure allows the staff in Lublin to accept more outpatients, which is significant because these make up 80 percent of all cases in brachytherapy.

Further, the Narodowy Fundusz Zdrowia (NFZ), the national Polish health fund, is well aware of the possible cost savings and regards the use of a CT to be 50 percent cheaper than conventional 2D radiography. In general, the NFZ invests 250 million Zloty (approximately 59,5 million Euros or 77 million US-Dollars) in the purchase of radiology equipment per year. “Because of that solid financial background, the fund has financed 85 percent of the cost for the SOMATOM system, with the rest being contributed by the hospital,” explains Krzysztof Paprota, Director of the Radiation Oncology Department.



*“There is not much tolerance for variation in the treatment dose.”*

Dariusz Kieszko, MD, PhD,  
St John's Cancer Centre,  
Lublin, Poland

With the possibilities of the CT located directly in the operating theater, brachytherapy treatments in Lublin have increased by about 50 percent. Currently, two new patients are treated each day, and about six patients come for repetitive treatment. Since spring of this year and using their image-guided suite, St John's Cancer Centre also started offering a new kind of very demanding treatment for liver cancer and 16 patients have been already treated to date.

### Treating liver cancer

Dariusz Kieszko learned about liver brachytherapy, quite an advanced procedure, at the University Clinic for Hematology and Oncology in Magdeburg, Germany. “We use it when chemotherapy yields no results and the location of the tumor does not allow an operation,” says Kieszko. Most of the cases are secondary malignancies, which are less than 8 centimeters. The treatment has a mainly palliative character – a real cure happens seldom.

The major therapeutic challenge is based on the fact that the liver does not tolerate high radiation and that it is well supplied with blood. For this reason, the radiation oncologist works together with an interventional radiologist, who can assist in the case of serious bleeding. Furthermore, the team consists of an anesthetist, who performs local anesthesia between the lower ribs, where the

catheter is implanted, plus two nurses and a technician.

The images provided by CT aid the physicians in the precise positioning of the needles and elastic applicator. This is of paramount importance in this form of image-guided radiation therapy (IGRT), during which the patient is lying and imaged on the operating table. However, even IGRT needs the help of additional imaging. Therefore, following anesthesia, contrast medium is injected in order to

locate the liver tumor. Here, too, precision is fundamental. After this, a standard biopsy needle is placed in the tumor, before an angiographic device with a hemostatic valve is inserted. Through the device, which is wider than the needle, elastic catheters can enter the body and reach the tumor: These will be used to deliver the treatment. In order to irradiate the entire tumor volume, clinicians plan carefully dwell positions throughout the targeted area, typically spacing them 2 centimeters apart from each other. Radiation treatment itself takes about 30 to 40 minutes, which is long for brachytherapy.

To establish the clinical target volume (CTV) two CT datasets are combined – one pre-surgery and the other acquired for planning. The high-definition 3D CT images are necessary to identify the parenchyma of the liver, the stomach, the large intestine, duodenum, the spinal cord, and bile ducts. These are critical structures, that have to be protected, while the dose deliv-

The 3D image-guided Brachytherapy Suite at the St John's Cancer Centre, in Lublin, Poland, is equipped with a large bore SOMATOM CT Sliding Gantry and GammaMedplus iX afterloader (Varian Medical Systems).



ered to the target ranging from 15 to 25 Gray by D90% depending on the tolerance of the neighboring organs.

After the treatment, the patient receives hemostatic agent to stop any possible bleeding, before another CT with contrast medium is performed to check that indeed no bleeding has occurred.

There are two worst-case scenarios that need to be considered with such treatment: Bleeding caused by a rupture of the liver vessels and bleeding caused by the removal of the applicators. But Kieszko ensures: "We are prepared for bleeding, which is hard to control, during and after the treatment." After a night at the hospital, the patient's pulse, blood pressure, and heart activity are checked again on the second day and a final CT with contrast medium is made to check once more that there is no bleeding. If everything is all right, the patient can go home.

### More IGRT in the future

For Kieszko, it is too early to talk about the success of such treatments. But by monitoring the 16 patients over several months via CT or MRI, the radiation oncologists in Lublin have seen a stabilization or even a reduction of the alteration activity of metastases in several patients – an encouraging result.

Up to now, five of the 16 patients were referred from other hospitals, even from the far-away capital of Warsaw. Kieszko believes the number will increase – with the same happening for other cancer types, such as breast cancer. In this case, the Polish Ministry of Health has invested 30 million zloty (approximately 7 million euros or 9 million US dollars) in educating women about the disease, leading to more patients being treated earlier.

One established treatment approach, recommended by renowned American medical societies consists in irradiating the breast externally after breast-conserving surgery, during which the tumor has been removed.

In addition to external beam radiation therapy, where the whole breast is irradiated, brachytherapy treatment as a boost (increasing radiation levels to the tumor bed) can hit the target precisely with a high dose, thereby shortening the treatment time in comparison with external irradiation.

With this technique, the neighboring tissue that has been partially infiltrated by cancer cells, receives a weaker but necessary dose of radiation. The high-definition 3D CT images help to visualize clearly and thereby protect the neighboring tissue and organs from unnecessary radiation.

Another method in use is accelerated partial breast irradiation (APBI), also performed after breast-conserving surgery, and used for smaller tumors. In this procedure, elastic applicators are inserted through the breast to lead the radiation to the area of the former tumor twice a day, and this for a week. This procedure also requires precise planning using CT-based 3D imaging for every application, in order to preserve sensitive structures. Today, 20 percent of breast cancer cases in Lublin are treated with brachytherapy.

Skin cancer is also an issue in the agricultural population of south-east Poland, because workers are intensively exposed to the sun during summer-time field work. With advanced skin cancer on the scalp, planning using CT is indispensable, too, in order to avoid radiation to the eyes and brain. As applicators need to be positioned on the surface of the head of the patient, the team in Lublin has developed an approach, using a meshed mask that keep the elastic applicators in place, during imaging and treatment.

According to Dariusz Kieszko, the brachytherapy department will use more IGRT in the future, and he and his team are already planning to broaden their treatment spectrum to prostate cancer and

metastases on the lung. "We are in a state of permanent development," Kieszko says, his gaze shifting to the cranes swinging over a construction site outside the window: The second enlargement of the St John's Cancer Centre has already started.

**Jens Mattern** born in Freiburg im Breisgau, Germany, works as a freelance journalist in Poland. He has contributed to countless German-language publications, among them *Berliner Zeitung*, *Tages-Anzeiger*, *Profil*, *Spiegel online*, *ZEIT online*, and *Welt.de*.



1 3D visualization of liver, kidney, target and applicator channel after contours are drawn. Position of maximum GTV dose is shown in red (see also Clinical Results, page 22).

The statements by Siemens customers described herein are based on results that were achieved in the customer's unique setting. Since there is no "typical" hospital and many variables exist (e.g. hospital size, case mix, level of IT adoption) there can be no guarantee that other customers will achieve the same result.

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## Case 1

# Reducing Metal Artifacts in a Patient with Dental Fillings

Henrik Hauswald\*, MD, Esther Bär\*\*

\* Department of Radiation Oncology, Heidelberg University, Germany

\*\* Department of Medical Physics in Radiation Oncology, DKFZ Heidelberg, Germany

## History

A 53-year-old male patient with otherwise controlled lung cancer was diagnosed with a solitary soft tissue metastasis in the left masseter muscle. Due to the limited disease burden, radiation treatment was chosen as a potentially curative method. A CT scan was ordered for radiation treatment planning.

## Comments

The images were reconstructed with weighted filtered back projection (WFBP), and additionally reconstructed using the iterative metal artifact reduction (iMAR)<sup>1</sup> algorithm.

Metal artifacts from dental fillings affected about 17 slices of the conventionally reconstructed images. Using the iMAR reconstruction algorithm, the metal artifacts were reduced. Figures 1–4 show two transversal slices of the metastasis;

WFBP and corresponding iMAR correction were presented respectively.

These results demonstrate that the iMAR reconstructed images showed significantly reduced metal artifacts, even when streaks were severely corrupting the imaging data reconstructed with WFBP. Further study should investigate potential clinical benefits iMAR can bring to Radiation Therapy patients.

## Examination Protocol

Scanner			
Scan area	Head	Pitch	0.55
Scan length	308 mm	Slice collimation	0.6 mm
Scan direction	Cranio-caudal	Slice width	2 mm
Scan time	8.6 s	Spatial resolution	0.33 mm
Tube voltage	120 kV	Reconstruction increment	2 mm
Tube current	215 mAs	Reconstruction kernel	H30s
CTDI <sub>vol</sub>	59.48 mGy	<b>Contrast</b>	
DLP	1916 mGy cm	Volume	100 mL
Rotation time	1 s	Start delay	5 s

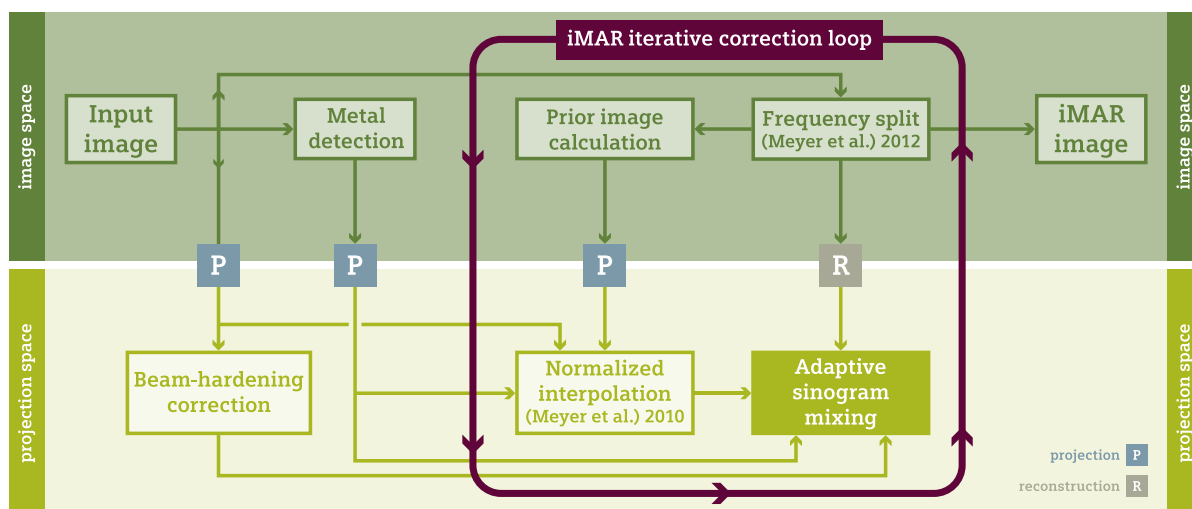
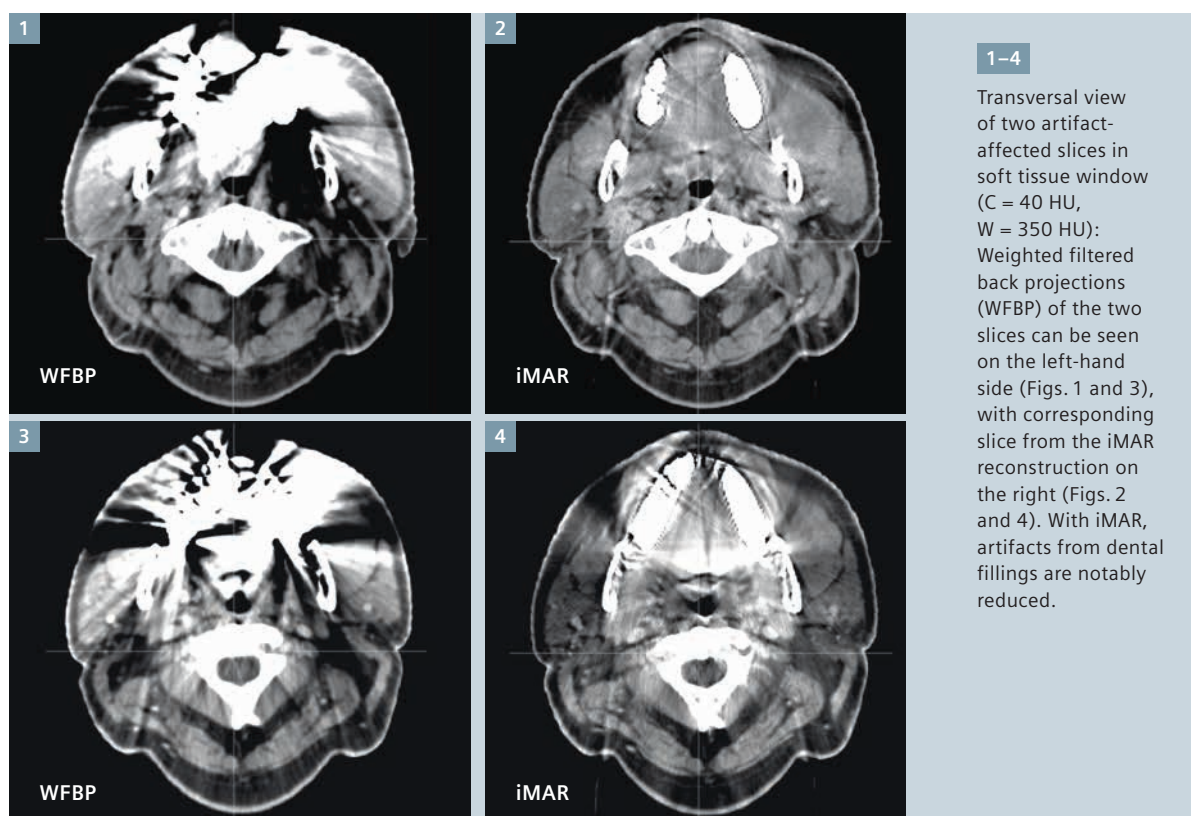
<sup>1</sup> iMAR is pending 510(k) and not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

iMAR is designed to yield images with a reduced level of metal artifacts compared to conventional reconstruction if the underlying CT data is distorted by metal being present in the scanned object. The exact amount of

metal artifact reduction and the corresponding improvement in image quality achievable depends on a number of factors, including composition and size of the metal part within the object, the patient size, anatomical location and clinical practice. It is recommended, to perform iMAR reconstruction in addition to conventional reconstruction.

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The iMAR algorithm uses an iterative method to correct artifacts. The metal image data is not simply suppressed; instead, the missing image information is supplemented from other parts of the sinogram. With an additional beam-hardening correction and the adaptive sinogram mixing Siemens has developed an algorithm that exceeds standard metal artifact reduction.

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## Case 2

# Treatment of Liver Metastases using HDR Brachytherapy with CT-guided Percutaneous Applicator Placement

Dariusz Kieszko, MD, PhD, Paweł Cisek, MD, Mirosław Nowicki, MD, Professor Jarosław Ćwikła, MD

Department of Radiation Oncology, St John's Cancer Centre, Lublin, Poland  
Department of Brachytherapy, St John's Cancer Centre, Lublin, Poland

## History

A 47-year-old female patient was diagnosed in 2009 with cancer in the left breast (cT1cN0M0). After partial excision of the left breast, a biopsy of the left axillary sentinel lymph node raised suspicion of distant metastasis and chronic lymphadenitis. Treatment was continued with a series of hormonal and adjuvant chemotherapies. In 2011, scintigraphy and PET showed numerous osteolytic metastases in the skeletal system. In 2013, metastases in 2 segments of the liver were detected. Besides palliative radiotherapy of the bones, pelvis, and spine, a decision was taken to treat the unresectable metastasis in segment 8 of the liver using high dose rate (HDR) brachytherapy.

## Comments

Our image-guided brachytherapy suite is equipped with a SOMATOM Sensation Open CT Sliding Gantry solution combined with a surgical table. In this particular case of liver interstitial brachytherapy, we used CT imaging to support the percutaneous insertion of the catheters. CT images were also used for contouring, dose calculation, and treatment planning –, following

our usual image-guided brachytherapy practice and using our BrachyVision treatment planning system (Varian Medical Systems) (Fig. 1).

With the CT Sliding Gantry setup, the patient was able to stay on the operating table for both CT fluoroscopy and spiral CT imaging. This is important for maximum patient comfort and eliminates the need to transport the patient to another room for CT imaging. CT guidance was particularly helpful in placing the interstitial liver applicator as the images show great detail compared with traditional X-ray imaging (Fig. 2).

The treatment was performed using the GammaMedplus iX (Varian Medical Systems) afterloader. We used one source with four different positions in the catheter (dwell position). To achieve a dose distribution as close as possible to the prescribed dose of 20 Gy, the treatment planning system calculates the time that is needed to release its dose at each position (dwell time) (Fig. 3).

The total volume of the target was 21.9 cm<sup>3</sup>. We were able to achieve D100% of 15.6 Gy, D95% of 19.6 Gy, and D90% of 21.4 Gy.

Dose to organs-at-risk was D66% of 3 Gy for the liver and D75% of 2 Gy for the right kidney (Fig. 4).

Five weeks after treatment, a follow-up CT showed a remarkable reduction in the tumor size, indicating a positive response to the CT image-guided brachytherapy treatment.

In conclusion, SOMATOM Sensation Open with Sliding Gantry is highly useful: It provides us with images that can be used to plan interstitial brachytherapy of liver malignancies. Additional Biopsy Mode and Care Vision options provide images that enable precise biopsy of metastatic liver tumor and insertion of brachytherapy catheters. CT images are essential for planning radiation treatment. This technique uses a fluoroscopy CT for catheter positioning and 3D CT datasets for dose planning. Development of HDR brachytherapy and the introduction of new treatment methods would hardly be feasible without such technology.

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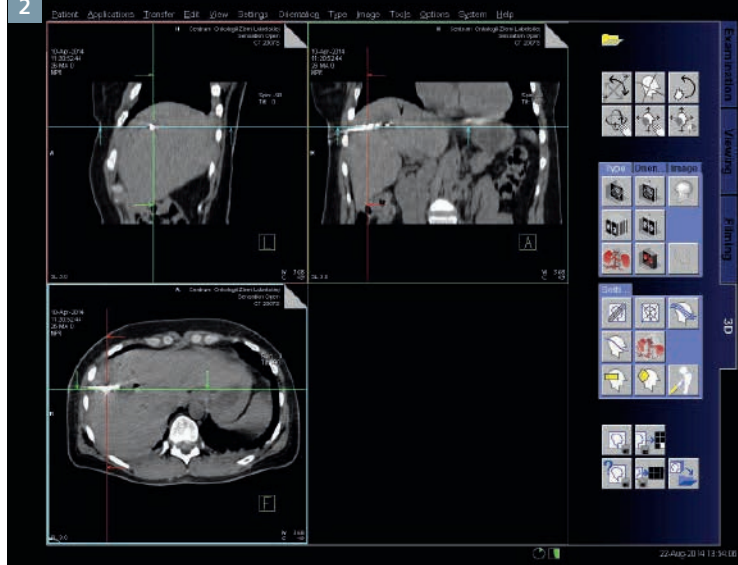
The products/features (here mentioned) are not commercially available in all countries. Due to regulatory reasons their future availability cannot be guaranteed. Please contact your local Siemens organization for further details.

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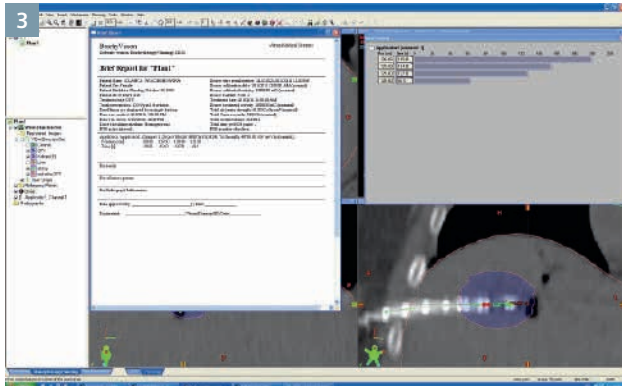
- 1 3D visualization of liver, right kidney, target and applicator channel after contours are drawn: Position of maximum GTV dose is shown in red.

2



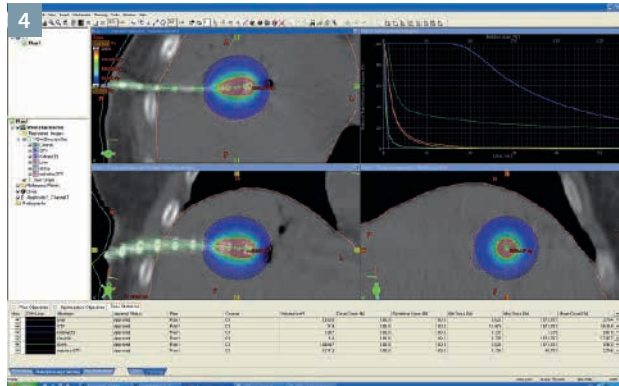
- 2 CT images guide the percutaneous insertion of brachytherapy catheters.

3



- 3 The patient report shows applicator positions and dwell times.

4



- 4 The treatment plan shows the CT images overlaid with the treatment dose distribution at target, organs-at-risk as well as the dose volume histogram (DVH – top right).

## Examination Protocol

Scanner	SOMATOM Sensation Open with Sliding Gantry		
Scan area	Abdomen	Rotation time	(TI) 0.5 s
Scan length	182 mm	Pitch	1.2
Scan direction	Cranio-caudal	Slice collimation	(cSL) 1.2
Scan time	3.44 s	Slice width	3 mm
Tube voltage	120 kV	Spatial Resolution	0.33 mm
Tube current	166 mAs	Reconstruction kernel	B20f smooth
Dose modulation	CARE Dose4D	<b>Contrast</b>	
CTDI <sub>vol</sub>	14.90 mGy	Volume	100 mL
DLP	355 mGy cm	Flow rate	3.5 mL/s



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#### **Global Business Unit**

Siemens AG  
Medical Solutions  
Computed Tomography  
& Radiation Oncology  
Siemensstraße 1  
91301 Forchheim  
Germany  
Phone: +49 9191 18-0  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)

#### **Local Contact Information**

##### **Asia/Pacific:**

Siemens Medical Solutionsw  
Asia Pacific Headquarters  
The Siemens Center  
60 MacPherson Road  
Singapore 348615  
Phone: +65 6490-6000  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)

##### **Canada:**

Siemens Canada Limited  
Healthcare  
2185 Derry Road West  
Mississauga ON L5N 7A6  
Canada  
Phone: +1 905 819-5800  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)

##### **Europe/Africa/Middle East:**

Siemens AG  
Healthcare  
Henkestraße 127  
D-91052 Erlangen  
Germany  
Phone: +49 9131 84-0  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)

##### **Latin America:**

Siemens S.A.  
Medical Solutions  
Avenida de Pte. Julio A. Roca No 516, Piso 7  
C1067ABN Buenos Aires Argentina  
Phone: +54 11 4340-8400  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)

##### **USA:**

Siemens Medical Solutions U.S.A., Inc.  
51 Valley Stream Parkway  
Malvern, PA 19355-1406  
USA  
Phone: +1-888-826-9702  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)

#### **Global Siemens Headquarters**

Siemens AG  
Wittelsbacherplatz 2  
80333 Munich  
Germany

#### **Global Siemens Healthcare Headquarters**

Siemens AG  
Healthcare  
Henkestrasse 127  
91052 Erlangen  
Germany  
Phone: +49 9131 84-0  
[www.siemens.com/healthcare](http://www.siemens.com/healthcare)