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SOMATOM Sessions

Radiation Therapy Supplement
Imaging in Brachytherapy

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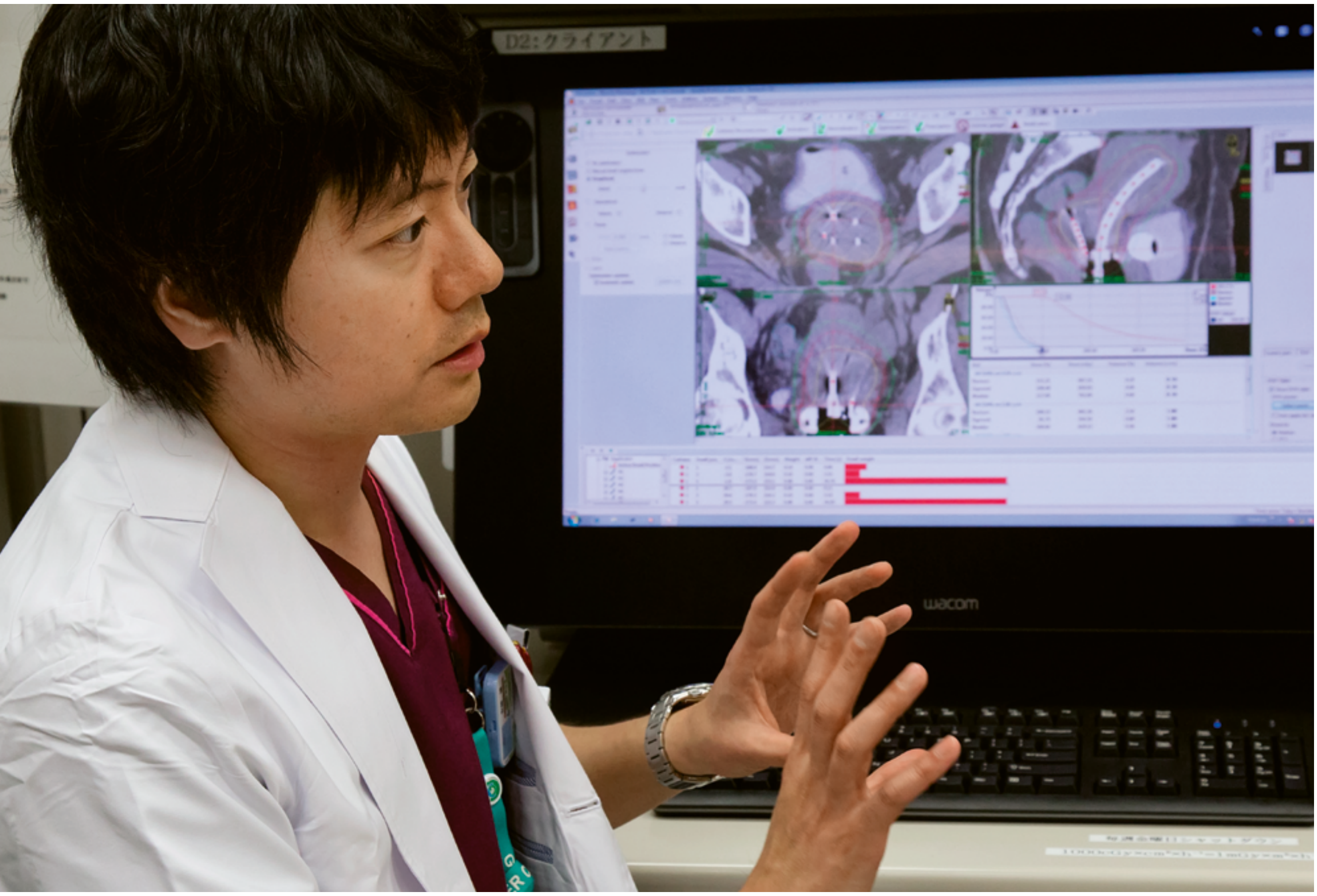
Contents

Fighting Cervical Cancer with Image-guided Brachytherapy

To Ken Ando, MD, the question is not whether to use brachytherapy; it is how to use this effective therapy with maximum accuracy and minimum patient discomfort. His choice of solutions is worthy of consideration.

Text: Charles T. Whipple, **Photos:** Hans Sautter



Ken Ando, MD, Director of Gynecology Radiation Therapy is a warrior in Japan's battle against cancer. He constantly works to reduce cervical cancer mortality.

In 2016, the National Cancer Center expects more than a million Japanese people to be diagnosed with cancer. Women will account for some 43 percent of these diagnoses, with some 30,000 of them suffering from uterine or cervical cancer.[1] In fact, according to the Japan Journal of Clinical Oncology, cervical cancer incidence and mortality began to increase from 1990, and while the rate of increase is not a rapid climb, the cancer has become the second most lethal among women aged 15 to 45.[2]

This is the last year in the Japanese government's Basic Plan to Promote Cancer Control Programs, which places cancer treatment at the top of the list of goals. Based on the Basic Plan, each prefecture develops its own plan to promote cancer control. In Gunma Prefecture, northwest of Tokyo, Gunma Prefectural Cancer Center (GPCC), with its 357 beds and fifteen departments, provides diagnosis and therapy for the prefecture as well as for the neighboring prefectures of Saitama and Tochigi. And it is very much a part of Japan's battle against cancer.

Ken Ando, MD, is a warrior in that battle. As Director of Gynecology Radiation Therapy, he constantly works to reduce cervical cancer mortality, and his work has brought him to brachytherapy.

Benefits of brachytherapy

Prostate, head, and neck cancer are generally treated at the Cancer Center using intensity modulated radiation therapy (IMRT). Radiation oncologists treat as many as 80 patients per day. Brachytherapy, however, is used mostly for cervical and uterus cancer patients. Ando says, "There are some cases of stump reoccurrence and vaginal cancer, but basically we deal with gynecological cancers. That's when we turn to brachytherapy, and for years our situation was far from optimal. In the radiation section of the hospital, we did our rather complicated brachytherapy planning based on 2D C-arm images. Applicators were placed and the patient then lifted onto a stretcher and transferred to a CT room, where we did CT imaging and later fused 2D C-arm with the 3D CT images."

At GPCC, brachytherapy is used mostly for cervical and uterus cancer patients. He constantly works to reduce cervical cancer mortality.

According to Ando, the procedure held a team of doctors, technicians, and nurses on site for three hours in complicated cases. Plus, if the CT scan showed that the applicators had shifted, more time was needed to restore them to the proper place. He wanted a system in which the entire brachytherapy could be done in the same room. Ken Ando finally applied for approval to set up an image-guided brachytherapy (IGBT) suite centered around a SOMATOM Scope Power-Sliding Gantry from Siemens Healthineers. With the system, the workflow changed.

> *"In this day and age, brachytherapy is a must, and I think that should mean in-room CT systems."*
>
> **Ken Ando, MD,** Director of Gynecology Radiation Therapy, GPCC, Japan

> *“The biggest advantage of the in-room CT is not having to move the patient.”*
>
> **Ken Ando, MD,** Director of Gynecology Radiation Therapy, GPCC, Japan

With the installation of an image-guided brachytherapy suite centered around a SOMATOM Scope Sliding Gantry, the workflow changed at GPCC. The entire brachytherapy can now be done in the same room.

A perfect fit

“The biggest advantage of the in-room CT is not having to move the patient from the table,” says Ando. “We can plan, place the applicators, do 3D imaging with our CT scanner, and do the fusion all in the same place. Before, two nurses had to be with the patient throughout the procedure. Now, one nurse is sufficient. A procedure that went smoothly used to take three hours to complete; now it takes two hours and a few minutes.”

Ken Ando seems more than happy that the entire compact system fits in a single room within the Radiation Therapy department.

“The CT aperture is 70 centimeters, ample for patients, producing very clear images – and it makes all the difference in the world to have a good clear picture of the problem area during therapy,” says Ando. “You could even say I’m a little proud of the fact that the system I suggested fits in our available space.”

IGBT: A must

IGBT is still not widely used for cancer therapy in Japan: Only about one-third of the cancer facilities which have brachytherapy capabilities in Japan have IGBT systems. However, Ando pointed out that in-room CT systems have been discussed at the brachytherapy meetings of the Japanese Society for Therapeutic Radiology and Oncology (JASTRO), and he said the opinion leaders in the industry virtually all use such systems. “In this day and age,” says Ando, “IGBT is a must, and I think that should mean in-room CT systems.”

MRI can also be used as an imaging modality in brachytherapy in Europe, but Ken Ando does not think that option is ideal for his situation. MRI would take more manpower. “I’ve talked with MRI technicians and prepared applicators for this purpose. Still, my experience is that the images we get from our CT are really good, even compared to those we might get from MRI.”

Gunma Prefectural Cancer Center with its 357 beds and fifteen departments is very much a part of Japan's battle against cancer.

As mentioned, Gunma Cancer Center serves a wider area than just one prefecture. Outlying hospitals and clinics learn of its expertise and refer their patients to the Cancer Center. Further, Ando is one of few oncologists in Gunma with extensive experience of IGBT, and he is called upon to help train more physicians, technicians, and nurses in this vital therapy. Now, with the SOMATOM Scope Sliding Gantry CT system and the skills of Ken Ando and his team in image-guided brachytherapy, the enemy called cancer faces competent warriors using accurate and effective weapons.

Charles T. Whipple is an international award-winning author and journalist based in Japan. His articles have appeared in magazines and newspapers such as Time, Newsweek, the Chicago Tribune, and the International Herald Tribune. He has lived in Japan since 1977 and is fluent in Japanese.

Facts and Figures

1 million

Japanese people expected to be diagnosed with cancer.

Women

will account for **43%** of these diagnoses

30.000

of them will suffer from uterine or cervical cancer.

References

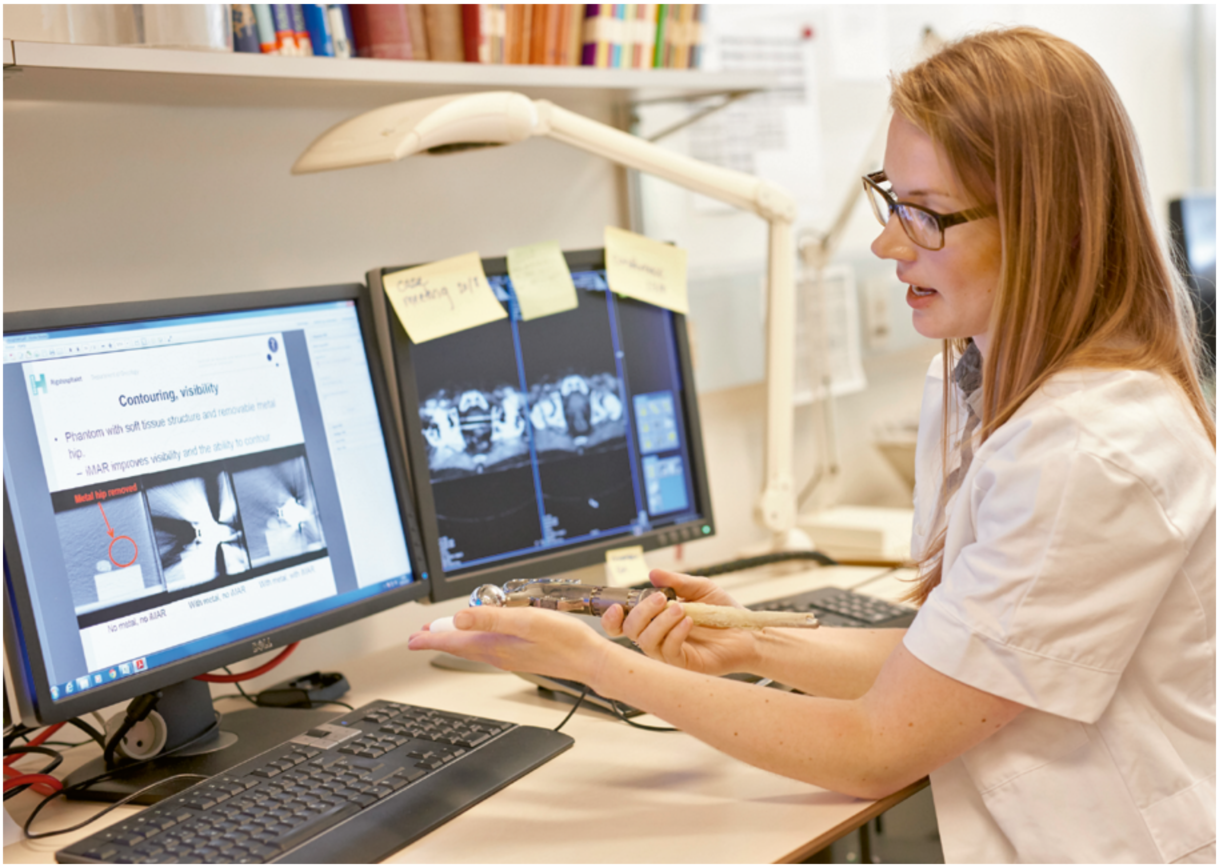
1 Otake T, Cancer diagnoses in 2016 expected to top 1 million for first time. The Japan Times. 2016

2 CO HPV Information Centre. Human Papillomavirus and Related Diseases Report. Japan. 2016

Tackling the Challenge of Metal Artifacts

Today's image-guided radiation therapy can be applied with great precision. One growing challenge is the increasing amount of metal in patients' bodies, which leads to artifacts in CT images and obscures vital information. Laura Ann Rechner, Medical Physicist at the Rigshospitalet Department of Oncology, Section of Radiotherapy in Copenhagen, Denmark, is exploring how to solve this challenge using the iMAR algorithm.

Text: Wiebke Kathmann, PhD, **Photos:** Morten Koldby

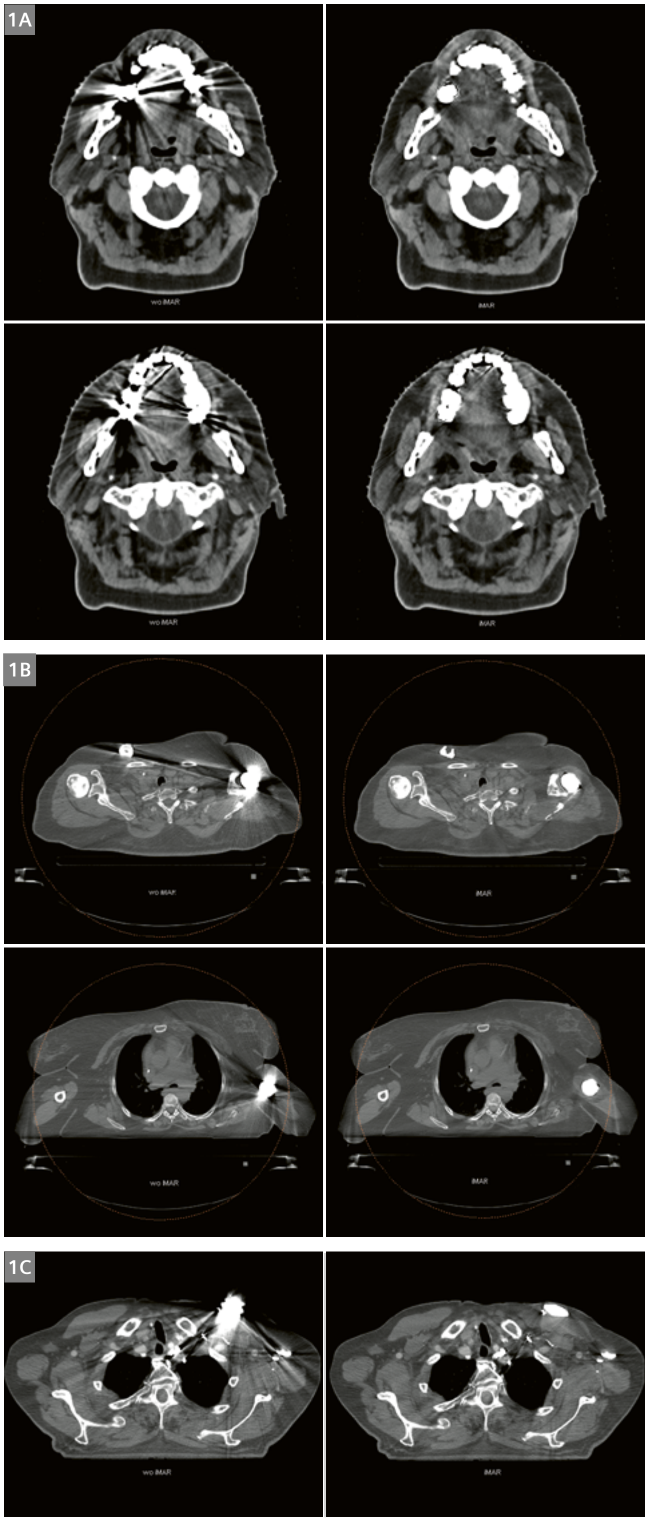


Laura Ann Rechner, Medical Physicist at the Rigshospitalet Department of Oncology, Section of Radiotherapy, explored the potential of the iterative metal artifact reduction (iMAR) algorithm in comparative studies with patient cases and phantoms.

Setting up a treatment plan for cancer patients with metal implants has so far required physicians to manually correct metal artifacts in the area of interest. Information about the tumor extension can be lost, and surrounding soft tissue needing protection from the radiation may remain undetected. In order to avoid the consequences of corrupted pictures, images must be manually corrected and contouring structures partially created using guesswork – this is a time-consuming and laborious task, and may result in inter-observer variability. In turn, this could jeopardize the levels of precision that today's radiation therapy can achieve.

This challenge is becoming more of an issue as metal implants are on the rise in most countries. Almost all head and neck patients have metal in the form of dental fillings, which obscure parts of the CT images. In pelvis and spine tumor cases, the situation is similar since spinal and hip implants are becoming increasingly common.

"So far, we override such a region by calculating it as water or air as our best guess, knowing that this is not correct," explains Rechner. "The precise contouring can be very time-consuming and difficult in these cases." Up to now, there was no better way to deal with the effects of metal implants. None of the techniques currently proposed for metal artifact reduction are in widespread clinical use, as some add artifacts or remove valuable information. This is why Laura Ann Rechner began exploring the potential of the iMAR (iterative metal artifact reduction) algorithm last fall. She was able to address these critical issues in comparative studies with patient cases and phantoms.



1 In patients with metal implants, such as dental fillings (Fig. 1A), shoulder and hip implants (Fig. 1B), and pacemakers (Fig. 1C), using the metal artifact reduction algorithm iMAR (right column) can make it easier to reconstruct images accurately.

Rechner tested the accuracy of iMAR in patient and phantom studies. One case that she found particularly convincing was that of a patient with cervical cancer who was treated with interstitial (MUPIT-type) pulsed dose rate (PDR) brachytherapy. "In this case, we lost a little information in the center due to the numerous metal implants, which resulted in somewhat blurred CT HUs (Hounsfield units) in the middle. But we decided that it was more useful to see the needles clearly," Rechner explained. "This case convinced us to use iMAR as standard on all of our scanners in order to better serve our patients with metal implants."

In her phantom study based on a tongue tumor, Rechner first performed contouring in the usual way. She then added the implant to the phantom and took the image with and without iMAR. Applying the algorithm, she was able to reduce the metal artifacts for a better image. The same was true for a pelvic phantom of a hip implant.

Reduction of streak artifacts

Another case with impressive results using MAR involved a patient with a bladder tumor and two metal hip implants. For most patients with hip implants, the artifact would be an irritation that one would have to draw over in contouring, but in this case the target was very much affected by the artifact. On the regular image, there was no information on the key region of interest, making itdifficult to decide where to treat. The algorithm helped to reduce the artifacts, according to Rechner. She tested multiple iMAR algorithm reconstruction kernels, each relating to a different metal density, size, and degree of artifact, and making sure that the HU were all correct. After comparing the different delineations and dose calculations with the usual procedure when drawing in water, the dose was roughly equivalent. According to Rechner, those patients scheduled for stereotacticradiation in particular may benefit. In these cases, small lesions need to be treated with a high degree of accuracy and with high doses, and therefore require images with reduced metal artifacts.

Great flexibility

Overall, iMAR reduces metal artifacts by combining three successful approaches: beam hardening correction in sinogram regions that have less severe metal attenuation; normalized sinogram inpainting in sinogram regions that have high metal attenuation; and frequency split to mix back noise texture and sharp details that are potentially lost during inpainting. The correction process is iteratively refined by repeating the normalized sinogram inpainting and the mixing steps up to six times. In turn, this leads to fewer artifacts, as an evaluation of artifact quantification using gold markers revealed. The risk of new artifacts is reduced thanks to Adaptive Sinogram Mixing, which flexibly combines normalized interpolation and a soft reduction metal artifact algorithm depending on the severity of the artifacts. Radiologist Anne Kill Berthelsen, MD, works in the radiation therapy department and believes that iMAR has great potential. "We are pretty convinced that it will reduce metal artifacts – mainly from dental fillings or from hip implants – in gynecological tumors. This will be a big improvement, as we don't know in advance which metal implants will lead to metal artifacts for which patients. We mostly hope to use it for head and neck patients where there are big holes in the scan. The radiation oncologists demand images with less and less metal artifacts as they want to make their radiation therapy more and more precise."

> *"We are pretty convinced that iMAR will reduce metal artifacts. So radiation therapy can be provided more and more precisely."*
>
> **Anne Kiil Berthelsen, MD,**
> Chief Radiologist at Rigshospitalet, University of Copenhagen

> *“iMAR saves us time, by reducing metal artifacts.”*

Laura Ann Rechner, Medical Physicist at the Rigshospitalet Department of Oncology, Section of Radiotherapy in Copenhagen, Denmark

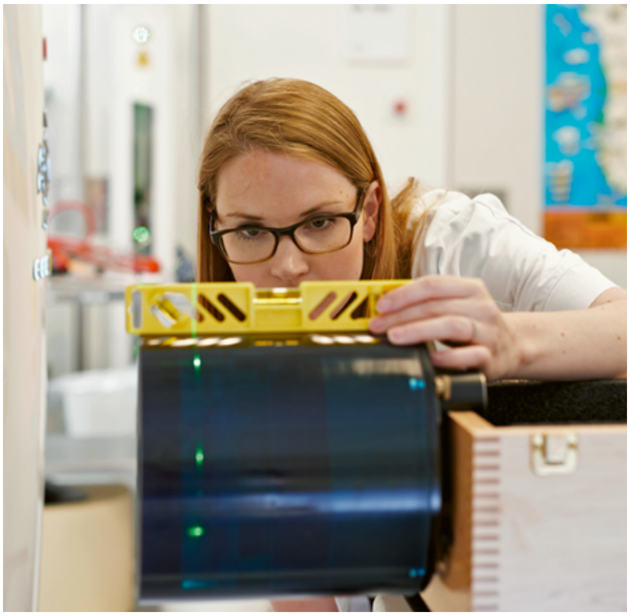
Easy to use on all tailored scanners

At the Rigshospitalet of the University of Copenhagen – an institution with over 10,000 employees, more than 1,600 beds, and around 100,000 inpatients and 650,000 outpatients – about 70 doctors, 16 physicists, and 25 radiographers work at the Department of Oncology. Altogether, 500 employees take care of approximately 4,000 patients per year. Until now, iMAR has been running on a SOMATOM Definition AS Open – RT Pro edition. Soon it will be running on all scanners as standard.

Based on her experience so far,Rechner sees the application for iMAR mostly in head and neck patients, as well as for pelvic patients.

Rechner underscores the two main advantages of iMAR: Firstly, “iMAR saves us time, which we love.” Secondly, according to the medical physicist, “iMAR helps the patient, as the main objective of our treatment planning is to optimize the balance between efficiently treating the tumor and sparing the surrounding tissue.The reduction of metal artifacts that is possible with iMAR helps us do our job.”

She is curious about combining iMAR with 4D CT in patients with thoracic tumors and dental fillings. The team already tried combining Dual Energy CT and iMAR. When using 130 kV Dual Energy CT and iMAR, they were quite happy with the metal artifact reduction from iMAR alone. Since soft tissue contrast is presumed to be better at 70 kV, they now hope to achieve better metal artifact reduction together with better soft tissue contrast and lower energy.



With regard to the workflow, it is too soon to tell. “In the beginning, incorporating iMAR added a little time to the process, as we compared the image and HU values to our standard of care. But in the long run, it will save us time. Besides, patient outcome might be better, as we can target what we want to treat and protect, what we want to spare.”

Wiebke Kathmann, PhD, is a frequent contributor to medical publications. She holds a Master’s in Biology and a PhD in Theoretical Medicine, and was employed as an editor for a number years before going freelance in 1999. She is based in Munich and Karlsruhe, Germany.

Case 2

Iterative Metal Artifact Reduction in Interstitial Brachytherapy Treatment Planning

By Laura Ann Rechner, MD; Jens Peter Bangsgaard, PhD; Henrik Roed, MD

Department of Oncology, Section of Radiotherapy, Rigshospitalet, Copenhagen, Denmark

History

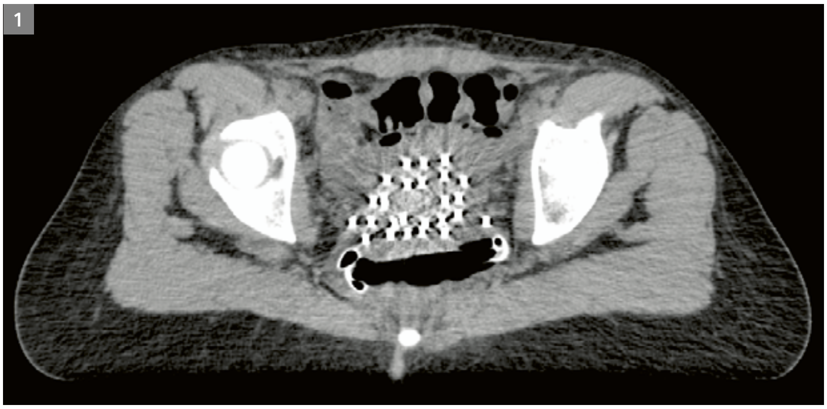
A 46-year-old woman was diagnosed with cancer of the vagina in 2015. A vaginal adenocarcinoma 2–3 cm in diameter that extended to the bladder was found on a clinical exam, and a PET scan revealed multiple positive lymph nodes. External beam radiation therapy was administered using volumetricmodulated arc therapy (RapidArc, Varian Medical Systems) to the pelvis of 50 Gy with an integrated boost to the PET positive lymph nodes of 64 Gy. Following external beam radiation therapy, an interstitial rachytherapy boost of 30 Gy to the gross tumor volume was applied. An MRI was performed with a vaginal obturator in place prior to needle insertion. After needle insertion, a CT scan was performed and fused with the MRI. Both the MRI and the CT were used during brachytherapy treatment planning.

Comments

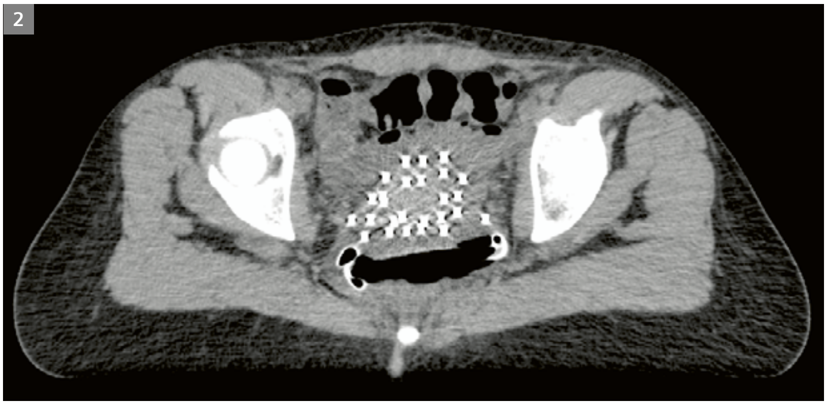
The CT scan used for interstitial brachytherapy treatment planning was reconstructed using the iMAR (iterative metal artifact reduction) algorithm, which reduced the artifacts around the stainless steel needles. An important and timeconsuming part of interstitial brachytherapy treatment planning is the definition of all the needles that can be used through which to send a radioactive source to irradi- Clinical Results ate the tumor from the inside. The reduction in artifacts made defining the needles in the treatment planning system faster, especially where needles crossed or were close together. One type of iMAR reconstruction (for spine implants) reduced many of the artifacts and retained the soft tissue contrastin the region. A stronger type of iMAR (with neuro coils) reduced more artifacts but also removed some of the soft tissue contrast near the needles. We elected to use the neuro coil iMAR reconstruction for this type of treatment due to the clear definition of the needles and because the soft tissue information was obtained through the fused MRI scan. In conclusion, iMAR reconstruction improved the speed and confidence of needle definition for interstitial brachytherapy treatment planning.

Examination Protocol

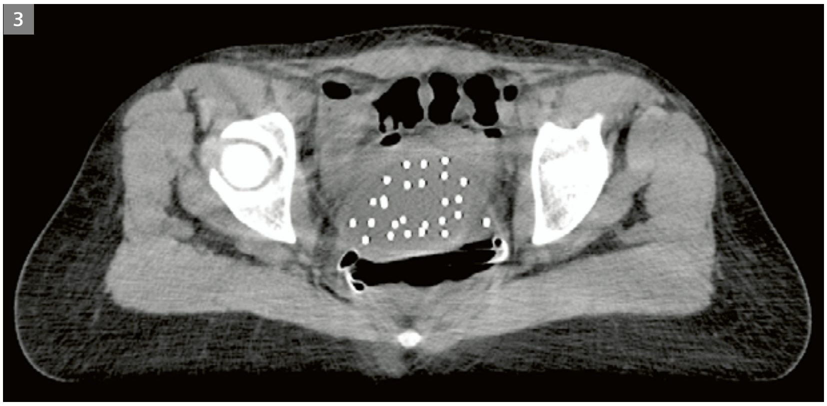
Scanner	SOMATOM Definition AS Open – RT Pro edition
Scan area	Pelvis
Scan length	19.2 mm
Scan direction	Cranio-caudal
Scan time	12 S
Tube voltage	100 kV
Tube current	335 mAs
Dose modulation	CARE Dose4D
$CTDI_{vol}$	12.74 mGy
DLP	453.83 mGy cm
Effective dose	9.1 mSv
Rotation time	0.5 S
Pitch	0.8
Slice collimation	1.2 mm
Slice width	2 mm
Reconstruction increment	2 mm
Reconstruction kernel	B31f



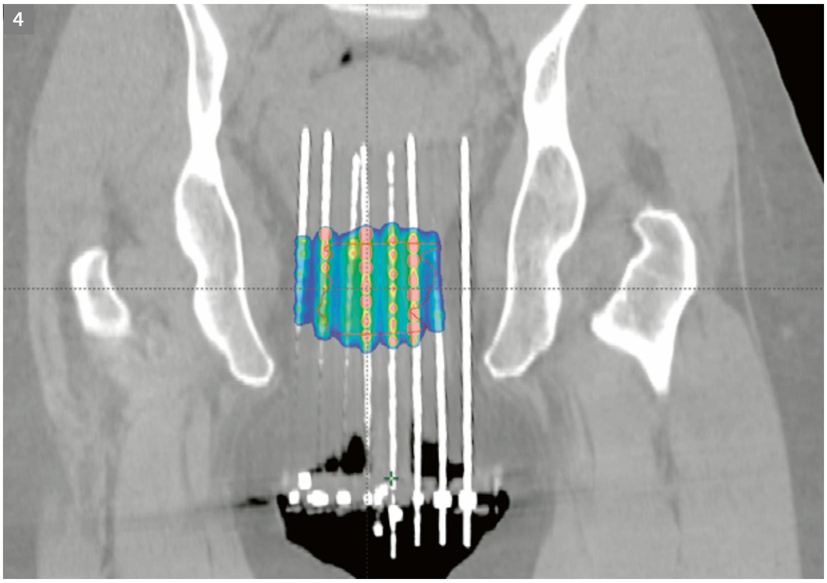
1 Interstitial brachytherapy treatment with no iMAR reconstruction.



1 Interstitial brachytherapy treatment with spine implant iMAR reconstruction.



1 Interstitial brachytherapy treatment with neuro coil iMAR reconstruction.



1 Coronal slice showing the dose distribution of the interstitial brachytherapy treatment displayed on a CT image reconstructed using iMAR.

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 combined 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 brachytherapy 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.

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.

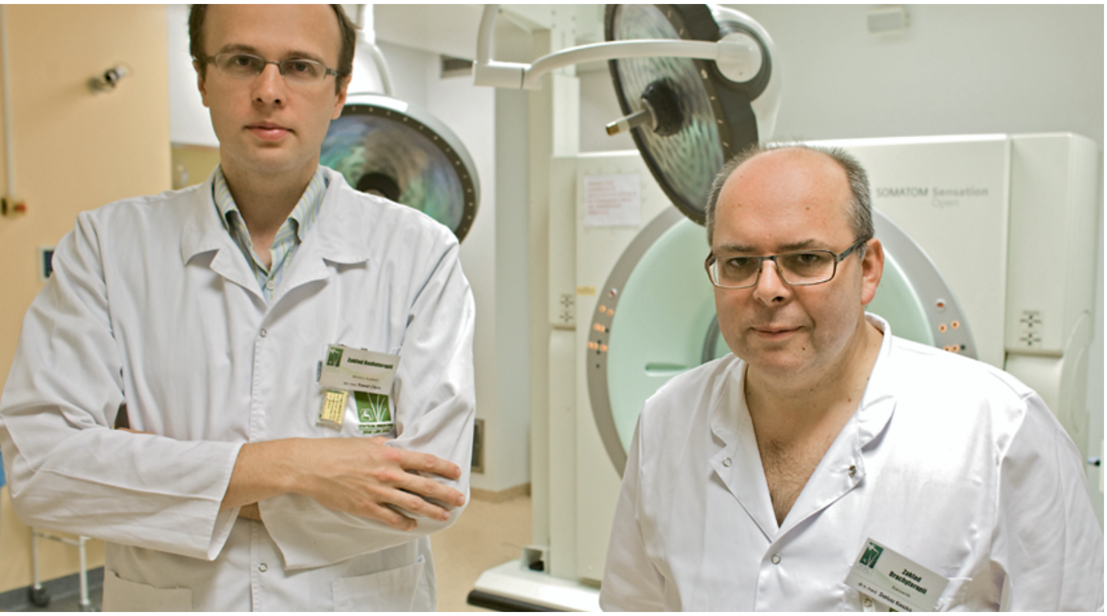
Issues of time ...

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



Dariusz Kieszko, MD, PhD (right) and Paweł 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 delivered

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).

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 southeast 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.

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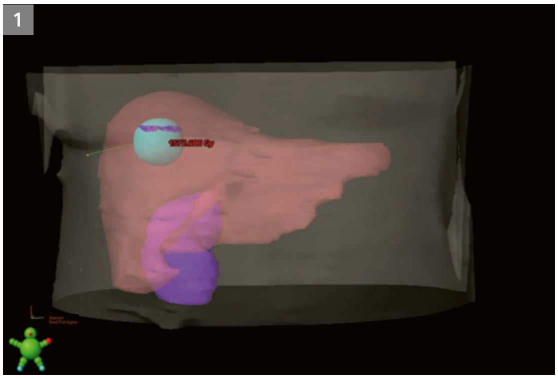

1 3D visualization of liver, kidney, target and applicator channel after contours are drawn. Position of maximum GTV dose is shown in red (see also Clinical Results, page 22).

Case 1

Reducing Metal Artifacts in a Patient with Dental Fillings

Henrik Hauswald*, MD, Esther Bär**

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)[1] 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 recon-structed 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
Scan length	308 mm
Scan direction	Cranio-caudal
Scan time	8.6 S
Tube voltage	120 kV
Tube current	215 mAs
CTDI_{vol}	59.48 mGy
DLP	1916 mGy cm
Rotation time	1 S
Pitch	0.55
Slice collimation	0.6 mm
Slice width	2 mm
Spatial resolution	0.33 mm
Reconstruction increment	2 mm
Reconstruction kernel	H30s
Contrast	
Volume	100 ml
Start delay	5 s

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 correspond-ing 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 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 results.

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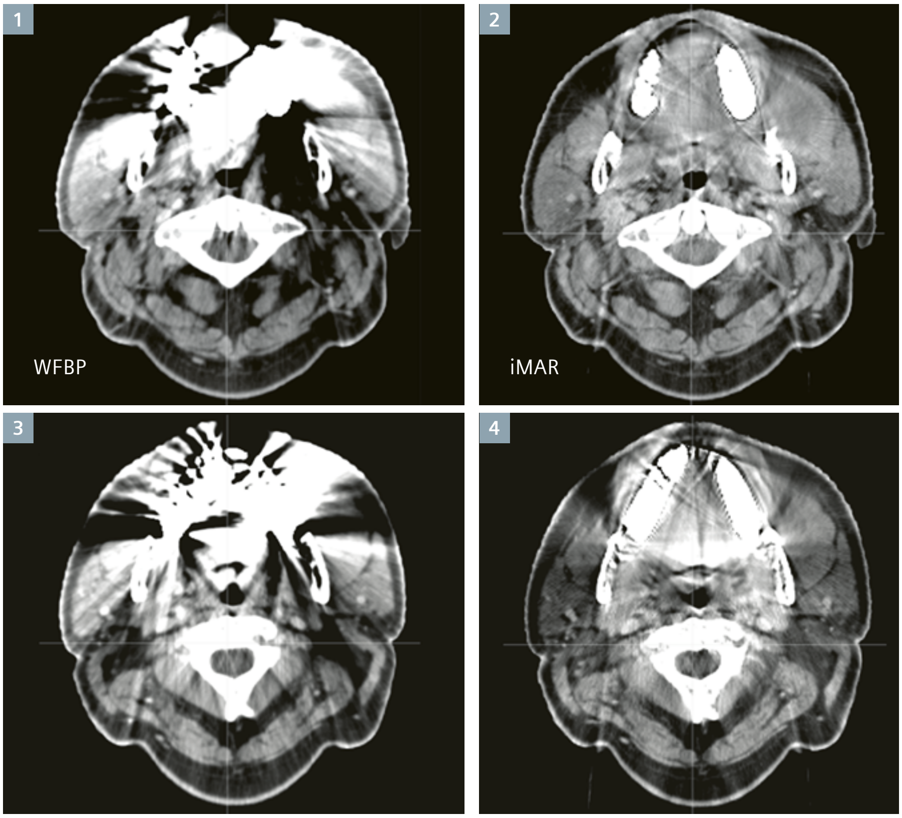
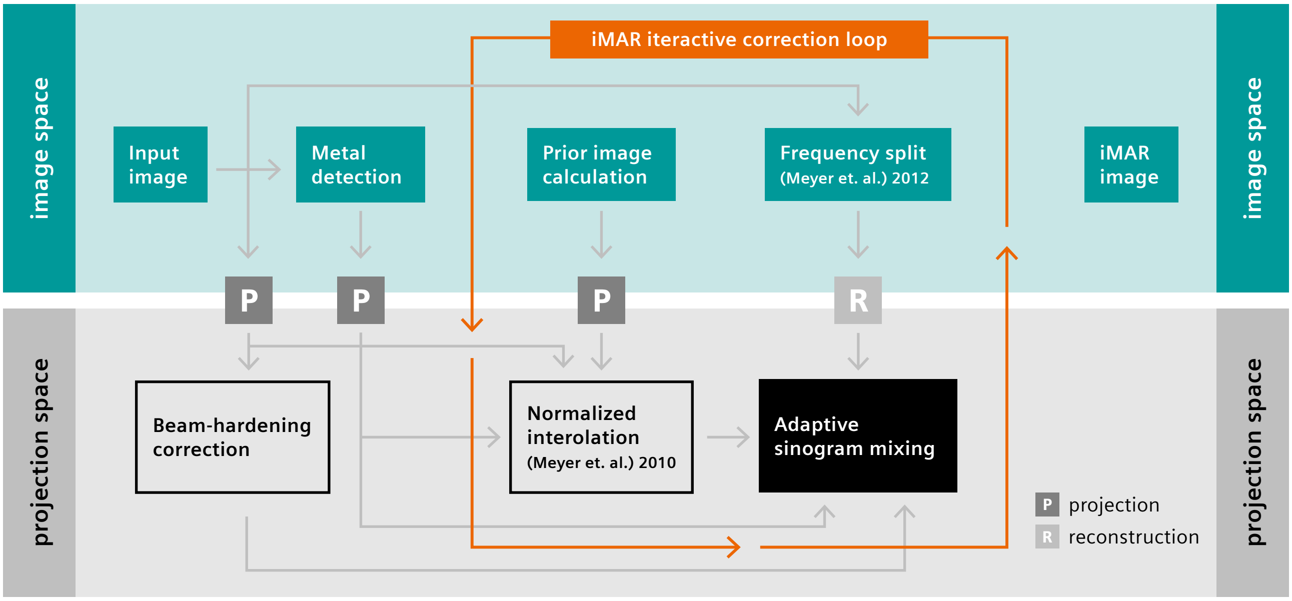
[1] *iMAR is pending 510(k) and not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.*



1–4

Transversal view of two artifact-affected slices in soft tissue window (C = 40 HU, W = 350 HU): Weighted filtered back projections (WFBP) of the two slices can be seen on the left-hand side (Figs. 1 and 3), with corresponding slice from the iMAR reconstruction on the right (Figs. 2 and 4). With iMAR, artifacts from dental fillings are notably reduced.



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 Healthineers has developed an algorithm that exceeds standard metal artifact reduction.

References

E. Meyer, R. Raupach, M. Lell, B. Schmidt, and M. Kachelries. Frequency split metal artifact reduction (FSMAR) in CT. Med. Phys. 39(4):1904-1916, April 2012

E. Meyer, R. Raupach, M. Lell, B. Schmidt, and M. Kachelries. Normalized metal artifact reduction (NMAR) in computed tomography. Med. Phys. 37(10):5482-5493, October 2010

Case 2

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

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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).

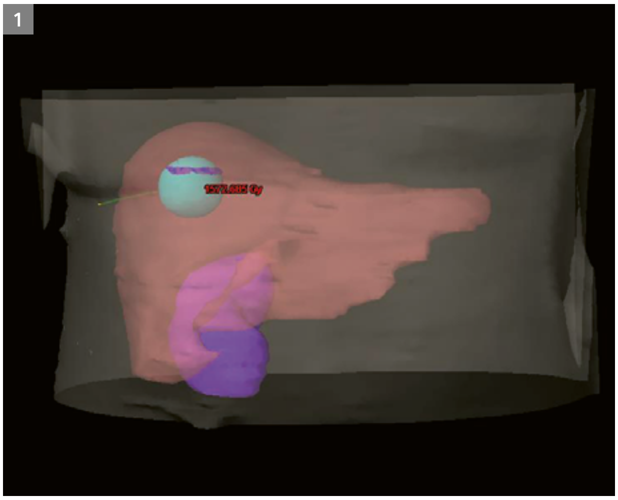
With the CT Sliding Gantry setup, the patient was able to stay on the operating table for both CT fluoroscopy and spiral CT imaging. This is important for maximum patient comfort and eliminates the need to transport the patient to another room for CT imaging. CT guidance was particularly helpful in placing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

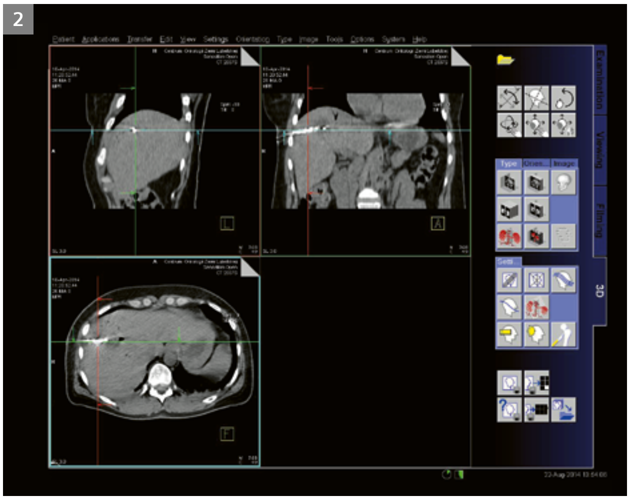
The treatment was performed using the GammaMedplus iX (Varian Medical Systems) afterloader. We used one source with four different positions in the catheter (dwell position). To achieve a dose distribution as close as possible to the prescribed dose of 20 Gy, the treatment planning system calculates 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 cm3. 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.

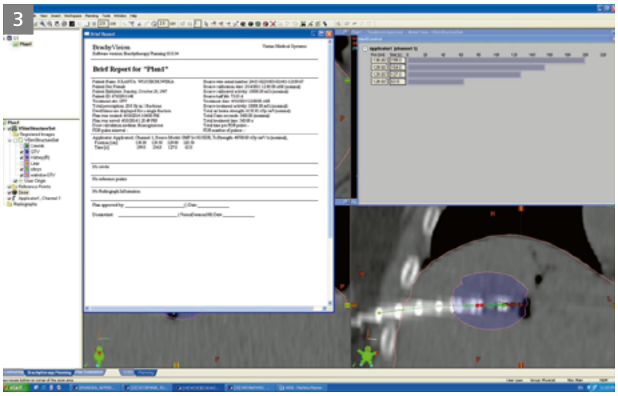
In conclusion, SOMATOM Sensation Open with Sliding Gantry is highly useful: It provides us with images that can be used to plan interstitial brachytherapy of liver malignancies. Additional Biopsy Mode and Care Vision options provide images that enable precise biopsy of metastatic liver tumor and insertion 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.

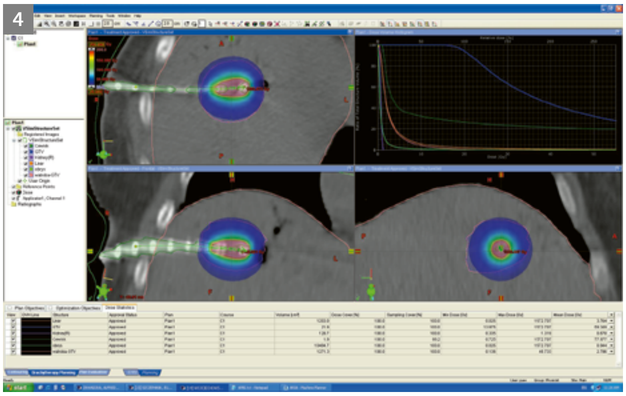




1 3D visualization of liver, right kidney, target and applicator channel after contours are drawn:
Position of maximum GTV dose is shown in red.

2 CT images guide the percutaneous insertion of brachytherapy catheters.





3 The patient report shows applicator positions and dwell times.

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	SSOMATOM Sensation Open with Sliding Gantry
Scan area	Abdomen
Scan length	182 mm
Scan direction	Cranio-caudal
Scan time	3.44 S
Tube voltage	120 kV
Tube current	166 mAs
Dose modulation	CARE Dose4D
$CTDI_{vol}$	14.90 mGy
DLP	355 mGy cm

Scanner	SSOMATOM Sensation Open with Sliding Gantry
Rotation time	(T) 0.5 S
Pitch	1.2
Slice collimation	(cSL) 1.2
Slice width	3 mm
Spatial Resolution	0.33 mm
Reconstruction kernel	B20f smooth
Contrast	
Volume	100 mL
Flow rate	3.5 mL/s

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