Second extended edition

MR-integrated Workflows in Radiation Therapy for MAGNETOM Systems

siemens-healthineers.us/magnetom-flash

SIEMENS Healthineers

David Roberge

Montreal, Canada

David Roberge graduated from the University of Montreal, Canada, with an MD in medicine in 1997 and completed a residency in radiation oncology from McGill in 2002. In 2002–2003 he completed two fellowships – at Stanford University Medical Center and St. Jude Children's Research Hospital. Following his training he joined as staff at the McGill University Health Center and the Sir Mortimer B. Davis Jewish General Hospital. In 2010 he completed a transition to the University of Montreal as head of radiation oncology for CHUM and researcher at the CRCHUM. He remains adjunct professor of oncology at McGill University and is associate professor of radiology/radiation-oncology/nuclear medicine at the University of Montreal.

Dr. Roberge recently oversaw the move into a new cancer center in downtown Montreal where clinical and research priorities will increasingly feature imaging dedicated to radiation oncology. The departmental philosophy has been to implement a wide variety of radiation delivery devices. As well, the department now operates in a single facility four CT simulators (including a Siemens dual source system), a PET/CT simulator and a dedicated MAGNETOM Aera RT Pro Edition.

Dr. Roberge has held a variety of administrative and leadership positions in radiation oncology, notably leading the association of Quebec radiation oncology department heads. He has co-authored reference documents for the IAEA and ICRU. He has supervised and co-supervised a number of students from medicine, radiation-oncology and medical physics. He has published more than 100 manuscripts and traveled the world for more than 60 presentations as visiting professor.

Although his interests are varied (cutaneous lymphoma, liver malignancies, radiotherapy of benign disease, ...), stereotactic radiation features prominently in his research funding, manuscripts and teachings. Most notably, he is co-principle investigator of a multinational randomized trial of adjuvant radiosurgery for brain metastases and principle investigator of an upcoming intergroup trial of radiosurgery for multiple brain metastases.

Eric Paulson, Ph.D.
Medical College of Wisconsin,
Milwaukee, USA

Yue Cao, Ph.D.
University of Michigan,
Ann Arbor, USA

Leah Best
Calvary Mater Hospital, Newcastle,
NSW, Australia

Trina Herbert
The Royal Marsden NHS Foundation Trust,
Sutton, UK

Maja Sohlin, Ph.D.
Sahlgrenska University Hospital,
Gothenburg, Sweden

Robba Rai, MHlthSc and Gary Liney, Ph.D.
Liverpool and Macarthur Cancer Therapy Centre,
Ingham Institute for Applied Medical Research,
Sydney, Australia

Cynthia Ménard, M.D., FRCPC
and David Roberge, M.D., FRCPC
Centre hospitalier de l'Université de Montréal,
Canada

Dear colleagues, dear readers,

What is MR in RT in 2018? MRI integration into radiation planning is nothing new. I personally can remember in 1995 using an overhead projector to overlay ('fuse') a sagittal MRI of the brain onto a 2D simulator film in order to define the posterior fossa for a medulloblastoma boost plan. Over the next three decades, co-registration of diagnostic MR images with planning CT images acquired in radiation oncology has become commonplace. In 2018, MR units are seen in radiation oncology departments and MR in RT is much more than sporadic diagnostic images overlaid on simulator films.

Why MR in RT: Motivation and effect on clinical outcome

While CT still remains an essential part of RT planning, across many tumor types, the improved target visualization in MR can be dramatic – one need only think of low-grade brain tumors or epidermoid cancers of the base of tongue. Across tumor types, there is compelling data demonstrating altered delineations when MR is co-registered to CT. The evidence that improvements in target delineation lead to improved clinical outcomes has been weaker. Retrospective comparisons do however suggest benefits such as reduced bowel toxicity in prostate cancer and improved tumor control for carcinoma of the uterine cervix.

In some circumstances similar information can be obtained by CT but at greater risk and discomfort for the patient – for example, one would not want to return to routine CT cysternograms to visualize trigeminal nerves.

Although the radiation dose from CT-simulation is not generally a concern in the context of radiotherapy, the non-ionizing nature of MR does open up opportunities such as evaluating motion management techniques over multiple respiratory cycles.

Without high-level evidence of benefits to the patient, what motivates some departments to invest in MR units dedicated to radiotherapy? For some it will be the hope of attracting more patients, for others a desire for technological preeminence, and others a striving for clinical excellence.

Clinical workflow incorporating CT and MR in external beam RT

The current standard backbone of radiotherapy planning is computed tomography. There remain notable exceptions – whether it be to plan superficial irradiation of a basal cell carcinoma or frame-based radiosurgery of a small brain metastasis. Current CT simulators offer the radiotherapy team:

- Large bore sizes which allow flexibility in patient positioning
- Large imaging field of view with reliable geometry
- Information on electron density which permits inhomogeneity corrections during treatment planning
- Fast examinations and large field 4D images
- High in-plane and through-plane resolution

Where does the MR fit in to the planning workflow? This will vary from one hospital to another and will depend on the clinical scenario. As MR in RT matures we are likely to see many changes in how MR is integrated. In 2018, the most common MR in RT paradigm will see the patient imaged with both MR and CT prior to treatment – MR used for tumor delineation and the CT for dose calculation. The following chapters will outline some of the variation in how MR is integrated as various institutional experiences with MR simulation are described. In many cases, the solutions selected represent compromises where target visualization, patient comfort and finances may be at odds. General considerations include the following:

Scheduling
When both CT and MR simulation are to be acquired, they are ideally done on the same day, in the same department. When this is possible, the patient need only have one venous access for contrast and one visit to the hospital. There is no strict rule as to what order the procedures should be done in but it will make sense to do the CT first if the immobilization is to be customized in the imaging device (as opposed to a 'mould room') as the CT has less restrictions (for ovens, pumps and other accessories used to fashion immobilization) and is less costly on an hourly basis. The counter argument is that the MR bore is more restrictive and acquiring the MR first ensures that the patient positioning will be compatible with both devices.

Lasers and immobilization
External lasers are not mandatory at MRI and will add little in cranial imaging, in cases with 'body frames', or when organs are co-registered using internal fiducials. On the other hand, lasers will be required for marking WIP use talked directly and aligning patients with looser immobilization systems.

Optimal patient position for treatment and ease of CT-MR registration are sometimes at odds and it will usually make more sense to chose a position which can be imaged in the MRI bore rather than using deformable registration between CT and MR. These compromises are somewhat lessened in the larger 70 cm MR bores.

The battle for SNR

Clinicians who need to work with MR images, whether for interpretation or radiotherapy segmentation will always favor images with as little noise as possible. Unfortunately, image quality will always be the result of compromises. Although the physics of MR imaging do not vary, the compromises around SNR will generally be tainted by the needs specific to radiotherapy.

Factors associated with improved SNR

- Increased magnet field strength
- Larger voxels (larger FOV, smaller matrix size, thicker slices)
- Closer proximity of the receive coils to the patient
- Larger number of coil elements
- Lower readout bandwidth
- Longer scan times

Once the MR device is purchased, one has no control on field strength. Although the higher field 3T magnets will typically allow for better SNR (and/or shorter scan times) the costs will not only be financial, there will also be added patient and staff safety issues as well as a greater potential for image distortions/artifacts.

The high overall level of accuracy in radiotherapy delivery would ideally lead one to choose isotropic 1 mm voxels for most applications. In order to improve SNR, one may need to compromise for larger voxels when not dealing with stereotactic cranial applications.

The use of immobilization devices, especially thick vacuum cushions set on MR radiotherapy table inserts, will move the patient away from the coils. Similarly, the use of aquaplast masks may force the use of flexible coils which will be further from the patient (and contain fewer coil elements) than dedicated multi-channel head coils.

When imaging the generally rigid anatomy of the cranium, it may make more sense to forgo immobilization at the MR and rely on image registration. The tradeoff here is potential loss of spatial resolution due to registration of images obtained with patients set up in two different positions.

The impact of distortions

The geometric accuracy of MR images is limited by the homogeneity of the static field (B_0), the linearity of the applied gradients, the magnetic susceptibility distribution of the patient, and chemical shift artifacts. While geometric distortions may not significantly impact the diagnostic usefulness of the images, they may lead to radiotherapy targeting inaccuracies or errors in dose calculation.

The distortions will depend on: the MR device used, the magnet strength, the distance from the MR isocenter (the image is most accurate near the isocenter), the pulse sequence used (diffusion images notoriously demonstrate distortions), readout bandwidth, and patient anatomy. Using distortion-correction algorithms provided on the MR device can reduce the severity of the gradient nonlinearity distortions.

The various distortions can be characterized by imaging phantoms with embedded grids. Patient-related distortions can be visualized in susceptibility maps (they will be worse at tissue-air interfaces and around metal implants), anthropomorphic phantom images and CT to MR registration.

It is important to understand how images are to be used, where the distortions occur and the magnitude of distortions. If one is registering a prostate on MR to a prostate on CT, the impact of geometric inaccuracies will be less than in planning pelvic radiotherapy without a CT. One should work towards inaccuracies of 1 mm for the central 20 cm of the magnetic field and 2 mm or less the patient periphery for anatomy outside of the head and neck.

A regular QA protocol will be required to insure that tolerances have not drifted over time.

Volume imaged, scan plane and slice thickness

The volume imaged is at odds with image distortion and scan time (scan time is a currency which must also be spent on other aspects of MR "quality", whether SNR or resolution). Obviously MR-only simulation requires imaging out to the skin. In other cases, image a volume too small and the target may be missed or image registration made imprecise. When voxels are cubic, scan plane will typically be along the shortest axis of the area to be imaged. This will usually mean sagittal images of the brain or spine but axial images of the pelvis. While the image acquisition plane and parameters will often be optimized for speed, the format for export will depend on the constraints of the treatment planning system (TPS). Does the TPS require axial images? Does the TPS have a limit on the maximum number of slices?

The presence of fiducials

Many radiation treatments rely on the presence of implanted fiducials for in-room image-guidance. Because of it's high atomic number and biocompatibility, gold is often the preferred material for these fiducials. Gold fiducials do not provide MR signal but are seen as a signal void. All sequences are not created equal as to how prominent this signal loss will be. It may be that an additional sequence is acquired specifically for the fiducials or that a compromise is made between target segmentation and fiducial identification (for example, selecting a T2* instead of a T2). An alternative is to consider magnetic susceptibility when selecting fiducials. This may mean replacing gold with platinum or using a hybrid gold/polymer fiducial.

From images to a treatment plan

With an MR dataset compatible with the treatment planning system, the images are transferred. The precise workflow will depend on the software available and the experience of the treatment planning team. In most cases, the MR will need to be co-registered to a planning CT. It may or may not be possible to segment the MR prior to image registration. When this is possible, segmented contours can be used to evaluate the registration. Deformable image registration could be the subject of its own treatise and must be used with caution – it may be preferable to perform a rigid registration focused on the volume of interest or even use more than one rigid registration.

Errors

The small discrepancies in where the radiation beam is aimed and where the tumor and organs are positioned can be random or systematic. The current means of dealing with these errors is to aim the radiation at a larger volume – the planning target volume. For patients treated with multiple fractions the impact of systematic error where the dose is consistently moved in the same direction is greater than that of random error through which there is a smearing of the dose. A significant source of systematic error is inaccurate delineation of targets on the planning images. The promise of MR in radiotherapy planning is that the improved soft tissue contrast will improve the quality of delineation and thus reduce systematic error. One needs to be cautious that this benefit is not lost to new sources of systematic error: chemical shift, geometric distortion, misregistration of the MR to the planning CT, misidentification of implanted fiducials. ... Until MR-only workflows become commonplace, it is prudent to always confirm segmentation on the planning CT.

Image-guidance for external beam radiotherapy

Treatment devices are becoming increasingly sophisticated at verifying and correcting the alignment of the patient to the treatment beam. Nonetheless, initial patient positioning remains important and surface markings made at simulation will help the therapist get the patient straight and centered prior to image-guidance.

Daily image-guidance procedures vary depending on the treatment device, the clinical scenario and institutional preference. The two most common modalities will be either a set of planar X-rays or a cone-beam CT performed prior to treatment. These images are compared to either the planning CT or simulated planar X-rays computed using the CT (so-called digitally reconstructed radiographs or DRRs). The images of the day are aligned to the planning images based on the target, surrogate anatomy or implanted fiducials. As examples, a lung tumor may be directly visualized on cone-beam CT, the skull may serve as a reliable surrogate for a brain tumor and implanted radio-opaque fiducials may guide treatment of a liver cancer. Patient translations and sometimes rotations are used to fine-tune the target alignment. In some cases compromises will be required when the anatomy is deformed or the position of the tumor has shifted in relation to a critical organ.

More sophisticated delivery paradigms aim to track tumor and/or patient position during treatment. The technologies used may involve structured light for surface mapping, continuous ultrasound, orthogonal X-rays, fluoroscopy or repeated CT imaging.

The nascent integration of MRI in the treatment delivery process promised to lessen reliance on implanted fiducials and other tumor surrogates. MRI also enables continuous daily soft tissue imaging without extra radiation dose. MRI-guided radiation is not without challenges – in dosimetry, safety and health economics. However MRI-guidance has a bright future as the field moves to adapting daily treatments to account for patient deformation and tumor response rather than simply translating the patient within pre-set treatment fields.

Special considerations in brachytherapy

Use of MR in brachytherapy shares many of the same issues of MR in external beam radiotherapy. In addition it has its own unique issues in the different steps of the workflow. Scheduling of brachytherapy cases is more difficult – the exact duration of the procedures can be unpredictable, scheduling is inflexible, the time the patient spends in the MR suite is typically longer and transport of the patient from the brachytherapy unit and/or operating room excludes use of a geographically removed MR unit. Additional MR-compatible hardware may be required to monitor the patient while in the magnet and shuttle the patient from a stretcher to the MR couch. Some concerns in designing imaging sequences are unique: precise visualization of the brachytherapy applicator, lessened importance of geographic distortions removed from the site of the brachytherapy implant, image distortion caused by the brachytherapy applicator and specific absorption rate (SAR) limits to prevent heating of metal applicators*. Despite the challenges, brachytherapy is a compelling application for an MR unit in the radiotherapy department.

The patient perspective

The hope is that MRI Simulation will improve patient RT planning process. To achieve these potential benefits, patients will be exposed to potential dangers and discomforts of MRI imaging. While injury caused by exposure to magnetic fields or gadolinium-based contrast agents should be exceedingly rare with proper screening and precautions, other inconveniences will be more commonly encountered. The most common will be claustrophobia, discomfort from immobilization systems and the inconvenience of added appointments. Measures can be taken to improve the patient experience:

- Can all planning appointments be given on the same day? This is certainly easier when all simulation work is performed in the same physical location.
- Have the number and duration of MRI sequences been optimized? Are the most important sequences acquired first in cases when the patient may not tolerate the entire procedure?
- What is the bore size of the MRI? Are patients screened for claustrophobia? Does the department have access to psychological counseling?

Looking into the future of MR in RT

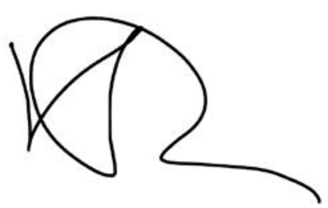
MRI in radiotherapy has the advantage of 'trialability'. Prior to investing in a device dedicated to radiotherapy, departments can increase the number of clinical scenarios in which they integrate MRI from their diagnostic radiology departments, if the scanners are accessible.

As the volume of radiotherapy examinations increases, so will the number of devices installed in radiotherapy departments. Training programs in therapy, oncology and physics will increasingly include courses in MR safety, science and interpretation. An important step in increasing adoption may be the development of simple and reliable MRI-only simulation workflows. Thus, as the contraindications to MR-imaging ever decrease, MRI-simulators may not so much cohabit with CT-simulators but replace them.

As the number of units installed in radiation oncology increase, so will the demand for true MR-simulators with hardware uniquely designed to meet the needs of treatment planning.

As daily MR guidance also gains adoption, deep-learning assisted segmentation will accelerate daily anatomical replanning. When devices can acquire functional data *during* treatment – thus without any time penalty – a large database will be mineable for clues to test dose painting strategies based on functional data. Adoption of such paradigms will likely be slower than those based on anatomical data and will require prospective validation – possibly in more innovative trial designs than the traditional randomized trial (registry randomized trials).

What is certain is that the future of MR in RT is bright!



David Roberge

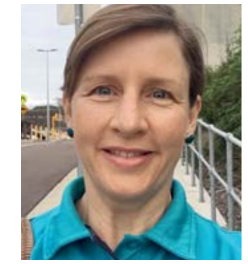
Thank you!

We would like to express our sincere gratitude to the following senior experts and their respective institutions who made this book possible.

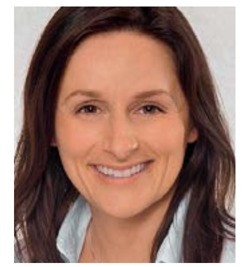
Yue Cao, Ph.D.
University of Michigan, Ann Arbor, USA

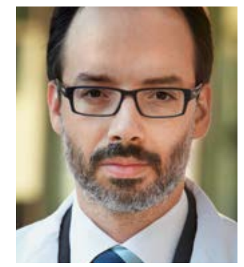
Eric Paulson, Ph.D.
Medical College of Wisconsin, Milwaukee, USA

Maja Sohlin, Ph.D.
Sahlgrenska University Hospital, Gothenburg, Sweden



Leah Best, MSc
Calvary Mater Hospital Newcastle, Newcastle, NSW, Australia





Cynthia Ménard, M.D., FRCPC and David Roberge, M.D., FRCPC
Centre hospitalier de l'Université de Montréal, Canada

Gary Liney, Ph.D. and Robba Rai, MHlthSc
Liverpool and Macarthur Cancer Therapy Centre, Ingham Institute for Applied Medical Research, Sydney, Australia

Discover ways to optimize the use of your MR simulation applications. You can download the .edx and .exar1 files at

siemens-healthineers.us/magnetom-flash

We look forward to hearing your feedback and suggestions, so that we at Siemens Healthineers can continually improve and do our part in the care of your patients.

Clinical teams of several institutions have created their own solutions to optimize images in an effort to add valuable clinical insights in treatment planning. This booklet is a compilation of study protocols and practical tips for several body regions provided by these experts.

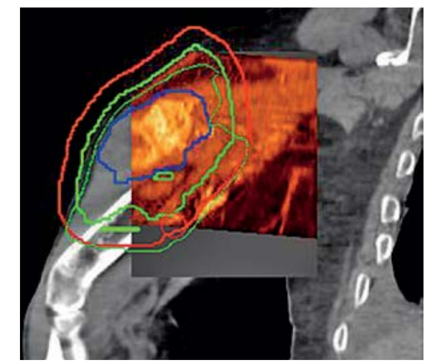
This compilation is being shared to foster clinical knowledge among medical professionals.

We would like to thank all the contributors who have worked tirelessly and generously shared their knowledge and expertise.

__Note:__ MAGNETOM systems are indicated for use as magnetic resonance diagnostic devices (MRDD) that produce transverse, sagittal, coronal and oblique cross sectional images, spectroscopic images and/or spectra, and display the internal structure and/or function of the head, body or extremities. These images and/or spectra and the physical parameters derived from the images and/or spectra when interpreted by a trained physician, yield information that may assist in diagnosis. The study protocols and any other information contained in this brochure were developed entirely by the medical professionals identified at the beginning of each section. These medical professionals did not receive financial support or any other kind of assistance from Siemens Healthineers. Not all of the 3rd party devices used by physicians have been tested or validated to be compatible with the MR systems being used. If you have any questions regarding the 3rd party device(s), please contact the 3rd party manufacturer for further regulatory or instructions for use of the device.

Patient results may vary depending on many factors including system, software version, options, coils, techniques and patient condition. Siemens Healthineers is not responsible or liable for results.

Content



Glioma 1

Robba Rai; Gary Liney

Liverpool and Macarthur Cancer Therapy Centre, Ingham Institute for Applied Medical Research, Sydney, Australia

Overview

This protocol uses a 20-channel head & neck coil without thermoplastic mask immobilisation to maintain homogenous and high image quality acquired with a site specific volume coil. Care should be taken when positioning the patient to ensure they are straight and head tilt matches CT.

Patient

Patient presentation	**High Grade Glioma:** Considered in all patients, especially if interval from Sim to diagnostic imaging > 3–4 weeks **Low Grade Glioma:** Considered if no post-operative MRI available, poor quality or non-contemporaneous diagnostic scan
Treatment prescribed	**Varies on grade and location of tumor:** • 3D Conformal • IMRT (intensity-modulated radiation therapy) • VMAT (volumetric modulated arc therapy) • Tomotherapy

Imaging study

Scanner	MAGNETOM Skyra 3T
Equipment required	• Head/Neck 20 coil • Immobilisation sponges
Patient prep needed	22-gauge intravenous cannula required prior to imaging
Setup and landmark	• Patient positioned head first supine. • Straighten patient through mid forehead, mid nose and mid chin using external lasers. • Use immobilisation sponges on the sides of patient's ears and top of head to prevent movement during imaging. • Landmark over the lower orbital margin (OM) using the bore lasers.

Figure 1:
Brain setup using 20-channel head and neck coil.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:15 min		
T1w MPRAGE 3D sagittal	5:21 min	Anatomical delineation	
T2w FLAIR 2D	4:26 min	Post-operative changes Target delineation	Use 2 concatenations to minimize cross talk artifacts and maintain grey-white matter contrast
T1w MPRAGE 3D sagittal + Gad	5:21 min	Tumor delineation Residual enhancement post-op	**Injection Rate** Hand bolus **Gad Vol** 0.1 mmol/kg (Gadobutrol) **Saline Flush** 10 ml before and after Gad

Special considerations

Tips and tricks	• When positioning patient copy chin to chest measurements from CT Sim to match head tilt position to minimize variation between CT and MRI. • Use the same slice position from reconstructed transverse T1w MPRAGE and transverse T2w FLAIR to minimize errors between CT-MRI registration.
Preparing images for planning	• Reconstruct the T1w MPRAGE pre and post-contrast in the transverse plane only for planning.
RTP requirements	• Use 3D distortion correction where applicable. If unavailable use 2D. • Maintain a receiver bandwidth with a ≤1 pixel fat-water shift (≥ 400 Hz/Px at 3T). • 0 mm interslice gap to eliminate interpolation in radiotherapy treatment planning (RTP) system. • 2 mm slices should be used for post-operative and high/low grade Glioma cases. • 1 mm slices should be used for stereotactic patients.

Example images

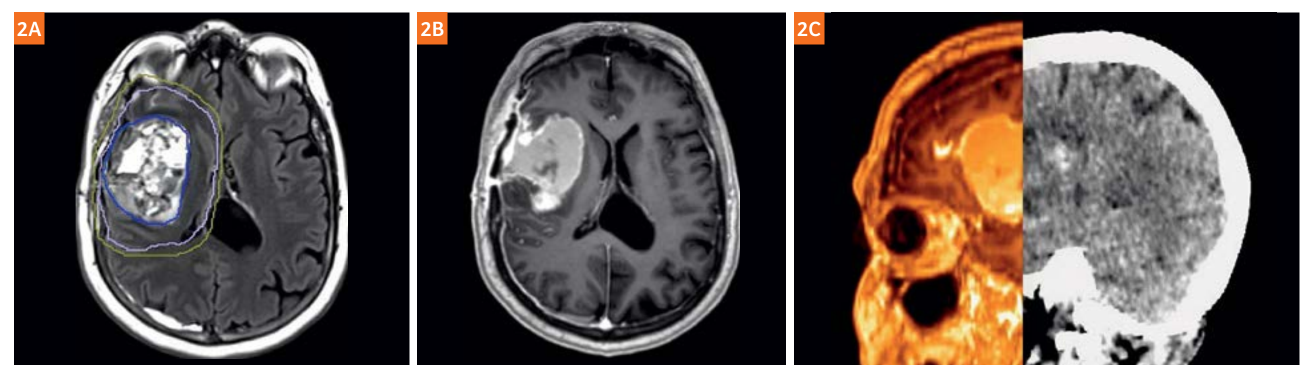


Figure 2:
T2w FLAIR showing gross tumor volume (GTV), clinical target volume (CTV), and planning target volume (PTV) margins **(2A)**, gadolinium-enhanced T1w MPRAGE demonstrating peripheral enhancement of post surgical margins with clear definition of brain structures **(2B)**, co-registration of non-contrast planning CT and post-contrast T1w MPRAGE, showing accurate registration of bone and soft tissue anatomy **(2C)**.

Glioma 2

Maja Sohlin, Ph.D.; Christian Gustafsson, Ph.D.

Sahlgrenska University Hospital, Gothenburg, Sweden

Reproduced with permission from the “Method book for the use of MRI in radiotherapy” (Version 3) of the Swedish Vinova project.

Patient

Treatment prescribed	Varies on grade and location of tumor

Imaging study

Scanner	MAGNETOM Aera 1.5T
Equipment required	• Two Flex 4 Large coils • Velcro fasteners • Sand bags
Setup and landmark	• Patient positioned head first supine. • Line things up based on the markings previously made on the immobilizing mask, if such exist. To ensure that the patient is positioned as straight as possible in the mask, it is particularly important to check that the sagittal laser follows the previously made marking, or is centered on the patient. • The coils are inserted and clamped in place under the head area of the flat table top so they also cover the rear of the head. They are held together in the front with Velcro fasteners. The spine coil elements are not used with this setup. • The coils are supported with sand bags on the sides to get closer to the head and prevent them from pressing on the patient’s nose and face.

Figure 1:
Patient setup using two Flex 4 Large coils supported by sandbags.

Brain

Imaging protocol

Sequence	Scan time	Utility for RT	Characteristics
Axial T1w	5:25 min	Matching to CT plus anatomy before contrast	
Axial T2w	5:47 min	Delineating of target and risk organs	
Axial T2w FLAIR	5:02 min	Outlining of vasogenic edema/infiltrative glioma (bright)	Potential artifacts from CSF pulsation
Axial T1w with contrast	5:25 min	Outlining of areas with defective blood brain barrier and neovascularization (bright)	Post-operative blood products – compare with pre-contrast T1w

Special considerations

Tips and tricks

- If possible, center the target volume in the isocenter to maximize field homogeneity and efficiency of any fat suppression and to minimize distortion caused by non-linear gradients.
- The T1-weighted image is used for matching to the CT and must therefore cover as large an area of the head as possible while maintaining correct registration.
- Other images must cover the target and any risk organs to be delineated.

Example images

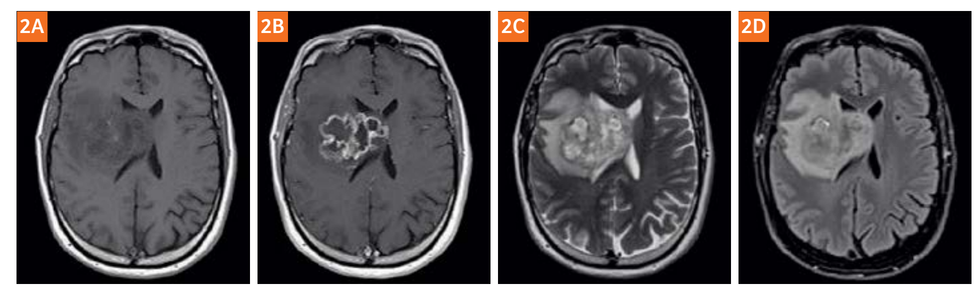


Figure 2:
(2A) T1 TSE tra (4:54 min)
(2B) T1 TSE Gd tra, (4:54 min)
(2C) T2 TSE tra (4:43 min)
(2D) T2 TIRM FLAIR tra (5:45 min)

Small targets for stereotactic treatment

Maja Sohlin, Ph.D.; Christian Gustafsson, Ph.D.

Sahlgrenska University Hospital, Gothenburg, Sweden

Reproduced with permission from the "Method book for the use of MRI in radiotherapy" (Version 3) of the Swedish Vinova project.

Patient

Treatment prescribed

Stereotactic treatment is used for small target areas that often require high-resolution MR images with thin slices for target delineating. This means that it may be advantageous to use 3D sequences for stereotactic patients.

Imaging study

Scanner

MAGNETOM Aera 1.5T

Equipment required

- Two Flex 4 Large coils
- Velcro fasteners
- Sand bags

Setup and landmark

- Patient positioned head first supine.
- Line things up based on the markings previously made on the immobilizing mask, if such exist. To ensure that the patient is positioned as straight as possible in the mask, it is particularly important to check that the sagittal laser follows the previously made marking, or is centered on the patient.
- A holder was specially fabricated for the stereotactic frame (CIVCO trUpoint ARCH™ SRS/SRT System, CIVCO Medical Solutions, Kalona, IA, USA)*. To get the holder in a stable position, it was made to be fastened below the protruding head section of the flat table top. Because of this, the patient must be positioned well down on the examination table, which could potentially be problematic for unusually tall people. The advantage of this setup is that the spine coil elements can be used to cover the rear part of the cranium.
- Two Flex 4 Large coils are wound around the stereotactic frame and are held in place with sand bags on the sides.

1

Figure 1:
Coil positioning for MAGNETOM Aera 1.5T system in Gothenburg with two Flex 4 Large coils covering the front part of the head. The rear part of the head is covered by the spine elements in the table.

Imaging protocol

Sequence	Scan time	Utility for RT	Characteristics
Axial T1w	5:25 min	Matching to CT plus anatomy before contrast	
Axial T2w	5:47 min	Delineating of target and risk organs	
Axial T2w FLAIR	5:02 min	Outlining of vasogenic edema/infiltrative glioma (bright)	Potential artifacts from CSF pulsation
Axial T1w with contrast	5:25 min	Outlining of areas with defective blood brain barrier and neovascularization (bright)	Post-operative blood products – compare with pre-contrast T1w

Special considerations

Tips and tricks

- If possible, center the target volume in the isocenter to maximize field homogeneity and efficiency of any fat suppression and to minimize distortion caused by non-linear gradients.
- The T1-weighted image is used for matching to the CT and must therefore cover as large an area of the head as possible while maintaining correct registration.
- Other images must cover the target and any risk organs to be delineated.

Example images

2A 2B 2C 2D

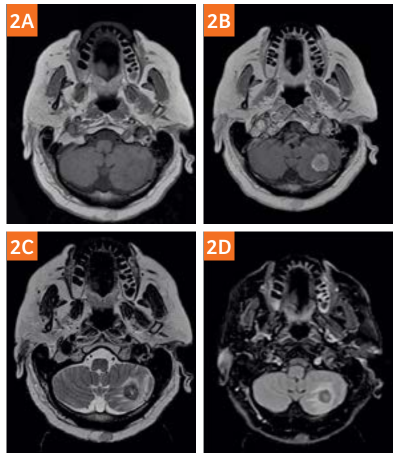


Figure 2:
(2A) T1 TSE tra (5:18 min),
(2B) T1 Gd tra (5:18 min),
(2C) T2 TSE tra (6:20 min),
(2D) T2 TIRM FLAIR tra (5:22 min).

Small targets for stereotactic treatments – Schwannoma

Maja Sohlin; Karin Petruson

Sahlgrenska University Hospital, Gothenburg, Sweden

Coverage

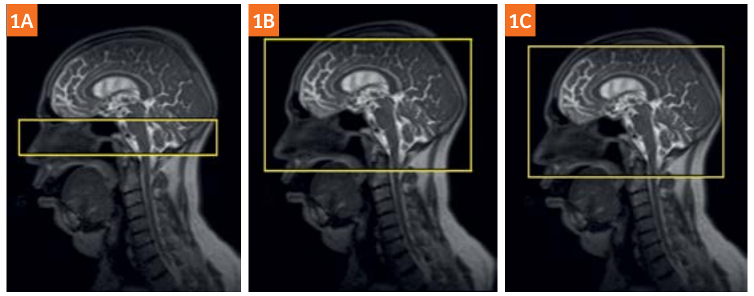


Figure 1: Patient image showing the coverage on the localizer.

Imaging protocol

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:32 min		
Axial T2 SPACE	6:03 min	Delineation of target and risk organ	1 mm slice thickness 44 mm slab thickness
Axial T1 SPACE + Gd	7:04 min	Delineation of target and risk organ	1 mm slice thickness
Axial T2 SPACE (Optional)	9:01 min	Delineation of target and risk organ	1 mm slice thickness 160 mm slab thickness

Example images

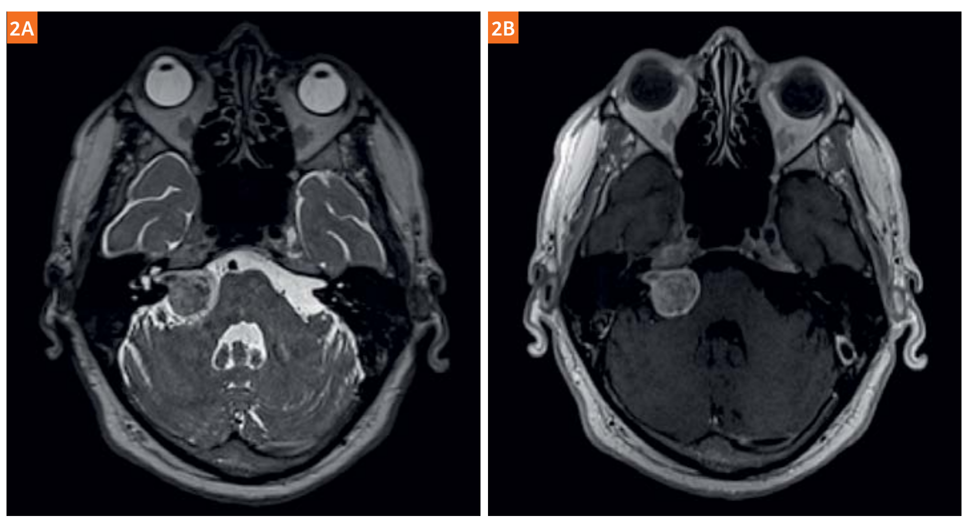


Figure 2:
(2A) Axial T2 SPACE
(2B) Axial T1 SPACE

[1]Optional
[2]Accuracy for repositioning from one direction

Framed Stereotactic radiosurgery

Christopher Schultz, M.D.; Colette Gage, BS RTR(MR); Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Brain metastases and pituitary adenoma
Treatment prescribed	Gamma Knife

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• 6-channel body matrix coils • Spine array coil • Two Nylon straps • Two sandbags • Flat table overlay • Head frame holder
Patient prep needed	• Change into gown and robe. • Patient will arrive at MRI with head frame positioned.
Setup and landmark	• Position flat table overlay over spine array. • Index head frame bracket at S2 over spine array. • Setup patient head-first supine and secure head frame into head frame holder. • Attach fiducial box to head frame. • Wrap two 6-channel body matrix coils circumferentially around head frame and fiducial box and secure with two Nylon straps. • Position sandbags to conform coils tightly against head frame. • Landmark over orbits.

Figure 1:
Custom fiberglass head frame holder **(1A)**, patient positioning over spine array **(1B)**, RF coil positioning **(1C)**, adjust volume and scan volume prescription **(1D)**.

MR pre-surgical planning for brain exams to be performed on GammaKnife and SRS headframe have been of cautionary concern to Siemens Applications/Service in the past. Their position has been that the third-party manufacturer (Elekta) of SRS device provides end user clinical guidance on the MR safe usage of their head frame within the MRI bore for patient exams. Siemens Applications have provided MR-related sequence exam support at the request of the customer with primary supervision responsibility from the third-party.

Imaging protocol

Download the .edx file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:30 min		
Ax B_0 Map	1:12 min	Generation of voxel shift map	
Ax 3D T1+C	5:30 min	Target delineation	A/P phase encode

Special considerations

Acquisition	• Confirm Quiet gradient mode set for all sequences and readout bandwidth set at 440 Hz/pixel (at 3T) to reduce eddy current-induced distortions. • Confirm ISO positioning mode (scan with prescribed volume at isocenter). • Prescribe adjust volume over brain. • Confirm A/P phase encode direction to minimize flow artifacts from fiducials.
Preparing images for treatment planning	• Apply 3D Distortion Correction to all images. • Inspect voxel shift map for local geometric distortions. • Avoid registering images in treatment planning system using fiducials within 2 cm of SRS frame.

Example images

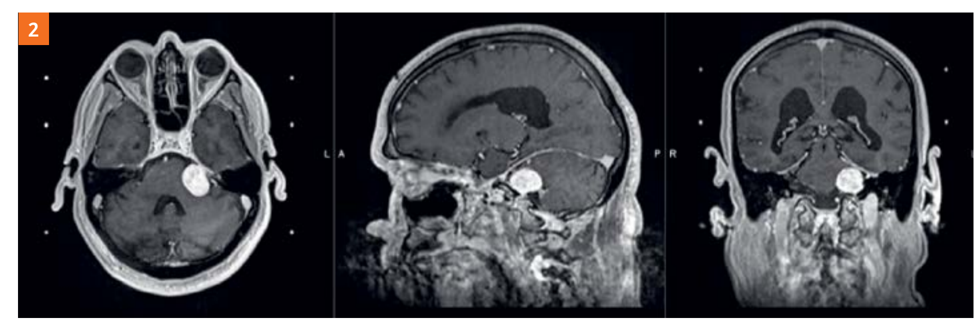


Figure 2:
3D post-contrast T1 images. Fiducial box markers use for registration in treatment planning system are visible.

Head & neck 1

Robba Rai; Gary Liney

Liverpool and Macarthur Cancer Therapy Centre, Ingham Institute for Applied Medical Research, Sydney, Australia

Overview

Protocol is designed for imaging in thermoplastic immobilisation mask. Coil arrangement has been developed to ensure homogenous signal throughout imaging volume whilst minimizing geometric distortions.

Patient

Patient presentation

Mucosal Primary:
- All nasopharyngeal primaries
- All other mucosal primaries where extent of disease uncertain after endoscopy/PET

Non-mucosal Primary:
- Consider if primary or nodal disease is close to critical structures.

Treatment prescribed

IMRT or Tomotherapy

Imaging study

Scanner

MAGNETOM Skyra 3T

Equipment required

- Two Body 18 surface coils
- RF coil bridges
- Flat table overlay
- Velcro straps
- Patient-specific immobilization device/s

Patient prep needed

22-gauge intravenous cannula required prior to imaging

Setup and landmark

- Adjust the flat table overlay by moving it down the MRI bed to ensure the top of the head of the thermoplastic mask is covered by the superior coil element of the integrated spine coil.
- Index patient-specific immobilization devices to flat table overlay.
- Patient to be positioned as per CT simulation. Head first supine.
- Straighten the patient according to the anatomical landmarks with the external laser system.
- Secure coil bridges to table and use Velcro straps to stabilize the Body 18 surface coil to the bridges. The coil should cover the vertex of the skull to the suprasternal notch.
- Lower the bridges so that it is close to the patient's mask but not touching.
- Place the second Body 18 surface coil over the patient's torso.
- Use longer Velcro straps to attach the two coils together, ensuring that there is minimal separation between the coils to minimize signal drop off in the images.
- Landmark over the chin.

Figure 1: Head & neck planning MRI setup using two 18-channel surface coils.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0.15 min		
T2 TSE Fast Dixon	3:17 min	Primary and nodal delineation (particularly where contrast not given)	Plan with in-phase and water images
T1 TSE Fast Dixon	3:05 min	Primary and nodal delineation (particularly where contrast not given)	In-phase images used for bone registration in RTP system
T1 TSE Fast Dixon + Gad	3:05 min	Primary and nodal GTV delineation	**Injection Rate** 2 ml/s **Gad Vol** 0.1 mmol/kg (Gadobutrol) **Saline Flush** 20 ml before and after Gad

Special considerations

Tips and tricks

- Dixon provides more robust and homogenous fat suppression as well as minimizing geometric distortion in the head and neck and should be considered for head & neck protocols.
- Adjust the coil bridges so the patient head is equidistant to the spine and surface coil. This will help create a more homogenous image.
- Landmark over the patient's chin using the in bore lasers before securing any coils in place as the coils will obstruct the view of the patient's external anatomy.

RTP requirements

- Use 3D distortion correction where applicable. If unavailable use 2D.
- Maintain a receiver bandwidth with a ≤1 pixel fat-water shift (≥400Hz/Px at 3T).
- 0 mm interslice gap to eliminate interpolation in radiotherapy treatment planning (RTP) system.
- All sequences should have the same centre slice to maintain consistency with CT-MRI rigid registration in RTP system.
- 2–3 mm slice thickness to encompass entire neck in an ideal acquisition time to maintain image quality.

Example images

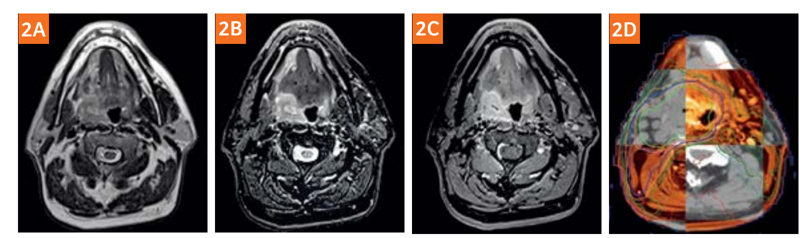


Figure 2: T2 Dixon in-phase **(2A)**, T2 Dixon water demonstrating robust fat suppression and delineation of tumor volume **(2B)**, post-contrast T1 Dixon water showing enhancement of tumor and surrounding vasculature **(2C)**, co-registration of planning CT and planning MRI **(2D)**.

Head & neck 2

Jared Robbins, M.D.; Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Squamous cell carcinoma
Treatment prescribed	Volumetric Modulated Arc Therapy

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• Two 6-channel Body Matrix coils • 4-channel extremity coil • Spine array coil • Three Nylon straps • Flat table overlay • Head rest • Patient-specific immobilization device
Patient prep needed	Change into gown and robe
Setup and landmark	• Position flat table overlay over spine array. • Index patient-specific immobilization devices to flat table overlay. • Setup patient head-first supine, using external lasers to align and straighten. • Wrap two 6-channel Body Matrix coils around patient's head and secure with two Nylon straps. • Confirm that the coils overlap anteriorly, are positioned as inferiorly as possible, and are symmetric. • Position 4-channel extremity coil over neck and secure with Nylon strap Landmark over patient chin.

Figure 1:
Immobilization device and RF coil positioning.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT
Localizer	0:19 min	
Ax STIR TSE	7:00 min	Delineation of gross tumor volume and associated edema
Ax T1 TSE	4:20 min	Organs at risk delineation
Ax DWI RESOLVE	5:30 min	Localization of gross tumor volume
Ax fat-suppressed T1 TSE + Gad	5:30 min	Delineation of gross tumor volume **Injection Rate** Hand bolus **Gad Vol** 0.1 mmol/kg (Gadobenic acid)

Special considerations

Acquisition	• Contiguous 3 mm slices with 1 mm in-plane resolution. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D distortion correction to all images. • Apply image standardization to all non-diffusion images.

Example images

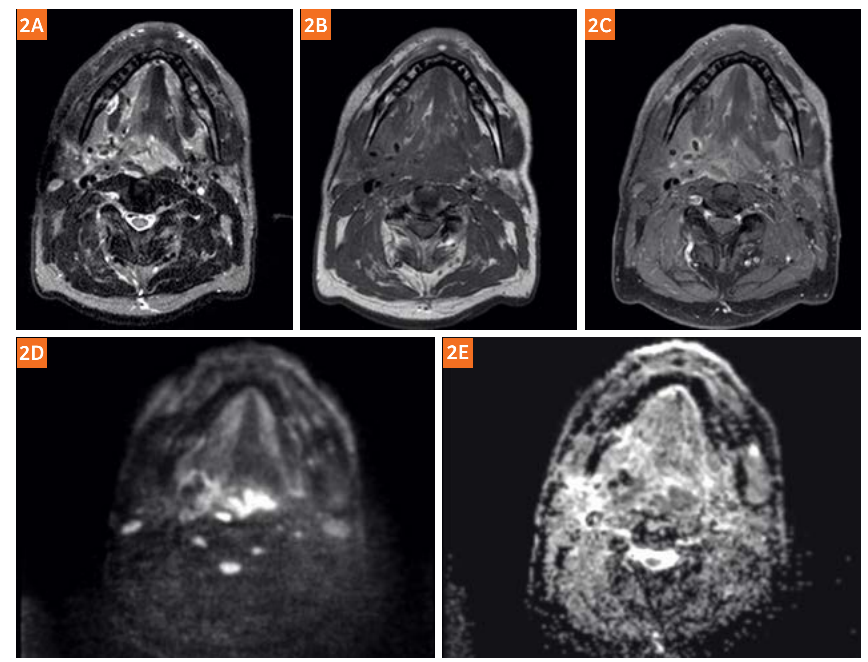


Figure 2:
Multiparametric images used for target and OAR delineation: STIR **(2A)**, T1w **(2B)**, fat-suppressed T1+Gad **(2C)**, RESOLVE DWI b=800 s/mm² **(2D)**, ADC, apparent diffusion coefficient map **(2E)**.

Head & neck 3

Maja Sohlin, Ph.D.; Christian Gustafsson, Ph.D.

Sahlgrenska University Hospital, Gothenburg, Sweden

Reproduced with permission from the "Method book for the use of MRI in radiotherapy" (Version 3) of the Swedish Vinova project.

Imaging study

Scanner	MAGNETOM Aera 1.5T
Equipment required	• Body 18 Long coil • Flex 4 Small coil • Coil holders • Flat table overlay • Patient-specific immobilization device
Setup and landmark	• Position flat table overlay over spine array. • Line things up based on the markings previously made on the immobilizing mask, if such exist. To ensure that the patient is positioned as straight as possible in the mask, it is particularly important to check that the sagittal laser follows the previously made marking, or is centered on the patient. • Coverage area see Figure 1.

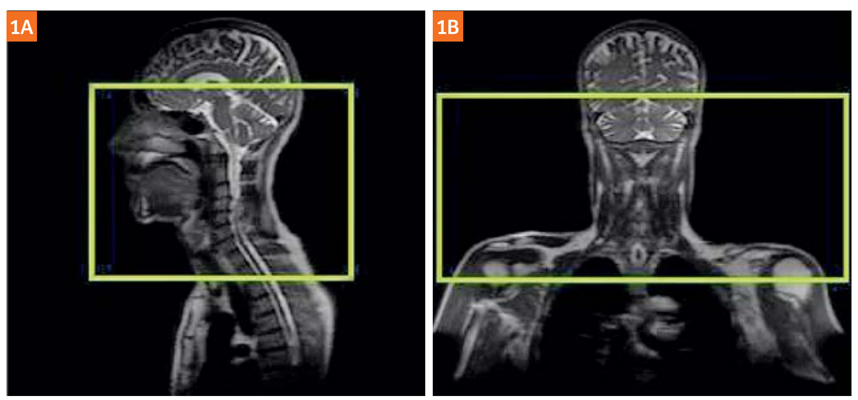


Figure 1:
Coverage areas (sag, cor) for head and neck. The large FOV used gives the skin contour of the patient and is used for better control of the matching.

Figure 2:
Coil positioning for head & neck with Body 18 Long. There is also a Flex 4 Small coil positioned posteriorly (under the table top) to increase the SNR from the rear skull parts.

Imaging protocol

Sequence	Scan time	Utility for RT	Characteristics
Axial T2 STIR	6:41 min	Differential edema (bright)	Potential swallowing artifacts, flow artifacts
Axial T1	6:36 min	Delineating of nerves and teeth	
Axial ADC		Plotting of hypercellularity (dark)	
Axial fat-suppressed post-contrast T1	6:36 min	Plotting of faulty, leaky tissue (bright)	Potential swallowing artifacts, flow artifacts

Special considerations

If the patient has dental fillings[1], these will appear as streak artifacts in CT. This problem is often avoided in MRI as the artifacts instead become small, local, signal-poor parts. The size of the artifacts in CT depend on what type of material the dental filling is made out of. The same applies to MRI, but the artifact there can instead take the form of a geometric distortion, signal loss and/or signal shift. With such severe geometric distortion, great care should be taken when defining the target and risk organs in or near the artifact.

Example images

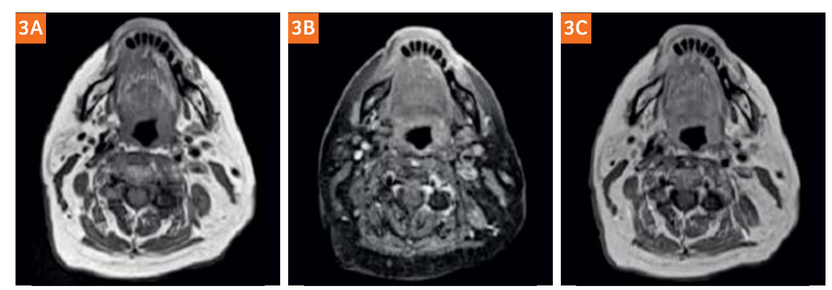


Figure 2:
(3A) T1 TSE tra 3 mm (6:36 min) **(3B)** T1 TSE tra 3 mm FatSat (6:36 min) **(3C)** T1 TSE tra 3 mm GD (6:36 min)

All run with Neck shim and WARP.

[1] The MRI restrictions (if any) of the metal implant must be considered prior to patient undergoing MRI exam. MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens Healthcare.

Head & neck 4

Yue Cao, Ph.D.; James Balter, Ph.D.

University of Michigan, Ann Arbor, MI, USA

Patient

Patient presentation	A patient is positioned in the treatment configuration using five-point face mask and bit bar as physician indication.
Treatment prescribed	Standard 35 fractions of 70 Gy. Protocol scans include local boosting.

Imaging study

Scanner	MAGNETOM Skyra 3T
Equipment required	• Flat table top • Body 18 long and Spine 32 matrix coils • Patient-specific mask, neck rest and bite block/dental guards when indicated • Sand bags • Head/neck board • Arm pulls if/as needed
Setup and landmark	• Flat table top is usually already in place, but place if needed. • Mask can be made in CT or in Zone 3 (sag laser on wall). • Patient zeroed at External Auditory Meatus, mask is positioned using indexed head/neck board using the exact bar. • Body 18 placed over mask, sand bags used near head region. • Scan range varies by disease site and diagnosis.

Figure 1: Body 18 coil placed over mask, with sand bags mounted on top near head region.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT
Localizer	0:13 min	
2D T1 TSE FS pre Gd	2:08 min	Assisting GTV delineation
2D DWI RESOLVE	5:00 min	Boost target delineation
2D T2 TSE fs	3:14 min	Assisting GTV delineation
2D T1 TSE post Gd	5:35 min	GTV definition

Example images

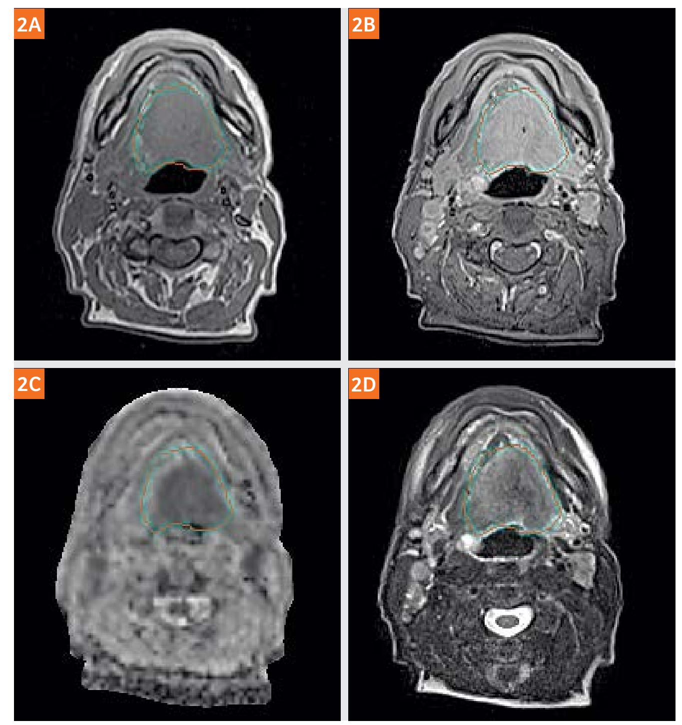


Figure 2:
(2A) T1 TSE FS pre-Gd,
(2B) T1 TSE FS post-Gd,
(2C)ADC map,
(2D) T2 TSE fs.

Spine 1

Giuseppina Laura Masucci, Jean-Charles Côté, Philip Wong, Karim Boudam

Centre hospitalier de l'Université de Montréal, Canada

Patient

Patient presentation	• Considered in all patients treated for spinal metastasis • Considered in all patients treated for primary spinal tumors
Treatment prescribed	Varies based on tumor location and extent • IMRT (intensity-modulated radiation therapy) • VMAT (volumetric modulated arc therapy) • Helical tomotherapy • Robotic radiosurgery (Cyberknife)

Imaging study

Scanner	MAGNETOM Aera 1.5T MAGNETOM Avanto^{fit} 1.5T
Equipment required	For tumors of the cervical and upper thoracic spine (C1-T3): • Spine 32 • Body 18 long • 2x Flex 4 Small • Flat table top • Thermoplastic mask (used for MAGNETOM Aera, removed before entering tunnel for MAGNETOM Avanto^{fit}) For tumors of the thoracic, lumbar and sacral spine (T3-S5): • Spine 32 • Body 18 • Full-body vacuum cushion when treatments are administered using IMRT, VMAT or tomotherapy (used for MAGNETOM Aera, a small reproduction of the spinal area is made for the MAGNETOM Avanto^{fit}) • Vacuum cushion for patients treated using Cyberknife
Patient prep	20-gauge intravenous cannula required prior to imaging if contrast is to be used (considered in patients with paraspinal disease and in the post operative setting)
Setup and landmark	• Patients are positioned head-first supine. • Setup shown here for a thoracic tumor with full-body vacuum cushion.

Figure 1:
Patient set-up with Body 18 coil **(1A)**, scout views showing coverage area **(1B, C)**.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
T2 SPACE sag 3D	5:07 min	Allows better definition of the spinal cord and thecal sac	1.0 x 1.0 x 1.0 mm
T1 SPACE sag 3D	4:55 min	To define tumor and spinal cord volumes	1.0 x 1.0 x 1.0 mm
T1 SPACE FS sag 3D post-contrast	4:55 min	Contrast usually used in the presence of paraspinal disease or in the post-operative setting to define tumor volumes	1.0 x 1.0 x 1.0 mm

Special considerations

Tips & tricks	• Table in ISO positioning mode. • 3D distortion correction applied (image outside correction zone not used). • Bandwidth of at least 220 Hz/mm (1 mm fat-water separation at 1.5 Tesla). • Save an axial MPR of all the SPACE.
Preparing images for planning	• Send images from MR to PACS. • Load images (MR and CT) from PACS on image registration console (MIM Vista, MIM Software Inc., Cleveland, OH, USA). • Rigid registration of MR to CT. • Send registered images to contouring server. • Contour volumes on contouring client (Somavision Varian Medical Systems, Palo Alto, CA, USA). • Send CT and contours from contouring server to planning console.

Example images

Figure 2: T2 SPACE sag 3D

Figure 3: T1 SPACE sag 3D

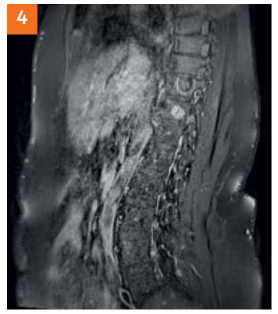


Figure 4: T1 SPACE FS sag 3D post-contrast

Spine 2

Leah Best; Jameen Arm; Nick Marks; Laura O'Connor; Narelle Grabham; Ben Ling; Melissa Lovell

Calvary Mater Hospital Newcastle, Newcastle, NSW, Australia

Patient

Patient presentation	69-year-old male, prostate cancer, treated with ADT and radiotherapy, completed 2014. Biochemical relapse with PSA 2.7. Intensely PSMA avid lesion at the left pedicle/transverse process of the L4 is consistent with bony metastatic disease seen on PET.
Treatment prescribed	SBRT (Stereotactic Body Radiation Therapy) – 24 Gy – 2 fractions to his spine with VMAT (volumetric moderated arc therapy) – nonconsecutive days

Imaging study

Scanner	MAGNETOM Skyra 3T system
Equipment required	• Spine array 32-channel surface coil • CIVCO flat table overlay • CIVCO Vac-Loc cushion – patient specific • Knee rest if needed
Immobilisation	CIVCO Vac-Loc cushion – patient specific
Patient prep needed	22-gauge cannula

Setup and landmark	• Position flat table overlay spine array.
	• Patient to be positioned head first supine.
	• Patient positioned as per positioning for CT simulation.
	• Patient aligned using rotation tattoos and external laser bridge.
	• Position and centre region of interest to isocentre
	• Position patient specific Vac-Loc cushion on table.
	  • Consider positioning patient closer to the foot end of table to enable the emergency buzzer to reach when arms above head.
	  • Consideration should be made when making Vac-Loc cushion to enable it to fit in the bore of scanner without movement.
	  • Patients unable to use the Vac-loc cushion use grey Siemens cushions to replicate treatment position.

Figure 1: Patient positioning for RT planning spine.

* The information shown herein refers to products of 3rd party manufacturers and thus are in their regulatory responsibility. Please contact the 3rd party manufacturer for further information.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Haste_3plane_loc	0:19 min	Localization of region of interest	
T2_tse_tra	3:38 min	Tumor contouring/anatomical contouring	
T2_space_tra	4:39 min	Tumor contouring/anatomical contouring	Better for upper spinal lesions. No CSF flow voids.
T1_vibe_fs_tra_pre	1:05 min	Baseline for contrast	
T1_vibe_tra_pre	0:59 min	Tumor contouring	
Contrast			Gadobutrol 0.1 mmol/kg
T1_vibe_fs_tra_pre	1:05 min	Tumor contouring	
T1_vibe_tra_pre	0:59 min	Tumor contouring	

Special considerations

Tips & tricks	• Ensure the Vac-loc bag is made as little thickness as possible at the spine region to minimize distance from the spine coil. • Can consider using anterior coil for extra signal however then need to adjust parameters to compensate for respiratory artifact. • Use saturation bands to reduce respiratory ghosting (Thoracic region). • Ensure patient is positioned so that region of interest is aligned to a spinal coil element.
Preparing images for planning	• No specific changes made. Images exported as is to RT Treatment planning software.
RTP requirements	• Patient positioned as per positioning for CT simulation. • Patient aligned using rotation tattoos and external laser bridge.

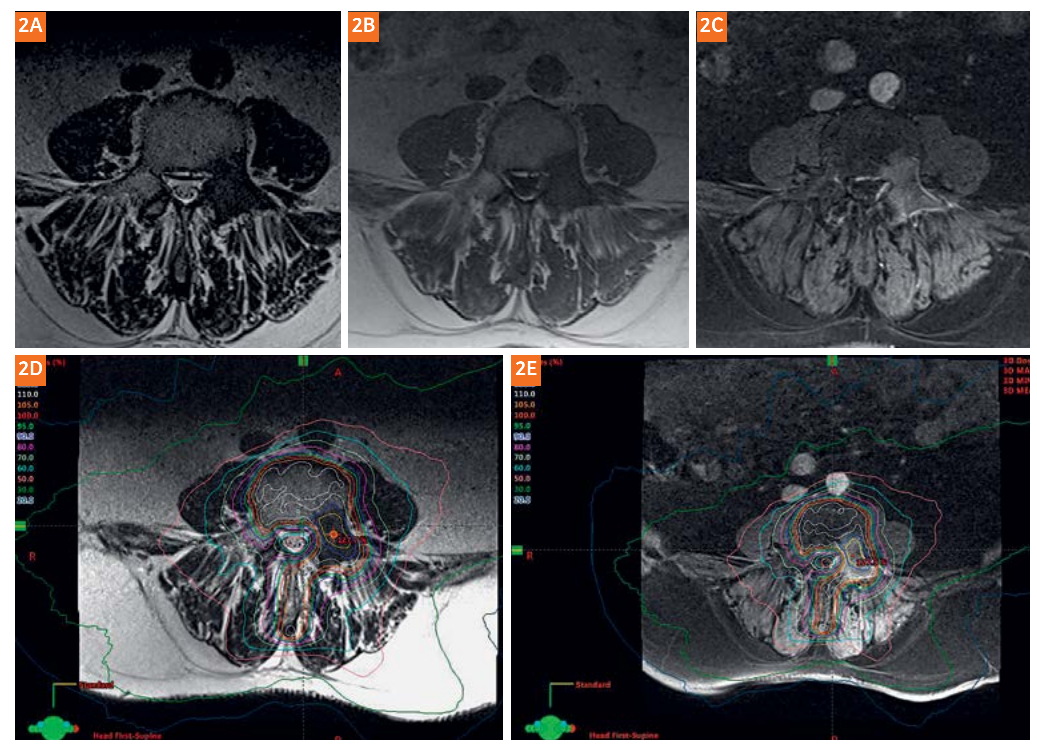


Figure 2:
(2A) T2w TSE transversal,
(2B) T1w VIBE transversal, pre-contrast,
(2C) T1w VIBE transversal with fat sat post-contrast.

(2D, E) Dose distribution shown on T1w VIBE images pre/post contrast. Treatment isodose shown in orange.

Esophagus

Candice Johnstone, M.D.; Paul Knechtges, M.D.; Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Esophageal cancer
Treatment prescribed	3D conformal radiation therapy

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• Two 6-channel Body Matrix coils • Spine array coil • Two adjustable coil bridges • Two Nylon straps • Flat table overlay • Headphones • ECG leads and Bluetooth transceiver • Patient-specific immobilization device/s
Patient prep needed	• Change into gown and robe. • Attach ECG leads and Bluetooth transceiver. • Place 22-gauge intravenous cannula into antecubital vein.
Setup and landmark	• Position flat table overlay over spine array. • Index patient-specific immobilization devices to flat table overlay. • Setup patient head-first supine, using external lasers to align and straighten, and confirm pelvic crest is above S9 on spine array coil. • Place RF coil bridges over thorax and conform to patient surface anatomy. • Wrap two 6-channel Body Matrix coils circumferentially over RF coil bridges and secure with two Nylon straps. • Place headphones on patient. • Landmark over thorax.

Figure 1:
Adjustable RF coil bridges and RF coil positioning.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer – free breathing	0:30 min		
Localizer – breath-hold	0:17 min		
Ax Restore T2 TSE	6:00 min	Delineation of gross tumor volume	Cardiac or respiratory gating
Ax BH T1 Dixon CAIPI pre	0:12 min	Reference for gross tumor volume delineation	
Care Bolus			**Injection Rate** 2 cc/sec **Gad Vol** 0.1 mmol/kg (Gadobenic acid)
Ax BH T1 Dixon CAIPI + Gad arterial	0:12 min	Reference for gross tumor volume	
Ax BH T1 Dixon CAIPI + Gad venous	0:12 min	Reference for gross tumor volume delineation	
Ax BH T1 Dixon CAIPI + Gad equilibrium	0:12 min	Reference for gross tumor volume delineation	

Special considerations

Acquisition	• Respiratory gating performed for tumors close to gastroesophageal junction (GEJ). • Cardiac gating performed for tumors close to heart. • Contrast injection performed using bolus tracking technique. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D distortion correction to all images. • Apply image standardization to non-DWI images. • Perform local rigid registration over gross tumor volume to align reference MR image with planning CT images.

Example images

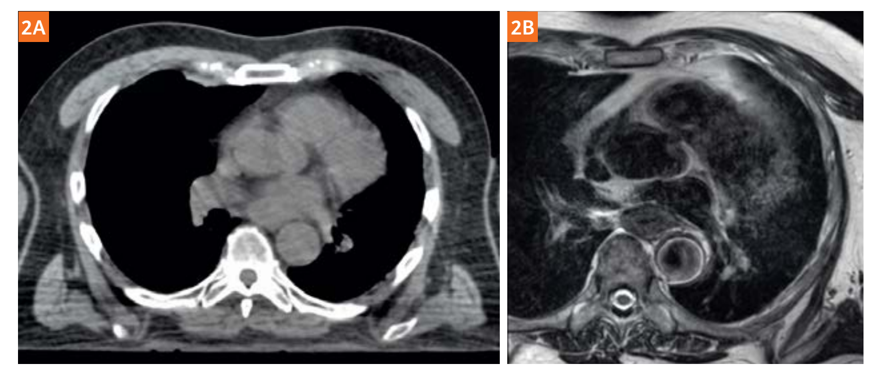


Figure 2:
Planning CT **(2A)** and cardiac and respiratory gated Restore T2 TSE **(2B)**.

Lung

Gary Liney; Robba Rai

Liverpool and Macarthur Cancer Therapy Centre, Ingham Institute for Applied Medical Research, Sydney, Australia

Overview

This is a free breathing procedure incorporating morphological and functional imaging protocols. Ultrashort echo time (UTE) imaging is incorporating for the purposes of MRI only planning and lung parenchyma assessment.

Patient

Patient presentation	Treatment response research – free-breathing protocol
Treatment prescribed	IMRT or 3D Conformal (Multifield)

Imaging study

Scanner	MAGNETOM Skyra 3T
Equipment required	• Body 18, 18-channel surface coil • Spine 32, 32-channel spine coil • RF coil bridges • Flat table overlay • Velcro straps • Patient-specific immobilization device/s
Patient prep needed	20-gauge intravenous cannula required prior to imaging
Setup and landmark	• Index patient-specific immobilization devices to flat table overlay. • Patient to be positioned as per CT Simulation. Head first supine. • Straighten the patient to AP and rotation tattoos with the external laser system. • Secure coil bridges to table and strap 18-channel surface coil to the bridges. • Lower the bridges so that it is close to the patient's torso but not deforming the external contours. • Ensure that the coil covers the top of lung apices to lower costophrenic angles. • Landmark over the cross hair of the coil (center of the thorax).

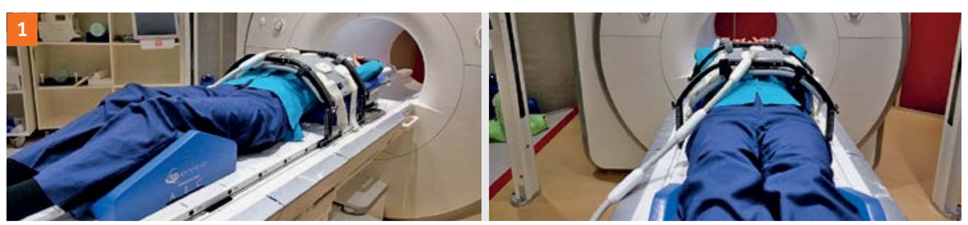


Figure 1: Patient positioned as per CT Simulation (straightened on tattoos with the external laser system). Coil bridges secured to the table and Body 18 coil strapped to the bridges.

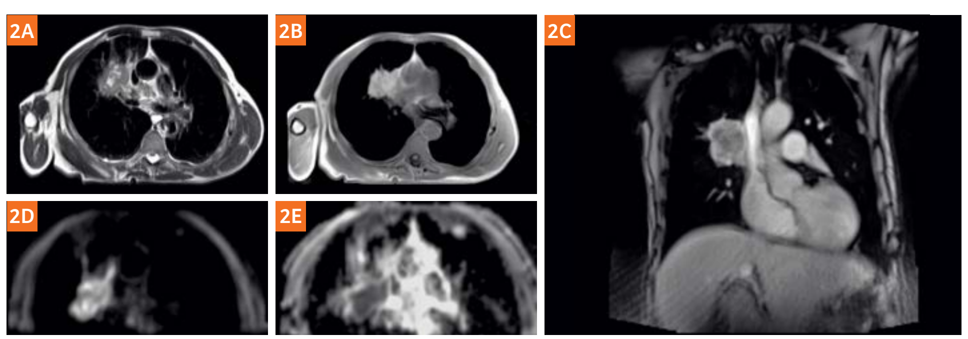


Figure 2: Free-breathing T2 HASTE using phase navigation for respiratory triggering **(2A)**, free-breathing T1 StarVIBE **(2B)**, free-breathing coronal T1 StarVIBE perfusion used for tumor perfusion analysis **(2C)**, free-breathing diffusion-weighted imaging, b-value 750 s/mm² **(2D)** and ADC map **(2E)**.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:09 min		
T2_HASTE_transverse	5:00 min	Target delineation	Respiratory Navigation
T1 StarVIBE_transverse	3:40 min	Node and bone delineation	
T2_TRUFI_coronal	0:19 min	Tumor motion	
T2_TRUFI_sagittal	0:13 min	Tumor motion	
ZOOMit_EPI_transverse	3:18 min	Target delineation	
Radial VIBE coronal	9:04 min	Lung parenchyma delineation and MR-only planning	
T1 StarVIBE coronal 2 degree flip angle	0:14 min	T1 Mapping	
T1 StarVIBE coronal 15 degree flip angle	0:14 min	T1 Mapping	
T1 StarVIBE coronal dynamic + Gad	5:42 min	Tumor perfusion	**Injection Rate** 4 ml/s **Gad Vol** 0.05 mmol/kg (Gadobutrol) **Saline Flush** 20 ml inject after 3 measurements
T1 StarVIBE SPAIR post Gad	4:13 min	Target delineation and nodal enhancement	**Injection Rate** 2 ml/s **Gad Vol** 0.05 mmol/kg (Gadobutrol) **Saline Flush** 20 ml scan after 20 sec. post Gad injection

Special considerations

Tips and tricks	• Use phase navigation for T2 HASTE for optimal image quality. • Place cardiac shim box over the heart for TrueFISP imaging to minimize off-resonance and flow related artifacts.
RTP Requirements	• Use 3D distortion correction where applicable. If unavailable use 2D. • Maintain a receiver bandwidth with a ≤1 pixel fat-water shift (≥400 Hz/Px at 3T). • 0 mm interslice gap to eliminate interpolation in radiotherapy treatment planning (RTP) system. • All sequences should have the same centre slice to maintain consistency with CT-MRI rigid registration in RTP system. • 3–4 mm slice thickness to encompass entire thorax in an ideal acquisition time to maintain image quality.

Breast prone unilateral

Adam Currey, M.D.; Colette Gage, BS RTR(MR); Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Breast cancer with the following indications: • Patients requiring surgical bed boost • Dense breast tissue • Small lumpectomy cavities • Long delays between surgery and start of RT • Inadequate surgical clips
Treatment prescribed	3D conformal radiotherapy

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• Sentinelle breast coil with base and all pads removed • Custom styrofoam arm support • Custom styrofoam body support • G9 fiberglass breast bridge
Patient prep needed	• Change into gown and robe (open to the front). • Place 22 gauge intravenous cannula into antecubital vein.
Setup and landmark	• Remove spine array and all other pads from MRI table. • Set Sentinelle breast coil (with base removed) onto MRI table. • Arrange styrofoam arm support to fit into MRI table and sit flush with breast coil. • Arrange styrofoam body support to fit onto the incline of the breast coil. • Arrange G9 fiberglass breast bridge to lay flat across the two styrofoam supports. • Use a blanket or pad for patient to rest their head. • Setup patient head-first prone. Secure upper extremities using padding or blankets. • Use external LAP lasers* to verify breast position. • Landmark over center of diseased breast.

* The information shown herein refers to products of 3rd party manufacturers and thus are in their regulatory responsibility. Please contact the 3rd party manufacturer for further information.

Figure 1:
Sentinelle breast coil (base removed) with pink styrofoam body support, white styrofoam arm support, and G9 fiberglass breast bridge.

Breast

Imaging protocol

Download the .edx file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:30 min		
Ax 3D T2(f)	6:00 min	Delineation of seroma	Rotate axial field of view
Ax 3D T1	3:30 min	Registration reference	Rotate axial field of view
Ax DWI RESOLVE	5:00 min	Localization of gross tumor volume	
Ax DCE	8:00 min	Delineation of gross tumor volume	

Special considerations

Acquisition	• Prescribe axial 3D T1 and 3D fat-suppressed T2 volumes with field-of-view slightly rotated tangentially to minimize cardiac motion effects over axilla. • Confirm L/R phase encode direction. • Prescribe high order shim volume over breast. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D Distortion Correction to all images. • Perform local rigid registration over breast.

Example images

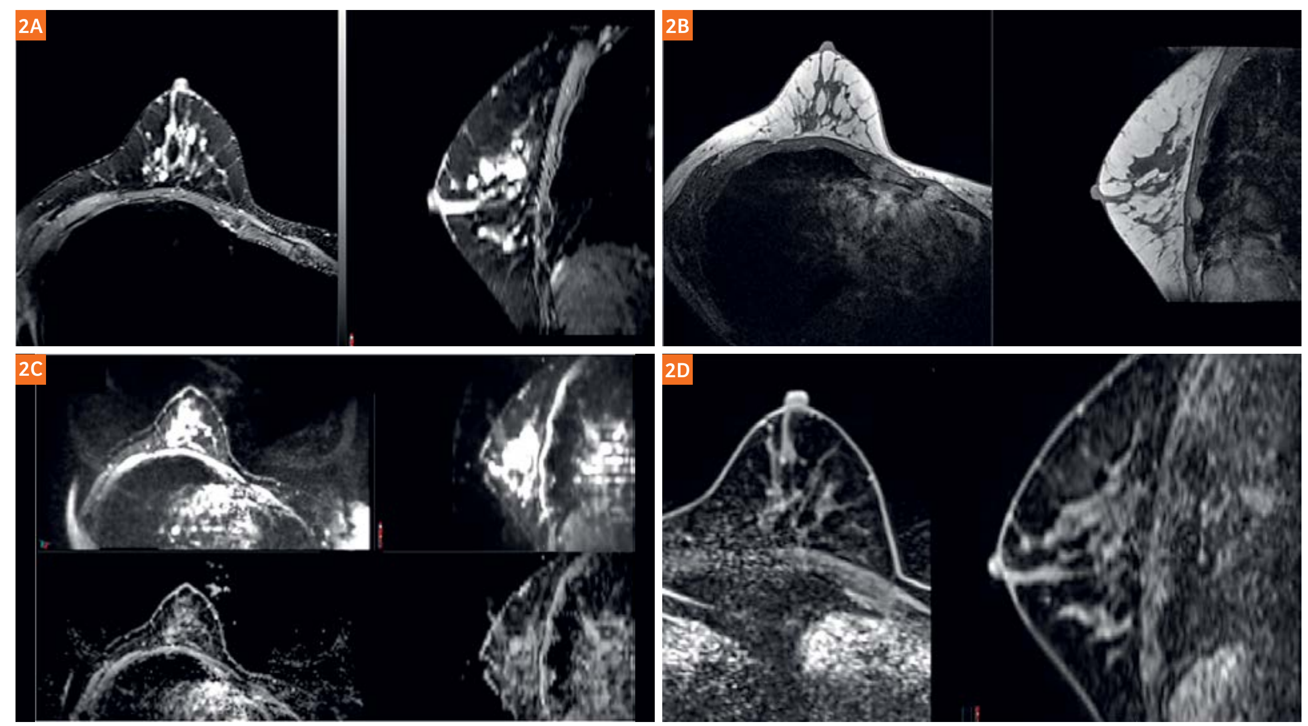


Figure 2:
Ax 3D fat-suppressed T2 **(2A)**, Ax 3D T1 **(2B)**, Ax DWI and apparent diffusion coefficient **(2C)**, and Ax DCE **(2D)** images used for target and OAR localization and delineation.

Breast supine unilateral

Adam Currey, M.D.; Colette Gage, BS RTR(MR); Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Breast cancer with the following indications: • Patients requiring surgical bed boost • Dense breast tissue • Small lumpectomy cavities • Long delays between surgery and start of RT • Inadequate surgical clips
Treatment prescribed	3D conformal radiotherapy

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• Two Large flex surface coils • Two Coil bridges • Two Nylon locking straps • MR-compatible CQUAL board • Headphones
Patient prep needed	• Change into gown and robe. • Place 22 gauge intravenous cannula into antecubital vein.
Setup and landmark	• Remove spine array and all other pads from MRI table. • Position MR-compatible CQUAL board on couch, typically at 5 degree incline. • Setup patient head-first supine with upper extremities in arm and wrist supports. • Place RF coil bridges over chest and adjust to conform patient surface anatomy. • Arrange both large flex coils circumferentially over RF coil bridges and secure with two nylon straps. Position coils as superior as possible without hitting arms. Confirm breasts are not deformed. • Place headphones on patient. • Landmark over center of breasts.

Figure 1:
MRI-safe CQUAL board at 5 degree incline **(1A)**, patient set-up with RF coils arranged on bridges to prevent deformation of breast **(1B)**.

Imaging protocol

Download the .edx file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT
Localizer (free breathing)	0:30 min	
Ax PACE T2 STIR HASTE	5:00 min	Delineation of seroma
Ax Lymphography	2:00 min	Visualization of lymph nodes
Ax PACE DWI	5:00 min	Localization of gross tumor volume
DCE	8:00 min	Delineation of gross tumor volume

Special considerations

Acquisition	• Prescribe axial volume to cover superiorly through larynx and inferiorly through diaphragm. • Prescribe Ax Lymphography volume centered to cover super-clavicular and axillary lymph nodes. • Adjust concatenations in respiratory triggered acquisitions to patient respiratory rate, ensuring all slices are acquired at specific respiratory state (e.g., end expiration).
Preparing images for treatment planning	• Apply 3D Distortion Correction to all images. • Calculate thin-slice maximum intensity projection of lymphography images. • Perform local rigid registration over breast.

Pancreas

Beth Erickson, M.D.; Paul Knechtges, M.D.; Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Locally advanced unresectable pancreatic adenocarcinoma
Treatment prescribed	Respiratory-gated intensity modulated radiation therapy

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• Two 6-channel Body Matrix coils • Spine array coil • Two adjustable coil bridges • Two Nylon straps • Flat table overlay • Headphones • Patient-specific immobilization device/s
Patient prep needed	• Change into gown and robe. • Place 22-gauge intravenous cannula into antecubital vein.
Setup and landmark	• Position flat table overlay over spine array. • Index patient-specific immobilization devices to flat table overlay. • Setup patient head-first supine, using external lasers to align and straighten, and confirm pelvic crest is above S9 on spine array coil. • Place RF coil bridges over abdomen and conform to patient surface anatomy. • Wrap two 6-channel Body Matrix coils circumferentially over RF coil bridges and secure with two Nylon straps. • Place headphones on patient. • Landmark over diaphragm.

Figure 1:
Adjustable RF coil bridges and RF coil positioning.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

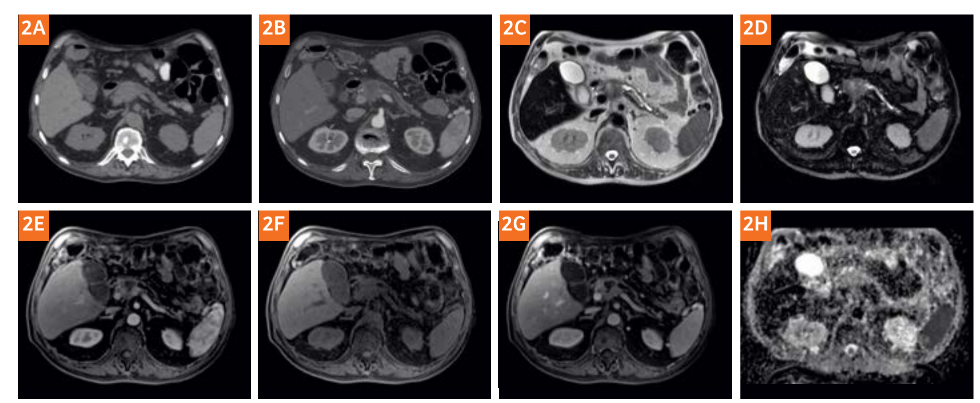
Sequence	Scan time	Utility for RT	Characteristics
Localizer – free breathing	0:30 min		
Localizer – breath-hold	0:17 min		
Ax PACE T2 HASTE	2:30 min	Organs at risk delineation	
Ax PACE fat-suppressed T2 HASTE	2:30 min	Localization of gross tumor volume	
Ax PACE DWI	5:00 min	Localization of gross tumor volume	
Ax BH T1 Dixon CAIPI pre	0:12 min	Reference for gross tumor volume delineation	
Care Bolus			**Injection Rate** 2 cc/sec **Gad Vol** 0.1 mmol/kg (Gadobenic acid)
Ax BH T1 Dixon CAIPI + Gad arterial	0:12 min	Delineation of gross tumor volume	
Ax BH T1 Dixon CAIPI + Gad venous	0:12 min	Reference for gross tumor volume delineation	
Ax BH T1 Dixon CAIPI + Gad equilibrium	0:12 min	Reference for gross tumor volume delineation	

Special considerations

Acquisition	• Contrast injection performed using bolus tracking technique. • Administer 1 mg Glucagon IV (1/2 at start of exam, 1/2 midway through exam) to suppress peristalsis. • Respiratory gating and breath-holds performed at end expiration to match phase of gating window used for treatment delivery. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D distortion correction to all images. • Apply image standardization to non-DWI images. • Identify a reference MR image and perform local MR-MR rigid registration over gross tumor volume to correct for inter-sequence motion. • Perform local rigid registration over gross tumor volume to align reference. • MR image with planning CT images.

Example images

Figure 2:
Multiparametric images used for target and OAR localization and delineation. Planning CT **(2A)**, IV contrast CT **(2B)**, T2 HASTE **(2C)**, fat-suppressed T2 HASTE **(2D)**, pre-contrast Dixon T1 **(2E)**, arterial phase Dixon T1 + Gad **(2F)**, venous phase Dixon T1 + Gad **(2G)**, apparent diffusion coefficient (ADC) map **(2H)**.



Cholangiocarcinoma

Jared Robbins, M.D.; Paul Knechtges, M.D.; Eric Paulson, Ph.D.; Allen Li, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Intrahepatic cholangiocarcinoma
Treatment prescribed	Liver stereotactic body radiation therapy

Imaging study

Scanner	MAGNETOM Verio 3T
Equipment required	• Two 6-channel Body Matrix coils • Spine array coil • Two adjustable coil bridges • Two Nylon straps • Flat table overlay • Headphones • Patient-specific immobilization device/s
Patient prep needed	• Change into gown and robe. • Place 22-gauge intravenous cannula into antecubital vein.
Setup and landmark	• Position flat table overlay over spine array. • Index patient-specific immobilization devices to flat table overlay. • Setup patient head-first supine, using external lasers to align and straighten, and confirm pelvic crest is above S9 on spine array coil. • Place RF coil bridges over abdomen and conform to patient surface anatomy. • Wrap two 6-channel Body Matrix coils circumferentially over RF coil bridges and secure with two Nylon straps. • Place headphones on patient. • Landmark over diaphragm.

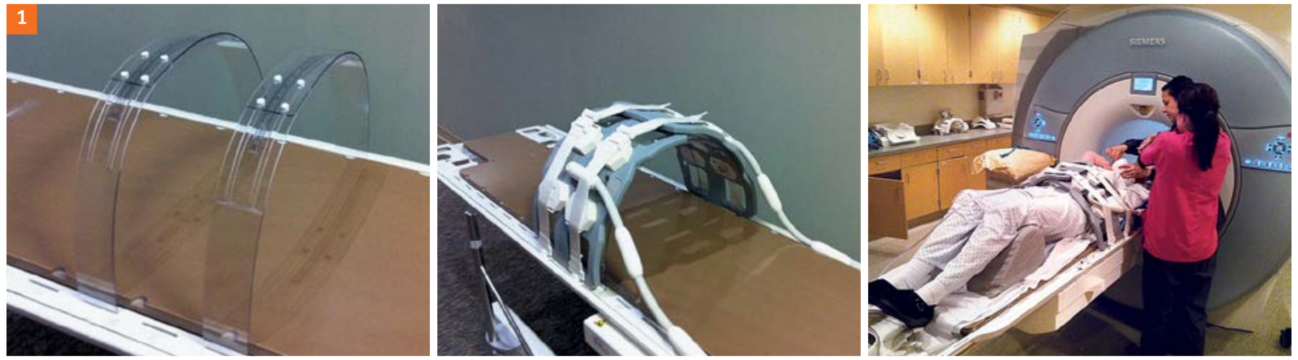


Figure 1:
Adjustable RF coil bridges and RF coil positioning.

Imaging protocol

Download the .edx file at siemens-healthineers.us/magnetom-flash

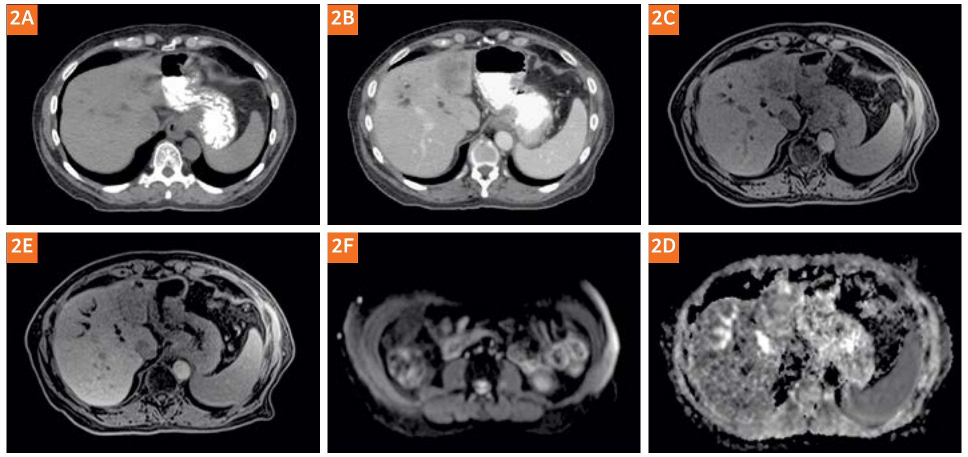
Sequence	Scan time	Utility for RT	Characteristics
Localizer – free breathing	0:30 min		
Localizer – breath-hold	0:17 min		
Ax BH T1 Dixon CAIPI pre	0:12 min	Reference for gross tumor volume delineation; organs at risk delineation	
Care Bolus			**Injection Rate** 2 cc/sec **Agent Vol** 10 mL (Gadoxetate disodium)
Ax PACE fat-suppressed T2 TSE	4:00 min	Localization of gross tumor volume	
Ax PACE DWI	5:00 min	Localization of gross tumor volume	
Ax BH T1 Dixon CAIPI 20 min delay	0:12 min	Localization of gross tumor volume	
Ax BH T1 Dixon CAIPI 30 min delay	0:12 min	Localization of gross tumor volume	

Special considerations

Acquisition	• Contrast injection performed using bolus tracking technique. • Administer 1 mg Glucagon IV (1/2 at start of exam, 1/2 midway through exam) to suppress peristalsis. • Respiratory gating and breath-holds performed at end expiration to match phase of gating window used for treatment delivery. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D distortion correction to all images. • Apply image standardization to non-DWI images. • Identify a reference MR image and perform local MR-MR rigid registration over gross tumor volume to correct for inter-sequence motion. • Perform local rigid registration over gross tumor volume to align reference MR image with planning CT images.

Example images

Figure 2:
Multiparametric images used for target and OAR localization and delineation. Planning CT **(2A)**, IV contrast CT **(2B)**, fat-suppressed T2 TSE **(2C)**, 30-minute delayed Dixon T1 + contrast medium **(2D)**, DWI b=500 s/mm^2 **(2E)**, ADC map **(2F)**.



Liver 1

Karim Boudam; Jean-Charles Côté; Marie-Pierre Campeau; Guila Delouya; David Donath; David Roberge

Centre hospitalier de l'Université de Montréal, Canada

Patient

Patient presentation	58-year-old man presenting with metastatic liver lesions from a primary colon cancer.
Treatment prescribed	Stereotactic Body Radiation Therapy (SBRT) 45 Gy in 3 fractions

Imaging study

Scanner	MAGNETOM Aera 1.5T
Equipment required	• Spine 32 surface coil • Body 18 surface coil • Wireless respiratory monitoring system
Patient prep needed	Immobilization device: Full-body vacuum cushion (BodyFIX, Elekta Instruments, Crawley, UK) + abdominal compression belt (Aktina Medical, Congers, NY, USA)
Setup and landmark	The patients are provided the compression belt and immobilized in treatment position using the vacuum cushion. The positioning on the couch is carried out using the Siemens MRI built in lasers.

Figure 1:
Patient immobilization setup.

Imaging protocol	All the sequences, except the 2D cine, are corrected for geometry distortion using the built in Siemens 3D correction algorithm.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:48 min		
T1 VIBE tra 3D	0:15 min	Positioning of the 2D cine slab	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm
2D cine without compression	1:00 min	Tumor motion assessment without compression	1.0 x 1.0 x 10 mm
2D cine with compression	1:00 min	Tumor motion assessment with compression	1.0 x 1.0 x 10 mm
T1 VIBE tra 3D pre-contrast sequence (Breath-held expiration)	0:15 min	Differentiation of hepatocytes from tumor (dark)	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm
T1 VIBE tra 3D pre-contrast sequence (Breath-held inspiration)	0:15 min	Differentiation of hepatocytes from tumor (dark)	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm
T2 FS TSE tra 2D (Triggered expiration)	5:00 min	Delineation of tumor (bright)	1.0 x 1.0 x 3.0 mm
T2 FS TSE tra 2D mBH	0:45 min	Optional sequence Delineation of tumor (bright)	2.0 x 2.0 x 3.0 mm
T1 VIBE tra 3D post-contrast: Gadobutrol – 30 seconds delay arterial phase (Breath-held expiration)	0:15 min	Delineation of hypervascular tumors (bright)	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm
T1 VIBE tra 3D post-contrast: Gadobutrol – venous phase (Breath-held inspiration)	0:15 min	Delineation of hypervascular tumors (bright)	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm
T1 VIBE tra 3D post-contrast: Gadobutrol – 5 min delay (Breath-held expiration)	0:15 min	Delineation of hypovascular tumors (dark)	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm
T1 VIBE tra 3D post-contrast: Gadobutrol – 5 min delay (Breath-held inspiration)	0:15 min	Delineation of hypovascular tumors (dark)	1.7 x 1.7 x 4.0 mm Resample: 1.7 x 1.7 x 2.0 mm

Sequences

The MR imaging workflow starts with a crude localization sequence followed by a 3D T1 VIBE sequence to identify the target area and thus fine tune the positioning of the 2D cine sequences. Tumor motion assessment is first done without compression then, multiple 2D cine sequences are acquired with increasing abdominal pressure. The belt pressure is chosen to obtain a clinically satisfying reduction in tumor motion within the limits of patient comfort.

Following this iterative evaluation of belt pressure, T1 and T2 sequences are acquired with the selected pressure. The T1 sequences are acquired in breath-hold at expiration and inspiration with and without contrast (30 seconds and 5 minutes post injection). The T2 sequence is obtained at expiration using the triggering module. A T2 multiple breath-hold sequence is also acquired if the tumor is not visible on the T1 inspiration images.

Special considerations

Preparing images for planning

Figure 2 describes the treatment planning registration workflow. A 4D CT scan is acquired in treatment position and the maximum expiration and inspiration phases are identified amongst the 10 binned phases. The MRI sequences are then anatomically registered using a manual 6D rigid transformation. The acquisition of sequences in expiration and inspiration allows us to minimize the differences between the CT and MR images.

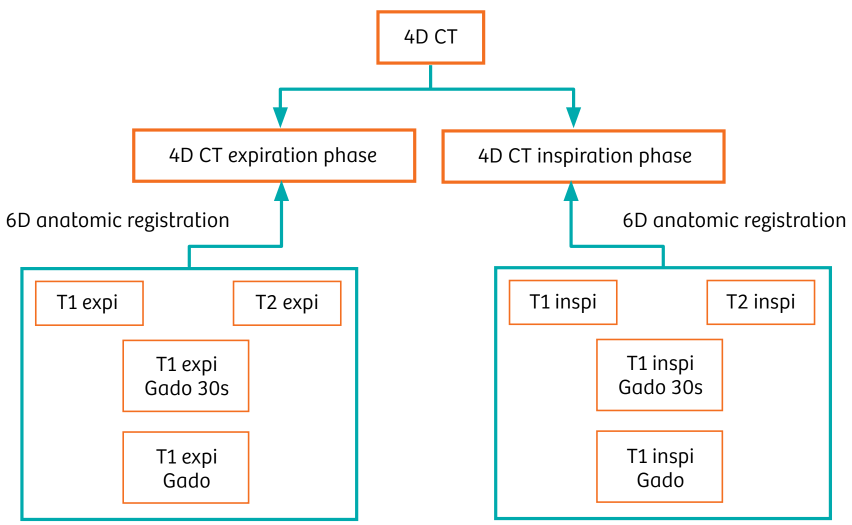


Figure 2:
Registration workflow between CT and MR images.

Example images

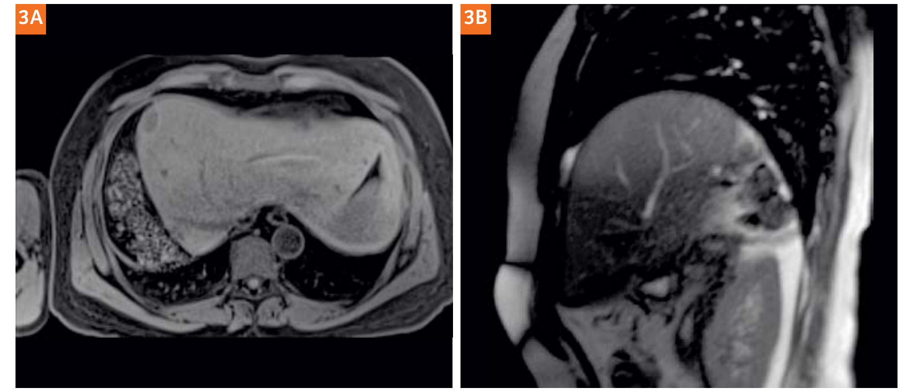


Figure 3:
T1w axial fs breath-hold sequence acquired in inspiration **(3A)**. 2D cine **(3B)**.

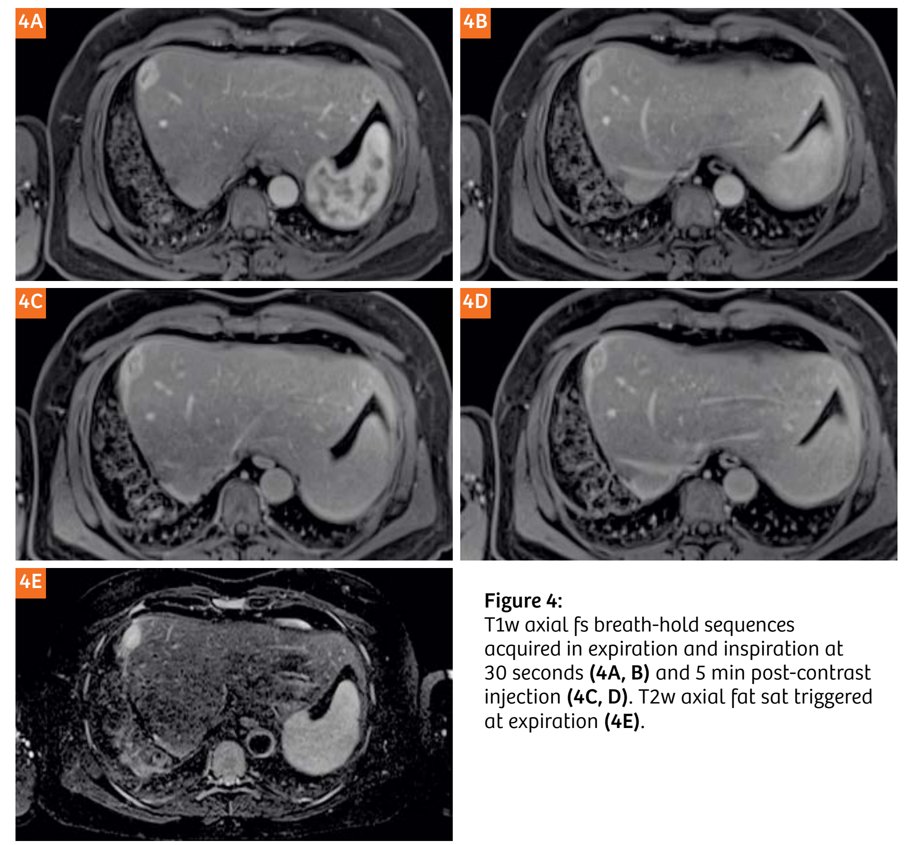


Figure 4:
T1w axial fs breath-hold sequences acquired in expiration and inspiration at 30 seconds **(4A, B)** and 5 min post-contrast injection **(4C, D)**. T2w axial fat sat triggered at expiration **(4E)**.

Liver 2

Leah Best; Jameen Arm; Nick Marks; Laura O'Connor; Narelle Grabham; Ben Ling; Melissa Lovell

Calvary Mater Hospital Newcastle, Newcastle, NSW, Australia

Patient

Patient presentation	60-year-old male, Hepatitis C positive with HCC in segment 6 of the liver. Previously treated twice with Trans Arterial Chemoembolization (TACE).
Treatment prescribed	Stereotactic Body Radiation Therapy (SRBT) – 50 Gy in 5 fractions to the PTV which is a 5 mm expansion on the Gross tumor volume. Treated on non-consecutive days. VMAT technique used.

Imaging study

Scanner	MAGNETOM Skyra 3T
Equipment required	• CIVCO flat table overlay* • Spine array 32-channel surface coil • Body 18-channel long surface coil • CIVCO Vac-Loc cushion – patient specific • Wing Board • Knee Rest • Contrast Injector
Patient preparation	• Fasting for 2 hours prior to CT scan, MRI after. • No carbonated beverages on the day of examination same as treatment. • 22-gauge cannula required – best placed in back of hand/wrist.

Setup and landmark	• Position flat table overlay on spine array coil.
	• Patient to be positioned head first supine.
	• Position patient specific Vac-Loc cushion on table.
	  • Consider positioning patient closer to the foot end of table to enable the emergency buzzer to reach when arms above head.
	  • Consideration should be made when making Vac-Loc cushion to enable it to fit in the bore of scanner without movement.
	  • Patients unable to use the Vac-loc cushion use wing board only.
	• Patient positioned as per positioning for CT simulation.
	• Patient aligned using rotation tattoos and external laser bridge.
	• Body matrix coil positioned over liver region and stabilized with Velcro straps.
	• Patient coached on breathing instruction for examination. All images taken on exhalation.

* The information shown herein refers to products of 3rd party manufacturers and thus are in their regulatory responsibility. Please contact the 3rd party manufacturer for further information.

Figure 1: Wingboard only setup, Vac-Loc cushion set up.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer_bh *expiration*	0:19 min	All scanning on expiration	
t1 vibe Dixon tra caipi pre	0:14 min	Base line for contrast	
t2 haste cor fs mbh	1:10 min	Organ contouring	
Care Bolus (Position trigger ROI on descending aorta 1 cm above diaphram)			**Injection Rate** 1 ml/s contrast media 1 ml/s Saline 10 ml 3 ml/s Saline 30 ml **Gad Vol** 0.1 mmol/kg (disodium gadoxetate)
t1 vibe dixon tra arterial	0:14 min	Tumor delineation	
t1 vibe dixon tra pv	0:14 min	Tumor delineation / Organ contouring	Gadobutrol 0.1 mmol/kg
t1 vibe dixon tra delayed	0:14 min	Tumor delineation	
t1 vibe dixon cor delayed	0:16 min	Tumor delineation	
localizer non bh *free breathing*	0:16 min	Tumor delineation	
t2 blade spair tra mbh	2:49 min	Tumor delineation / Organ contouring	
ep2d diff b50-800 *free breathing*	3:35 min	Tumor delineation	
t1 vibe dixon tra 15 min delayed	0:15 min	Delineation of non-functioning liver tissue	
t1 vibe dixon cor 15 min delayed	0:16 min	Delineation of non-functioning liver tissue	

Special considerations

Tips & tricks	• Vac-loc bag sits on wing board. If the Vac-loc bag is too wide to fit into the bore, wing board only used – position as normal using tattoos and external lasers. • Subtract images of the arterial phase, allows better delineation of tumor enhancement. Inline subtraction can be set up as part of routine Liver Dot Engine. • Contrast choice dependent on lesion type as determined by radiation oncologist. • T1 Post contrast imaging most useful for tumor contouring.
Preparing images for planning	• No specific changes made. Images exported as is to RT treatment planning software.
RTP requirements	• 3D distortion correction selected • Bandwidth selection shift < 1 hz/pixel

Example images

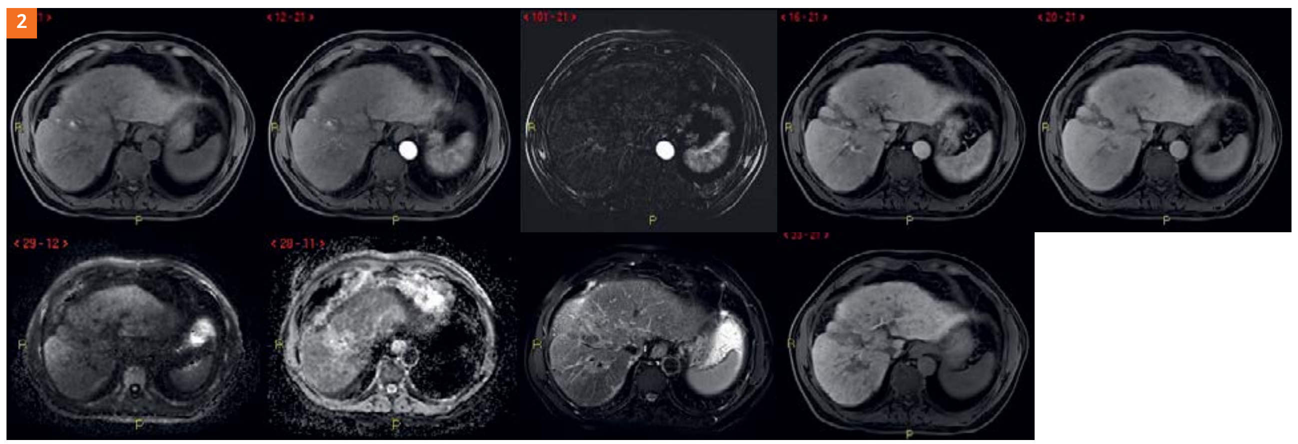


Figure 2:
T1 pre-contrast, T1 arterial phase, T1 arterial subtracted, T1 portal venous phase, T1 delayed, b-value 1400 s/mm², ADC, T2 BLADE SPAIR, T1 delayed 15 min. HCC lesion not well seen in these images post TACE. Post-contrast T1 imaging most useful for tumor delineation.

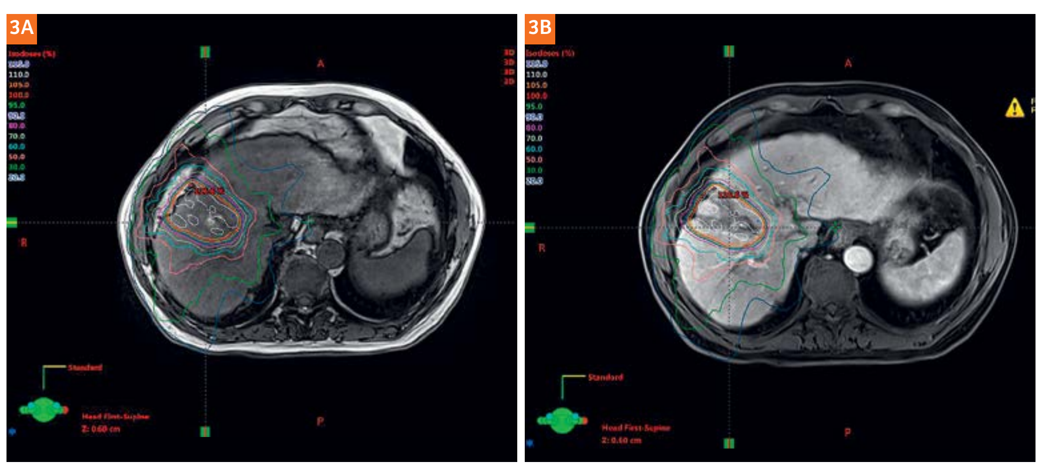
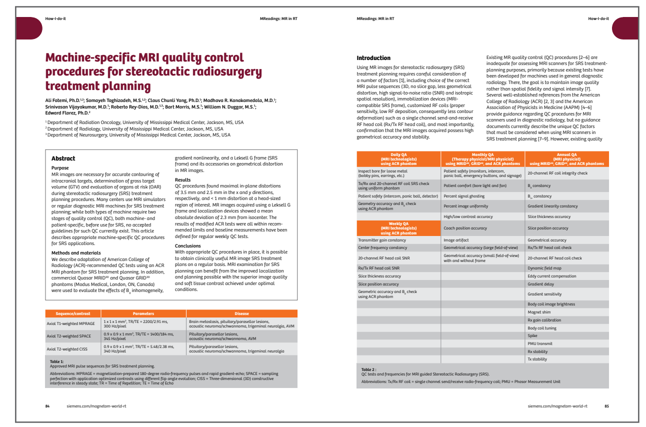


Figure 3:
Dose distribution superimposed on T1 post-contrast images.

Relevant clinical information at your fingertips

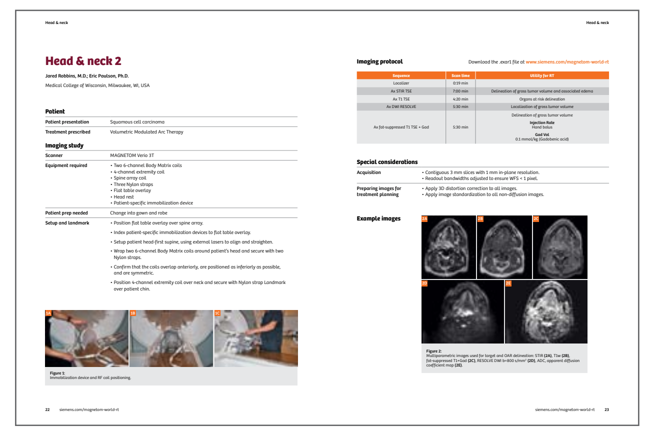
From technology to tips and tricks, you will find the news on all aspects of MRI in Radiation Therapy at:
siemens-healthineers.us/magnetom-flash



Just a mouse click away you will find application tips and How-I-do-it articles allowing you to optimize your daily work and exploit the full potential of your MAGNETOM system.

Machine-specific MRI quality control procedures for stereotactic radiosurgery treatment planning

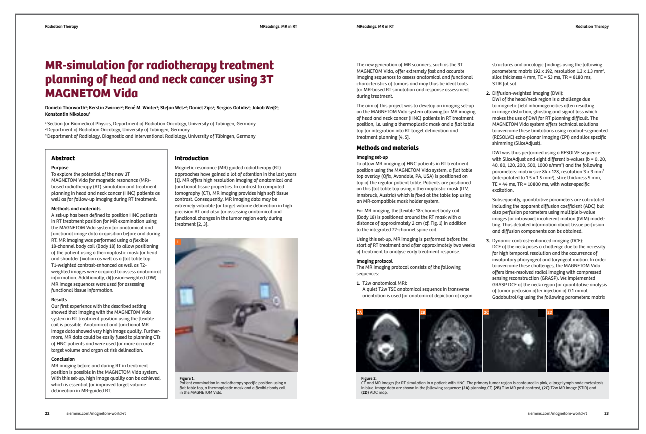
Ali Fatemi, Ph.D. et al.
Mississippi Medical Center, Jackson, MS, USA



The centerpiece of the MAGNETOM World Internet platform consists of our users' clinical results. Here renowned experts share their optimized MR protocols for various body regions.

Head & neck

Eric Paulson, Ph.D. et al.
Medical College of Wisconsin, Milwaukee, WI, USA



With the wealth of articles available at the MAGNETOM World we aim to increase peer-to-peer exchange of practices and to demonstrate how MAGNETOM users around the world are tackling the challenges posed by the introduction of MRI in the radiotherapy routine.

MR-simulation for radiotherapy treatment planning of head and neck cancer using 3T MAGNETOM Vida

Daniela Thorwarth, Ph.D. et al.
University of Tübingen, Germany

Prostate 1

Cynthia Ménard[1]; Jean-Charles Côté[1]; Guila Delouya[1]; Maroie Barkati[1]; Karim Boudam[1]; Carole Lambert[1]; Gary Liney[2]

[1] Centre hospitalier de l'Université de Montréal, Canada
[2] Liverpool and Macarthur Cancer Therapy Centre, Ingham Institute for Applied Medical Research, Sydney, Australia

Patient

Patient presentation 67-year-old man presenting with intermediate-risk prostate cancer, clinical stage T1c, Gleason VII (3+4) with 7/18 biopsies positive, PSA 5.46.

Treatment prescribed SBRT 36.25 Gy in 5 fractions, one fraction per week.

Imaging study

Scanner MAGNETOM Aera 1.5T

Equipment required
- Spine 32 surface coil
- Body 18 long surface coil
- Foot rest

Patient prep needed
- Fiducial markers (4 in-house 1 x 3mm platinum cylinders) are implanted under transrectal ultrasound (TRUS) guidance at least 7 days prior to treatment planning.
- Patients are instructed to empty their bladder before simulation. Bowel prep includes a fleet enema before imaging.
- Buscopan 20 mg IM at 1ml/min, 10 to 15 minutes before MRI (unless contraindicated).

Setup and landmark Patients are positioned supine directly on the spine coil with foot rest.

1

Figure 1:
Patient positioned on the spine coil with the Body 18 long surface coil on top, and with a foot rest.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:18 min		
T2 SPACE tra 3D	6:22 min	Prostate segmentation	1.0 x 1.0 x 1.0 mm
PD T2 TSE tra 2D	5:41 min	Marker-based registration and corresponding diagnostic T2w TSE image for tumor identification	0.8 x 0.8 x 3.0 mm
DWI tra b=50, 400, 800 s/mm^2, 2D	5:14 min	Tumor segmentation	1.8 x 1.8 x 4.0 mm ADC and calculated b-value of 1400
T1 SPACE cor 3D	5:12 min	Diagnostic image highlighting intraprostatic blood (assist tumor segmentation) as well as pelvic bones and lymph nodes	1.1 x 1.1 x 1.2 mm

- Table in ISO positioning mode
- 3D distortion correction applied for anatomical images (2D for diffusion)
- Bandwidth of at least 220 Hz/mm (1 mm fat-water separation at 1.5 Tesla)
- Include prostate, seminal vesicles and a part of bladder, rectum
- Save separately PD and T2 of PD T2 TSE TRA 2D
- Save an axial MPR of the T1 SPACE COR 3D

This imaging protocol strives to balance treatment planning requirements (segmentation and registration), while complying with PIRADS v2.0 to permit valid diagnostic reporting. For the purpose of PIRADS reporting, the T2 SPACE image can be reconstructed in sagittal and coronal planes.

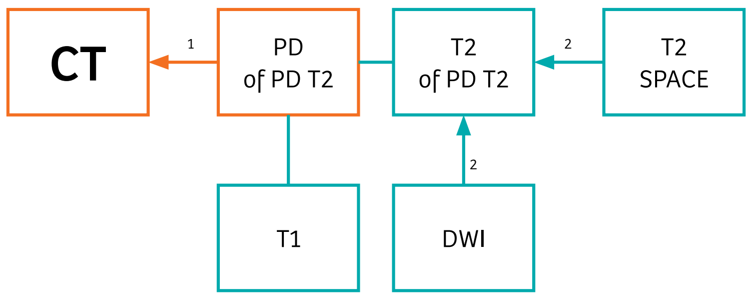
The examination is designed to keep each individual acquisition under 6 minutes to minimize motion related artifacts, and the overall examination under 30 minutes. The imaging range is the prostate gland, with the exception of the final T1-weigthed image, where the range is the entire pelvis.

A dual-echo (PD/T2) 2D acquisition is at the center of a rigid marker-based MRI-CT registration workflow. A volumetric T2w acquisition can be anatomically registered to the 2D T2w dataset if motion is observed between adjacent acquisitions. In that case, anatomic registration (T2 to T2) can be performed. The last two image sets can be used by clinicians to assist in tumor segmentation.

Special considerations

Preparing images for planning

- Send images from MR to PACS.
- Load images (MR and CT) from PACS on fusion console (MIM Vista, MIM Software Inc., Cleveland, OH, USA).
- Register MR to CT (see Figure 2).
- Send registered images to contouring server.
- Contour volumes on contouring client (Somavision Varian Medical Systems, Palo Alto, CA, USA).
- Send CT and contour from contouring server to planning console.



[1] Manual point-based registration (PD to CT) using 4 implanted markers (sup and inf) for a total of 8 points.

[2] If required (due to motion) anatomic automated registration prostate-to-prostate using mutual information algorithm.

Figure 2:
Workflow for registering MR images to planning CT.

Example images

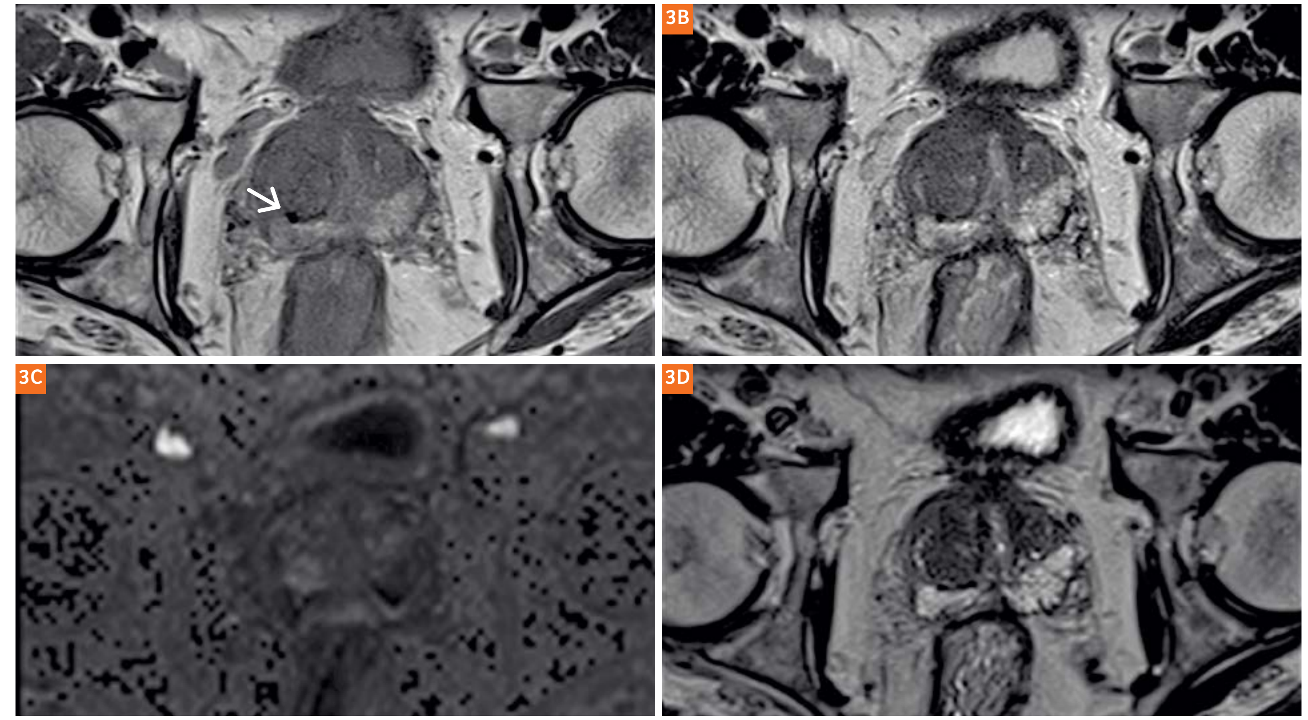


Figure 3:
Slice corresponding to implanted marker right mid-gland best visualized on PD image **(3A)**.

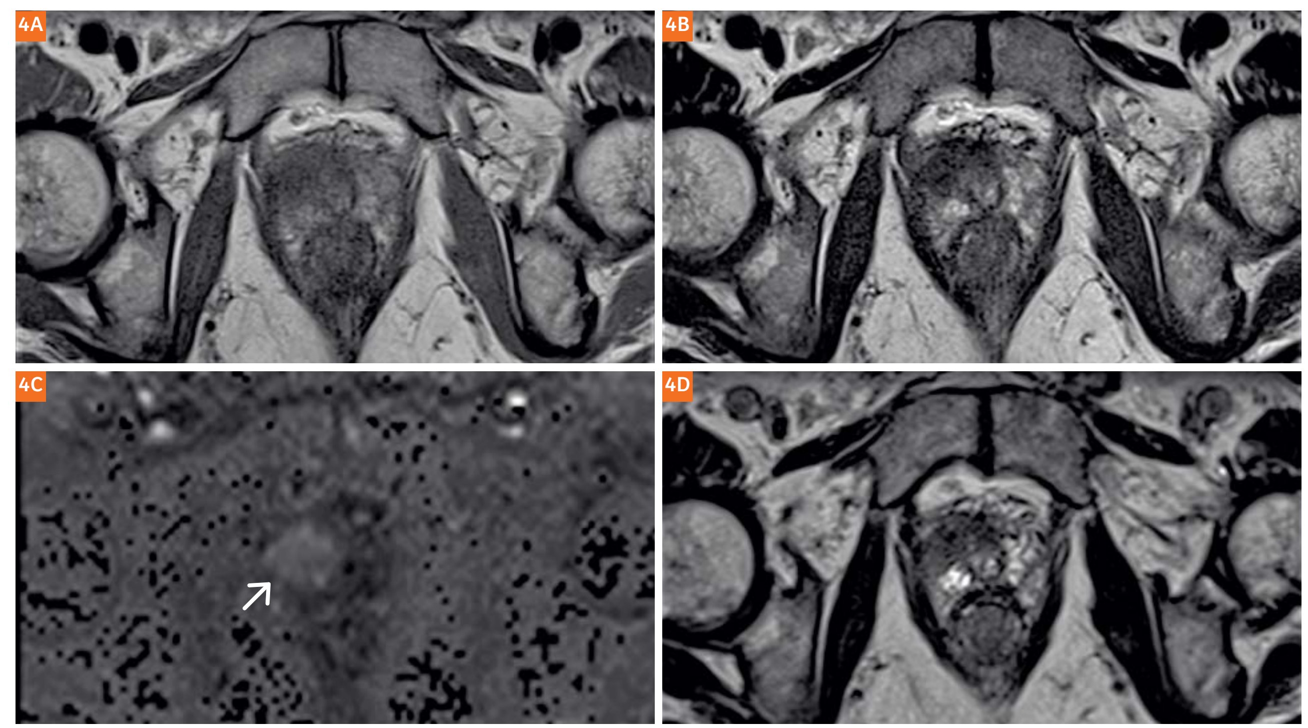


Figure 4:
Slice corresponding to tumor at right anterior apex best visualized on calculated b=1400 DWI **(4C)**.

Pelvis

Prostate 2

Maja Sohlin, Ph.D.; Christian Gustafsson, Ph.D.

Sahlgrenska University Hospital, Gothenburg, Sweden

Reproduced with permission from the "Method book for the use of MRI in radiotherapy" (Version 3) of the Swedish Vinova project.

Imaging study

Scanner	MAGNETOM Aera 1.5T
Equipment required	• Body 18 Long coil • Coil holders • Flat table overlay (Civco Medical Solutions, Kalona, IA, USA)* • Knee support on an in-house moveable rail
Setup and landmark	• If the patient comes in for the MRI after undergoing the CT scan and creating a CT treatment plan, then there will already be body markings that were applied to the patient's hip during the CT visit. The position of these body markings are determined by a laser with preset definitions that are the same as the preset definitions for CT and the treatment unit. By matching this laser system with these markings, the patient can be positioned the same way in each radiotherapy fraction and you get a reproducible position for the patient. This avoids rotation of the pelvis, thereby minimizing the prostate's position deviation between different radiotherapy fractions. • When the patient comes in to MRI it is advisable for the same positioning procedure to be used. There is therefore usually a laser system in the MRI room. If the laser system does not align with the body markings, you can rotate the patient's hip by taking hold of it and rotating. • Once this is done, it is advisable to ask the patient to lift their pelvis straight up in the air slightly and then lower it again. Then check that the laser aligns with the body markings as shown below:

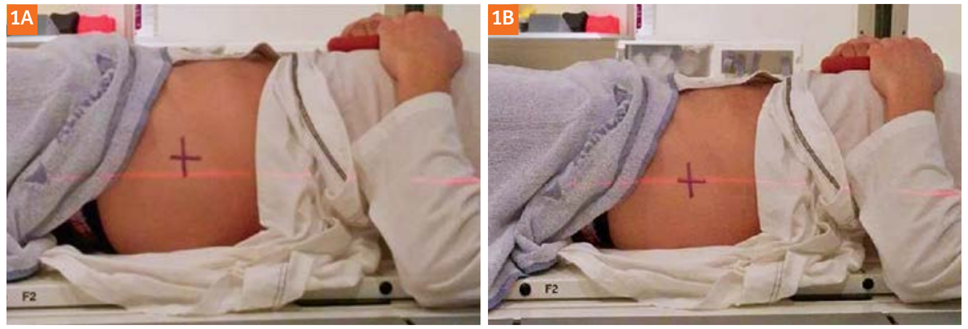


Figure 1:
(1A) Patient's position requires correction, **(1B)** patient's position is correct.

* The information shown herein refers to products of 3rd party manufacturers and thus are in their regulatory responsibility. Please contact the 3rd party manufacturer for further information.

• Because of the manual rotation performed with the hip, there is a risk of the buttocks will end up slightly asymmetrical. By asking the patient to lift their hips slightly, you avoid having the buttocks end up in different positions between the CT image and the MR image, which could make registration between these images more difficult. The separation between the buttocks can be used as a landmark to check whether any asymmetry has occurred in the position (see Figure 2).

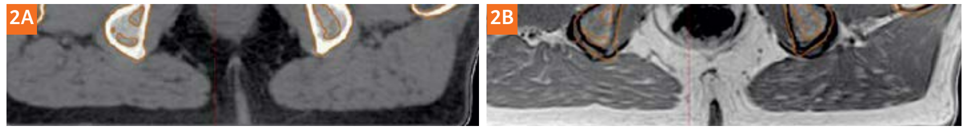


Figure 2:
Separation of the buttocks on **(2A)** CT image, and **(2B)** MR image.

• Coverage areas (cor, sag, tra) for a transverse T2-weighted series: cover the entire prostate, approx. 3–4 slices, from above the bladder base down to the penis root.

• Coverage areas (cor, sag, tra) for a transverse T1-weighted series: use a large FOV to visualize the skin contour for better quality control of the registration.

Figure 3:
Coil positioning with Body 18 Long coil. The coil holders prevent the coil from pressing on the skin contour. The knee support sits on a moveable rail created at the workshop. The knee support should be the same type as in CT to obtain the best reproducible patient positioning.

Imaging protocol

Sequence	Scan time	Utility for RT	Characteristics
Sag T2		Delineating of rectum and bladder	
Axial T2	6:17 min	Delineating of prostate and extracapsular disease (dark)	Potential post-biopsy hemorrhage, difficult to see the marker
Axial fat suppressed T2		Delineating of extracapsular disease (dark), lymph nodes (bright)	Potential post-biopsy hemorrhage
Axial T1	3:38 min	Detection of post-biopsy haemorrhaging (bright), visualization of markers	
Axial Diffusion ADC		Delineating of tumor (dark)	

Special considerations

- The use of contrast medium is governed by local procedures. The procedures for when the patient should drink and/or urinate are governed by local regulations, but the recommendation is to use the same method for CT, MRI and the radiotherapy treatment unit for each radiotherapy fraction.
- It is important to pay attention to what type of ink is used for the body markings as certain ink types have been shown to produce artifacts in the form of signal loss on the MR image. This is not acceptable when MRI is used for treatment planning, but in connection with matching the MR image to a CT image it is not as critical since only a small proportion of the skin has disappeared. After automatic matching, always check that the results are correct.
- For patients with MRI-compatible hip prostheses[1], the protocols can be adjusted so that metal artifacts are as small as possible. This is best done by applying any metal artefact reduction functions, such as WARP. If this is not available, a higher bandwidth and reduced echo time could limit the spread of metal artifacts. The artifacts are generally smaller on 1.5T compared to 3T. On CT, streak artifacts penetrate the prostate, while the prostate is intact on the MRI. Bear in mind that automatic matching with CT, if used, may be incorrect. Carefully check the matching manually.
- In order for a T2-weighted image series to be matched against CT data, you often rely on an image series where the gold markers are clearly visible and instead register these to the CT. This image series is often taken with some type of gradient echo-based imaging technique to show the position of the gold seeds in the prostate more clearly. We call this image series the differentiation series. The registration between the T2-weighted image series and the CT data then follows automatically since the T2-weighted image series and the differentiation series are taken in the same frame of reference. A disadvantage of this approach is that there is a risk that the patient and/or the patient's anatomy has moved between the image capture of the T2-weighted image series and the image capture of the differentiation series. This can be addressed by directly visualizing the gold markers in the T2-weighted image series. It may be challenging to visualize the gold markers directly on the T2-weighted image series because the gold markers themselves are small, and the T2-weighted image series is often based on the turbo spine echo technique (TSE), which automatically minimizes and to some degree compensates the susceptibility artifacts from the gold markers. In TSE sequences, there is also smearing in the image as a result of the repeated 180° pulses it uses. On a MAGNETOM Aera 1.5T system, the following adjustments have been shown to visualize the gold seeds directly on the T2-weighted image series:

[1] The MRI restrictions (if any) of the metal implant must be considered prior to patient undergoing MRI exam. MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens Healthcare.

- Increase the spatial resolution of the image. Approx. 0.7 x 0.7 mm, depending on the size of the gold markers used.
- Reduce the slice thickness to reduce partial volume artifacts. Approx. 2.5 mm.
- Reduce echo train smearing by reducing the echo train length in the TSE sequence.
- Restrict the number of NEX to just 1 to reduce the smearing caused by averaging.
- Eliminate imaging acceleration to increase SNR.
- Restrict imaging to 1 package.
- Use movement correction, if available.
- These measures often lead to a reduction in SNR and thereby an increase in scan time to obtain acceptable image quality.

Figure 3:
(3A) T1 VIBE tra 2 mm (3:38 min), **(3B)** T2 TSE tra 2 mm (6:17 min).

Prostate 3

Colleen Lawton, M.D.; Eric Paulson, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Prostate adenocarcinoma
Treatment prescribed	Volumetric modulated arc therapy

Imaging study

Scanner	MAGNETOM 3T Verio
Equipment required	• Two 6-channel Body Matrix coils • Spine array coil • Two adjustable coil bridges • Two Nylon straps • Flat table overlay • Patient-specific immobilization device(s)
Patient prep needed	• Change into gown and robe. • Bladder filling protocol.
Setup and landmark	• Position flat table overlay over spine array. • Index patient-specific immobilization devices to flat table overlay. • Setup patient head-first supine, using external lasers to align and straighten, and confirm pelvic crest is above S9 on spine array coil. • Place RF coil bridges over pelvis and conform to patient surface anatomy. • Wrap two 6-channel Body Matrix coils circumferentially over RF coil bridges and secure with two Nylon straps. • Landmark over diaphragm.

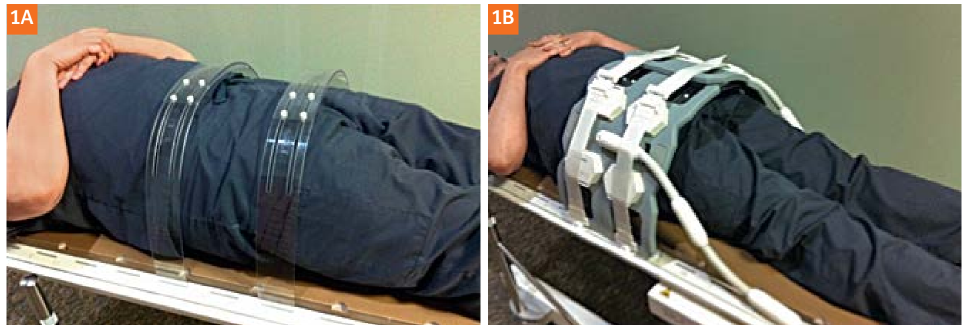


Figure 1:
Adjustable RF coil bridges and RF coil positioning.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:30 min		
Sag Restore T2 TSE	3:00 min	Delineation of gland and rectum / gland interface	
Ax Restore T2 TSE	5:00 min	Delineation of gland	
Cor Restore T2 TSE	3:00 min	Delineation of gland and localization of urethra	
Ax DWI	5:00 min	Localization of gross tumor volume	Acquired b-values: 200, 600, 1000 s/mm²; calculated b-value: 1400 s/mm²

Special considerations

Acquisition	• Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D distortion correction to all images. • Apply image standardization to non-DWI images. • Perform local rigid registration over prostate gland to align reference MR image with planning CT images.

Example images

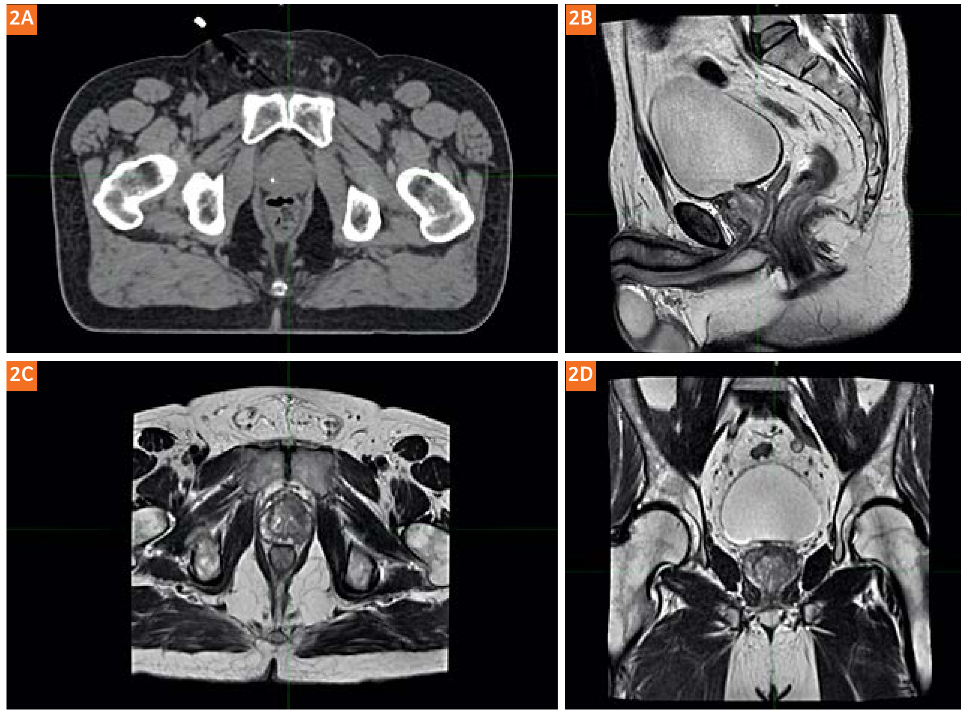


Figure 2:
Multiparametric images used for target and OAR localization and delineation.

Planning CT **(2A)**, sagittal T2 TSE **(2B)**, axial T2 TSE **(2C)**, and coronal T2 TSE **(2D)**.

Prostate 4

Leah Best; Jameen Arm; Nick Marks; Laura O'Connor; Narelle Grabham; Ben Ling; Melissa Lovell

Calvary Mater Hospital Newcastle, Newcastle, NSW, Australia

Patient

Patient presentation	80-year-old male presenting with prostate cancer.
Treatment prescribed	39-day treatment – VMAT (volumetric moderated arc therapy) glandular prostate 78 Gy, prostate with 7 mm margin 74.1 Gy, seminal vesicles with 8 mm margin 65 Gy, pelvis lymph nodes 55 Gy simultaneous integrated boost

Imaging study

Scanner	MAGNETOM Skyra 3T system
Equipment required	• Spine array 32-channel surface coil • Body matrix 18-channel long surface coil • Knee rest • Foot rest • Plastic ring
Immobilization	• Patient lays on table with knees over knee rest and feet in foot rest. • Patient holds plastic ring on chest.
Patient prep needed:	• Low fibre diet • Empty bladder 30 minutes prior to appointment time, drink 1 glass of water (250 ml) and do not empty bladder until examination complete.
Setup and landmark	• Patient can either be positioned feet first or head first. • We position the patient feet first for comfort. • Ensure patient is aligned so prostate is central to a spinal coil element. • Body matrix coil centered over prostate. • Centre over prostate. Prostate to isocentre.

Figure 1: Patient positioning for routine RT prostate planning.

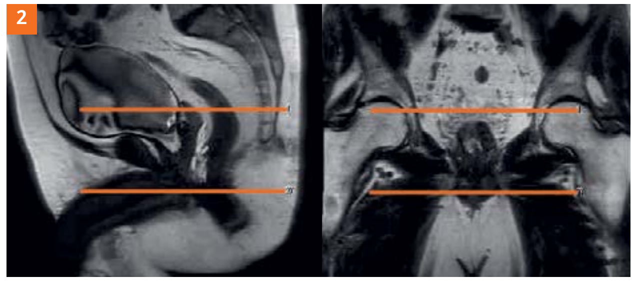


Figure 2: Coverage for T2 TSE tra and T1 FLASH tra.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:17 min		
Haste Localizer	0:29 min	Positioning and review bladder size, rectal filling	
T2 tse tra 2D	4:35 min	Prostate anatomy and tumor delineation. Organ contouring.	
T1 FLASH tra 2D	3:06 min	Gold seed identification	T1 useful to see blood products
Options			
T2 BLADE sag	3:23 min	Review Rectafix postion	To review depression of Rectafix rod
Diffusion	3:46 min	Assess aggressiveness of tumor	Use high b-value (> 1500 s/mm²)

Special considerations

Tips & tricks	• Use high flip angle (80°) for T1 FLASH to delineate blood products. • T1 FLASH is used to delineate the gold seeds in the prostate for IGRT. • Assess bladder filling and rectal gas on haste localizer. May require additional prep as per radiation therapists. • Rectafix (Scanflex Medical AB, Täby, Sweden) is a rectal positioning device used for SBRT prostate treatments to depress the rectum away from the prostate for treatment. • CIVCO flat table overlay used for patients with Rectafix rod*.
Preparing images for planning	• No specific changes made. Images exported as is to RT treatment planning software.
RTP requirements	• Patients scanned feet first images flipped to match planning CT at planning stage. • Patient positioned as per positioning for CT simulation. • Patient aligned using rotation tattoos and external laser bridge.

Example images

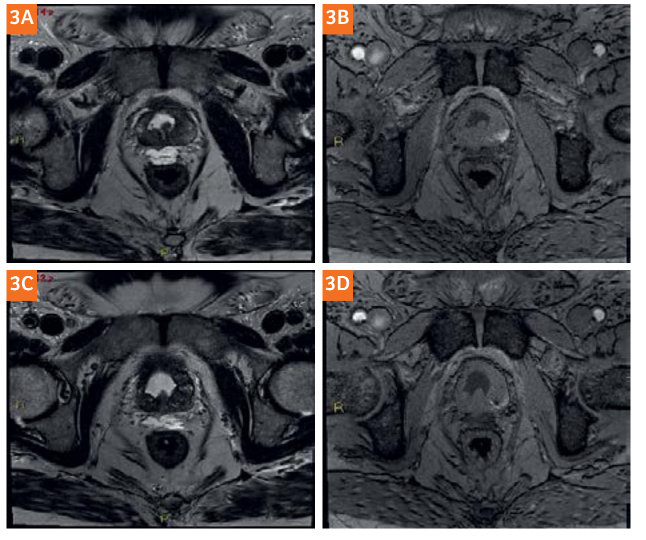


Figure 3:
(3A) T2 transverse lesion, **(3B)** T1 gradient lesion, lesion seen in the right peripheral zone. T2 seed, T1 gradient seed. **(3D)** Arrow shows gold seed surrounded by increased signal intensity associated with blood products.

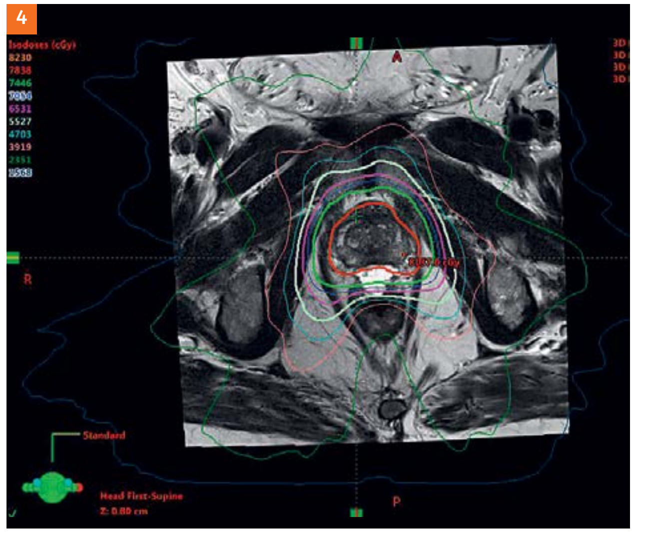


Figure 4:
Final dose distribution.

* The information shown herein refers to products of 3rd party manufacturers and thus are in their regulatory responsibility. Please contact the 3rd party manufacturer for further information.

Cervix

Beth Erickson M.D.; Colette Gage, BS RTT(MR); Allen Li, Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Cervix cancer
Treatment prescribed	3D conformal radiotherapy

Imaging study

Scanner	MAGNETOM 3T Verio
Equipment required	• Two 6-channel body matrix coils • Spine array coil • Two Adjustable coil bridges • Two Nylon straps • Flat table overlay • Patient-specific immobilization device(s) • Ultrasound gel • 60 cc syringe
Patient prep needed	• Change into gown and robe. • Have patient empty bladder. • Place 22 gauge intravenous cannula into antecubital vein.
Setup and landmark	• Position flat table overlay over spine array. • Index patient-specific immobilization devices to flat table overlay. • Setup patient head-first supine, using external lasers to align and straighten, and confirm pelvic crest is above S9 on spine array coil. • Place RF coil bridges over pelvis and conform to patient surface anatomy. • Wrap two 6-channel body matrix coils circumferentially over RF coil bridges and secure with two Nylon straps. • Landmark over diaphragm.

Imaging protocol

Download the .edx file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:30 min		
Sag Driven Equilibrium T2 TSE	3:00 min	Delineation of gross tumor volume	
Ax Driven Equilibrium T2 TSE	5:00 min	Delineation of gross tumor volume	
Ax DWI	5:00 min	Localization of gross tumor volume	Acquired b-values: 200, 600, 1000 s/mm^2; calculated b-value: 1400 s/mm^2
Ax Fat-Suppressed T1 TSE + Gad	5:30 min	Delineation of gross tumor volume	**Injection Rate** Hand bolus **Gad Vol** 0.1 mmol/kg (Multihance)

Special considerations

Acquisition	• Inject vaginal gel at start of exam. • Administer 1 mg Glucagon IV (1/2 at start of exam, 1/2 midway through exam) to suppress peristalsis. • Contrast injection performed using bolus tracking technique. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D Distortion Correction to all images. • Apply image standardization to non-DWI images. • Perform local rigid registration over cervix to align with planning CT images.

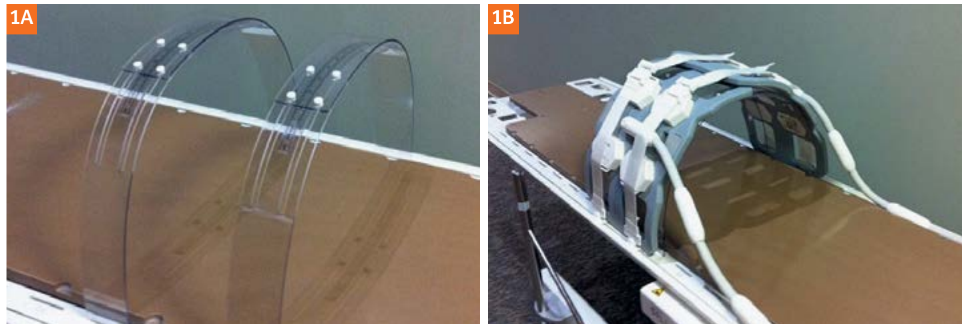


Figure 1:
Adjustable RF coil bridges and RF coil positioning.

Cervix – Brachytherapy

Beth Erickson M.D.; Jason Rownd MS; Eric Paulson Ph.D.

Medical College of Wisconsin, Milwaukee, WI, USA

Patient

Patient presentation	Cervix cancer
Treatment prescribed	High dose rate brachytherapy boost

Imaging study

Scanner	MAGNETOM 3T Verio
Equipment required	• Two 6-channel Body Matrix coils • Spine array coil • Two adjustable coil bridges • Two Nylon straps • Flat table overlay • MR-compatible physiological monitoring equipment
Patient prep needed	• Brachytherapy preparation (including anesthesia)
Setup and landmark	• Position flat table overlay over spine array. • Transfer patient from brachytherapy suite to MR table, setting up patient foot-first supine and confirm pelvic crest is below S9 on spine array coil. • Attached physiological monitoring devices. • Place RF coil bridges over pelvis and conform to patient surface anatomy. • Wrap two 6-channel Body Matrix coils circumferentially over RF coil bridges and secure with two Nylon straps. • Landmark over diaphragm.

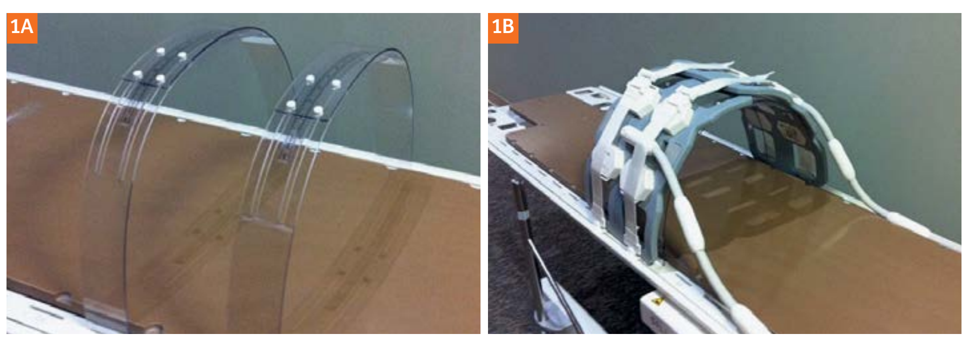


Figure 1:
Adjustable RF coil bridges and RF coil positioning.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:30 min		
3PL T2 HASTE	0:59 min	Confirmation of applicator positioning and absence of perforation	Aligned to applicator in three planes
Ax 3D T2 SPACE	12:00 min	Planning MR image, delineation of targets and OAR	1 x 1 x 1.5 mm³ voxels
Ax T2 TSE	4:00 min	Delineation of gross tumor volume and high risk clinical target volume	Para-axial, parallel to ring
Sag T2 TSE	3:00 min	Delineation of gross tumor volume and high risk clinical target volume	Para-sagittal, parallel to tandem
Cor T2 TSE	3:00 min	Delineation of gross tumor volume and high risk clinical target volume	Para-coronal, parallel to tandem

Special considerations

Acquisition	• Administer 1 mg Glucagon IV (1/2 at start of exam, 1/2 midway through exam) to suppress peristalsis. • Readout bandwidths adjusted to ensure WFS < 1 pixel.
Preparing images for treatment planning	• Apply 3D distortion correction to all images. • Apply image standardization to all images.

Example images

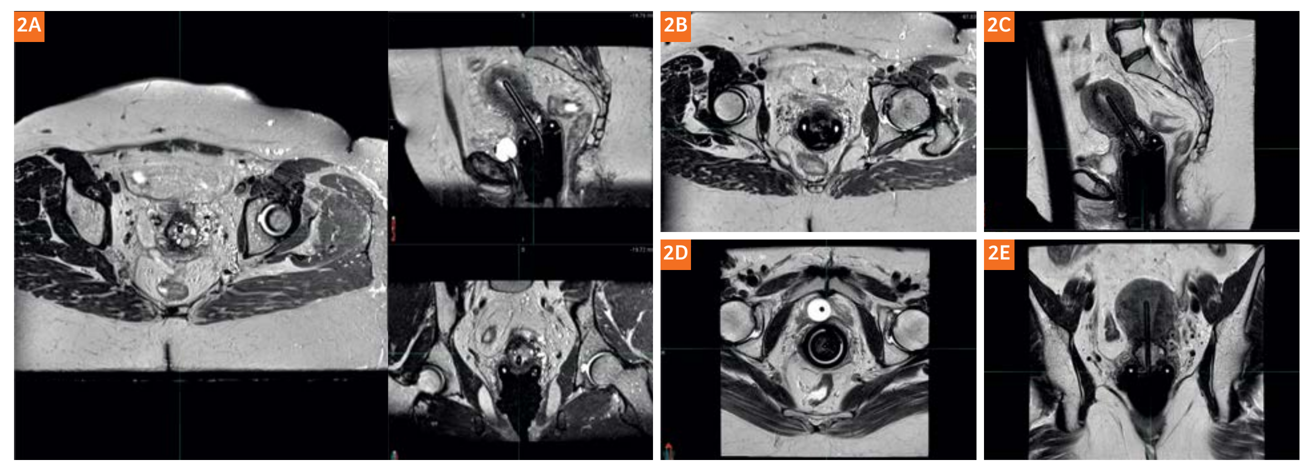


Figure 2:
Multiparametric images used for target and OAR localization and delineation. **2A**: Axial 3D T2 SPACE planning MR images displayed with sagittal and coronal reformats. A saline filled dummy catheter, inserted into the tandem lumen, is visible on the sagittal image. Registered 3D T2 SPACE **(2B)**, para-sagittal 2D T2 TSE **(2C)**, para-axial 2D T2 TSE **(2D)**, and para-coronal 2D T2 TSE **(2E)** images. A saline filled dummy catheter, inserted into the ring lumen, is visible on the para-axial images. The saline filled dummy catheters assist in aligning applicator templates during brachytherapy treatment planning.

Cervix – Brachytherapy

Maja Sohlin; Karin Petruson; Karin Bergmark; Mona Riström Waite

Sahlgrenska University Hospital, Gothenburg, Sweden

Patient

Patient presentation	Cervical cancer
Treatment prescribed	MRI-guided high dose rate brachytherapy

Imaging study

Scanner	MAGNETOM Aera 1.5T
Equipment required	• Body 18 Long coil • Spine array coil • Knee support • Velcro straps • Sand bags • MR-compatible physiological monitoring equipment
Patient prep needed	• Brachytherapy preparation (including anesthesia) • Insertion of MR marker into applicator ring and tandem • Clamp urinary catheter right before MRI
Setup and landmark	• Prepare table without flat table overlay and with mattress. • Undock table and remove outside examination room for patient transfer. • Transfer patient from brachytherapy suite to MR table, setting up patient head-first supine using pillow and customized knee support. • Attach physiological monitoring devices. • Dock table and place the 18-channel Body Matrix coil over the patient's pelvis without using RF coil bridges and attach coil firmly using velcro straps. • Support outer side of patient's feet using sand bags. • Landmark over pubic symphysis.

Figure 1:
Patient setup using Body 18 Long coil and knee support.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:08 min		
Localizer ISO positioning	0:44 min	Positioning of applicator ring in magnet iso-center	The transversal stack is planned with its center in the ring plane
T2 TSE sag	3:06 min	Planning MR image, delineation of targets and OAR	0.9 x 0.9 x 3 mm^3 voxels Parallel to tandem if visible in localizer_ISOpos
T2 TSE para-cor	3:25 min	Planning MR image, delineation of targets and OAR	Para-coronal, parallel to tandem 0.9 x 0.9 x 3 mm^3 voxels
T2 TSE para-tra	5:07 min	Delineation of targets and OAR	Para-axial, parallel to ring 0.9 x 0.9 x 3 mm^3 voxels
T2 SPACE para-tra	7:35 min	Reconstruction of applicator and needles	Para-axial, parallel to ring 0.9 x 0.9 x 1 mm^3 voxels

Special considerations

Coverage

• t2_tse_sag: Obturator muscle
• t2_tse_para-cor: Uterus – Cervix – Vagina – Tumor
• t2_tse_para-tra: Above uterus – 3 cm below applicator/full vagina

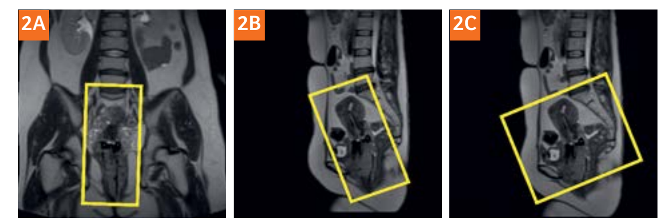


Figure 2:
Coverage areas.

Preparing images for planning	Apply 3D distortion correction (automatic)
RTP requirements	• Readout bandwidths adjusted to ensure WFS < 1 pixel. • 0 mm inter-slice gap for 2D acquisitions to eliminate interpolation in the RTP system.

Example images

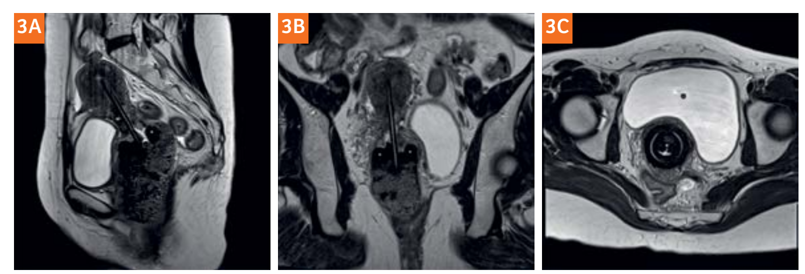
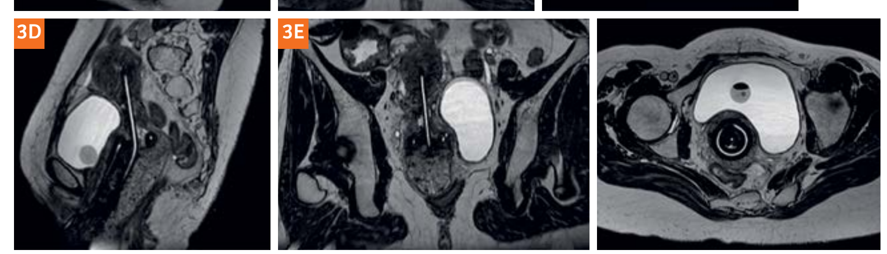


Figure 2:
(3A) Sagittal 2D T2 TSE
(3B) Para-coronal 2D T2 TSE
(3C) Para-transversal 2D T2 TSE



(3D) Para-sagittal reformat of transversal 3D T2 SPACE
(3E) Para-coronal reformat of 3D T2 SPACE
(3F) Para-transversal reformat of 3D T2 SPACE

Rectum

Cynthia Eccles; Helen McNair; Trina Herbert; Shree Bhide

The Royal Marsden NHS Foundation Trust, Sutton, UK

Patient

Patient presentation	Increased bowel frequency, redness in stool, transient episodes of fatigue and mild rectal discomfort; biopsy confirmed moderately differentiated carcinoma 7 cm from anal verge from approximately 10 o'clock to 12 o'clock; Diagnosis T3C
Treatment prescribed	Radical RT 52.5 Gy/25 simultaneous integrated boost; 6 MV VMAT

Imaging study

Scanner	MAGNETOM Aera 1.5T
Equipment required	• Body 18 1.5T Tim coil • In-house (custom) coil bridge • In-house (custom) flat table top • Combifix™ with knee pad • Head rest • Beekley Dots on anterior and lateral tattoos
Patient prep needed	• 700 ml water drunk after emptying 1 hour prior to RT. • 700 ml water drunk after emptying 30 minutes prior to MRI. • Change into hospital gown, underwear removed.
Setup and landmark	• Index immobilization equipment according to patient treatment setup. • Setup patient head-first supine . • Use external lasers to align and straighten with reference to RT planning tattoos. • Place coil and bridge over pelvis area, ensuring patient contour preserved. • Give patient ear plugs and headphones. • Landmark at level of tattoos.

Figure 1:
Hard table top.

Figure 2:
Combifix™ and head rest.

Figure 3:
Coil in bridge.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Sequence	Scan time	Utility for RT	Characteristics
Localizer		Planning of sequences	
mDixon[1]	4:48 min	Research – for workup of synthetic CT and delineation of normal tissues including nodes	Include external contour; cover from L3 to mid-femur
T2 SPACE	14:00 min	Target delineation; OAR delineation	
T2 TSE	12:57 min	Nodal delineation	

Example images

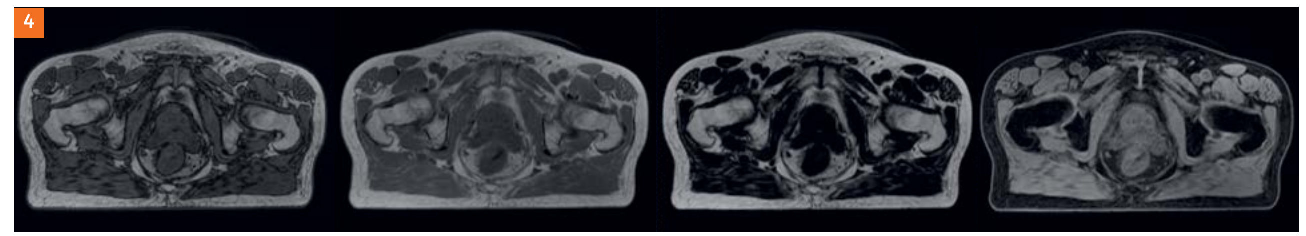


Figure 4:
mDixon[1].

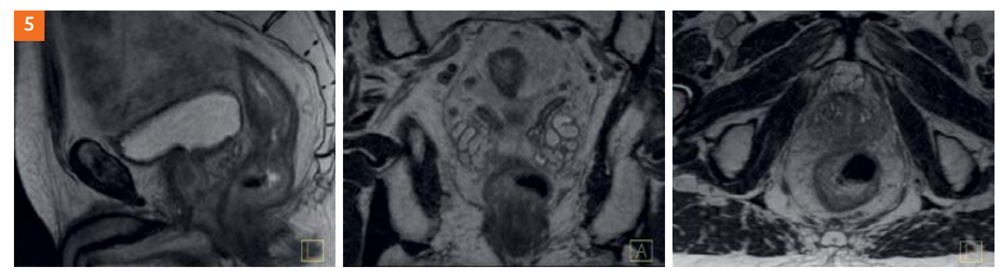


Figure 5:
T2 SPACE, acquired axially.

Figure 6:
T2 TSE.

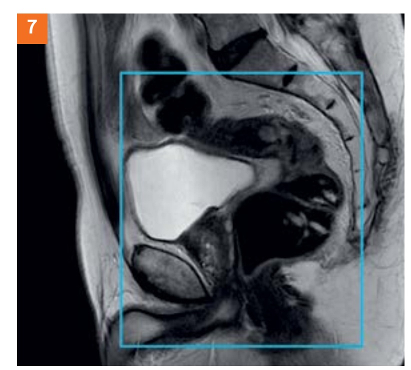


Figure 7:
Patient image showing the coverage.

[1] WIP, the product is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.

Musculoskeletal

Robba Rai; Gary Liney

Liverpool and Macarthur Cancer Therapy Centre, Ingham Institute for Applied Medical Research, Sydney, Australia

Overview

Coil and protocol selection will vary depending on the anatomical site of interest and patient positioning. For areas greater than 30 cm in scan length, TimCT should be considered to maintain geometrical integrity of scans for accurate CT-MRI rigid registration in radiotherapy treatment planning system.

Patient

Patient presentation	Any peripheral primary or secondary lesions • Sarcoma • Osteosarcoma • Metastatic disease
Treatment prescribed	Dependent on location and disease extent

Imaging study

Scanner	MAGNETOM Skyra 3T
Equipment required	• Flex 4 Large and Small (Site dependent) • Body 18 surface coil (Site dependent) • Flat table overlay (CIVCO)* • Velcro straps • Patient-specific immobilization device/s
Patient prep needed	22-gauge intravenous cannula required prior to imaging if gadolinium is requested.
Setup and landmark	• Index patient-specific immobilization devices to flat table overlay. • Patient to be positioned as per CT Simulation. • Straighten the patient's anatomy of interest using the rotation tattoos with the external laser system. • Depending on the region of interest.

Figure 1:
MR Sim setup using vacuum bag for immobilisation over tricep Sarcoma. 18-channel surface coil used over centre over affected arm. Patient was offset to position arm in the isocentre of the MRI scanner.

* The information shown herein refers to products of 3rd party manufacturers and thus are in their regulatory responsibility. Please contact the 3rd party manufacturer for further information.

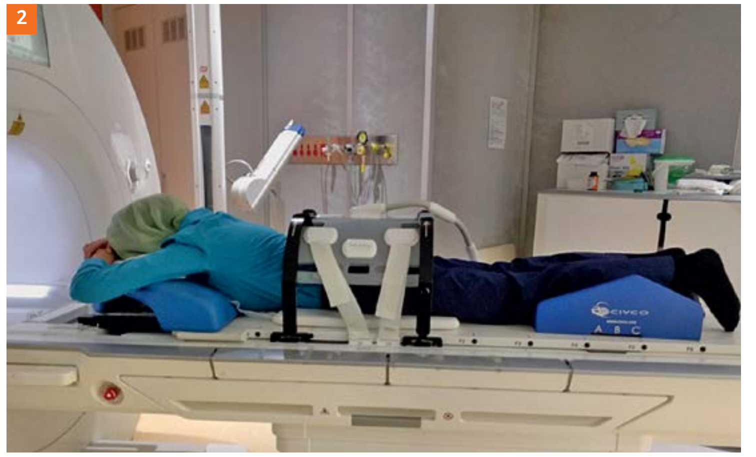


Figure 2:
MR Sim setup in prone position for gluteal sarcoma. 18-channel surface coil used over centre of affected area.

Figure 3:
MR Sim setup for TimCT of femur using a combination of coils including 18-channel surface coils and two 4-channel flex coils.

Imaging protocol

Download the .exar1 file at siemens-healthineers.us/magnetom-flash

Small region of interest

Sequence	Scan time	Utility for RT	Characteristics
Localizer	0:09 min		
T1 TSE	2:04 min	Bone registration to CT	
T2 TSE Dixon	2:40 min	Delineation of gross tumor volume, nodes and associated edema	
T1 TSE Dixon + Gad	2:40 min	Delineation of gross tumor volume	**Injection Rate** Hand bolus **Gad Vol** 0.1 mmol/kg (Gadobutrol) **Saline Flush** 10 ml before and after Gad

Long bones and larger regions of interest (TimCT)

Sequence	Scan time	Utility for RT
Localizer	0:09 min	
T1 FLASH TimCT	4:48 min	Bone registration to CT
T2 HASTE FS TimCT	6:43 min	Delineation of gross tumor volume and nodes
T2 HASTE TimCT	6:43 min	Delineation of gross tumor volume and associated edema

Special considerations

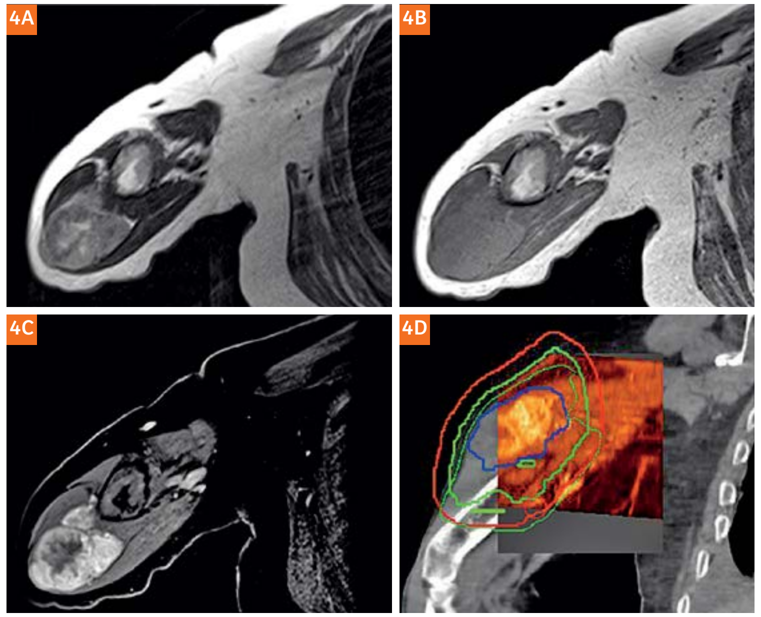
Tips and tricks

- Use MRI markers over reference tattoos to help with CT-MRI registration in radiotherapy treatment planning system.
- Use immobilisation methods such as sponges and tape to ensure patient does not move during image acquisition.
- Run two localizers for upper extremities e.g. arm with the second localizer offset to the affected side. Acquire second localizer in ISO positioning mode.
- If possible, MR staff to be present at CT Sim to assist with positioning and provide advice on immobilisation to ensure compatibility with MRI.
- Use Dixon where applicable for robust fat suppression particularly for upper extremities.
- For areas longer than 30 cm, such as long bones, consider TimCT to maintain geometrical integrity of anatomy.

RTP requirements

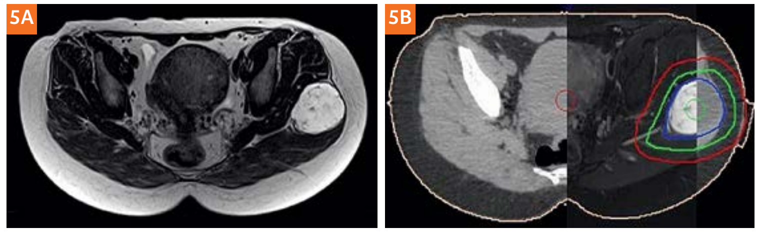
- Use 3D distortion correction where applicable. If unavailable use 2D.
- Maintain a receiver bandwidth with a ≤ 1 pixel fat-water shift (≥ 400 Hz/Px at 3T).
- 0 mm interslice gap to eliminate interpolation in radiotherapy treatment planning (RTP) system.
- All sequences should have the same centre slice to maintain consistency with CT-MRI rigid registration in RTP system.
- 2–3 mm slice thickness will vary on anatomical site of interest. Ensure that the slices encompass entire extremity in an ideal acquisition time to maintain image quality.

Example images



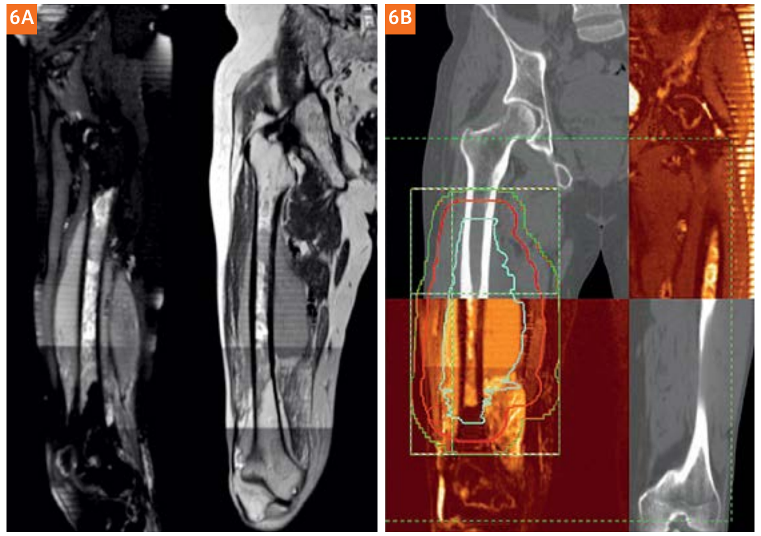
Tricep Sarcoma

Figure 4:
T2 Dixon in-phase **(4A)**, T1 Dixon in-phase **(4A)**, T2 Dixon water **(4C)**, co-registration of post-contrast T1 Dixon water (thermal window) with planning CT, showing agreement between two scans and good registration of tumor volume.



Gluteal Sarcoma

Figure 5:
T2 Dixon in-phase **(5A)**, co-registration of planning CT and T2 Dixon water sensitive planning MRI, showing robust fat suppression over a large field of view and excellent registration of bony and soft tissue anatomy **(5B)**.



Metastatic disease in femur using TimCT for a 60 cm scan length

Figure 6:
Reconstructed T2 HASTE with SPAIR showing hyperintense metastic disease in bone marrow of femoral shaft **(6A)**, coronal reconstructed T1 FLASH used for bone registration to planning CT **(6B)**, accurate co-registration of planning CT with T2 HASTE planning MRI.

Thank you!

The entire staff at Centre hospitalier de l'Université de Montréal, Canada and at Siemens Healthineers extends their appreciation to all the radiation oncologists, technologists, physicists, experts and scholars who donate their time and energy – without payment – in order to share their expertise.

At Siemens Healthineers, our purpose is to enable healthcare providers to increase value by empowering them on their journey towards expanding precision medicine, transforming care delivery, and improving patient experience, all enabled by digitalizing healthcare.

An estimated 5 million patients globally benefit every day from our innovative technologies and services in the areas of diagnostic and therapeutic imaging, laboratory diagnostics and molecular medicine, as well as digital health and enterprise services.

We are a leading medical technology company with over 170 years of experience and 18,000 patents globally. With more than 48,000 dedicated colleagues in 75 countries, we will continue to innovate and shape the future of healthcare.

On account of certain regional limitations of sales rights and service availability, we cannot guarantee that all products included in this brochure are available through the Siemens Healthineers sales organization worldwide. Availability and packaging may vary by country and is subject to change without prior notice. Some/All of the features and products described herein may not be available in the United States.

The information in this document contains general technical descriptions of specifications and options as well as standard and optional features, which do not always have to be present in individual cases.

Siemens Healthineers reserves the right to modify the design, packaging, specifications, and options described herein without prior notice. For the most current information, please contact your local sales representative from Siemens Healthineers.

Note: Any technical data contained in this document may vary within defined tolerances. Original images always lose a certain amount of detail when reproduced.

Siemens Healthineers Headquarters
Siemens Healthcare GmbH
Henkestr. 127
91052 Erlangen, Germany
Phone: +49 9131 84-0
siemens-healthineers.com

Published by
Siemens Medical Solutions USA, Inc.
40 Liberty Boulevard
Malvern, PA 19355-9998, USA
Phone: 1-888-826-9702
siemens-healthineers.us

Published by Siemens Medical Solutions USA, Inc. · Order No. MR-18-1203-01-76 · Online Pdf · 09-2018 · ©Siemens Medical Solutions USA, Inc., 2018