New Clinical Possibilities and Increased Productivity after Upgrading from MAGNETOM Aera to MAGNETOM Sola Fit

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Introduction

ZNA Jan Palfijn is an important general hospital in the north of the city of Antwerp in Belgium, covering almost all medical fields. The hospital serves outpatients in an outpatient clinic, as well as patients admitted to the hospital or receiving treatment in the day hospital. ZNA Jan Palfijn has a large, recently renovated emergency department and an important intensive care unit.

The hospital also includes an orthogeriatric department where orthopedists and geriatrists work together to provide optimal orthopedic treatment for vulnerable elderly patients. In 2016, the institute became part of the Iridium Cancer Network, a network of multidisciplinary doctors, nurses, and an extensive counselling team who strive for the optimal diagnosis, treatment, and aftercare of each individual cancer patient in the Greater Antwerp and Waasland region. The network has the specific technology and knowledge needed to offer intraoperative radiotherapy, radiosurgery, prostate brachytherapy, and innovative radiotherapy in clinical trials if necessary. In this context, we acquired a new PET-CT scanner in June 2018.

The medical imaging department at ZNA Jan Palfijn offers all imaging techniques: conventional radiography, mammography (the services are recognized as mammographic screening centers), computer tomography (CT), magnetic resonance imaging (MRI), and ultrasound examinations. Medical imaging is also used for infiltration of joints (under ultrasound or fluoroscopic guidance), fine needle aspiration cytology or FNAC (e.g., for thyroid gland nodules), and core biopsy (e.g., for breast lesions) whenever accurate visualization is important and a minimally invasive, non-operative technique is preferable.

We have one 1.5T MRI scanner in our facility, on which we perform a full range of MRI examinations – from neurological to musculoskeletal, abdominal, and breast. Cardiac MRI is the only examination we do not perform. When Siemens Healthineers offered us the possibility to upgrade our existing MAGNETOM Aera 1.5T system to a MAGNETOM Sola Fit with BioMatrix technology (Fig. 1), we considered this a good opportunity to expand our clinical capabilities, reduce our acquisitions times, and increase our patient throughput at a very attractive cost-benefit ratio compared to installing an entirely new system.

We decided to purchase the world's first MAGNETOM Sola Fit upgrade and take part in the customer use test from Siemens Healthineers. In order to really compare and demonstrate the changes in MR scanning achieved with the upgrade, we installed a teamplay receiver on our MAGNETOM Aera system shortly before the upgrade. Additionally, we granted Siemens Healthineers the rights to analyze our system service data so that we could look into more detailed scan parameters. In order to make datasets comparable, we chose time periods with a comparable number of working days, avoiding times with a high number of holidays or vacations. The MAGNETOM Aera data presented here covers the period from June 19 to July 28, 2019, and the MAGNETOM Sola Fit data covers October 2 to November 10, 2019. In this article, we share our results after having operated the upgraded system for almost a year.

1 MAGNETOM Sola Fit at our institute.

Installation

The installation of the upgrade had to be really fast as we didn't have a back-up MRI system and couldn't scan any patients at all during the installation process. We received the MAGNETOM Sola Fit upgrade kit in the first week of August 2019. Even though this was the first installation of its kind globally, the upgrade went very smoothly and fast, taking a total of 13 working days for de-installation of old components, installation of the Sola Fit components as well as tuning and ramp-up. Due to a missing CE label, the go-live of the system was unfortunately delayed for another two days. The upgrade itself included new RF components, new electrical cabinets, new covers with BioMatrix touch panels, a new patient table, a new 32-channel spine coil with respiratory sensors, a new tiltable 20-channel head/neck coil with CoilShim technology, and a new MRI workplace with a large-screen monitor. All our existing licenses were transferred, and existing coils could be used after the upgrade. The upgrade also came with a new 18-channel transmit/receive knee coil, a 16-channel flexible shoulder coil, and new Turbo Suite licenses containing the latest acceleration techniques from Siemens Healthineers.

On the very first day of going live, the scanner already produced high-quality images. In the first week, we scanned volunteers and patients in the time slots we usually worked with in the past (to allow the technicians to get used to the new protocols and work environment). During the second week, we were able to scan patients within a shortened schedule and without significant delays at the end of the day.

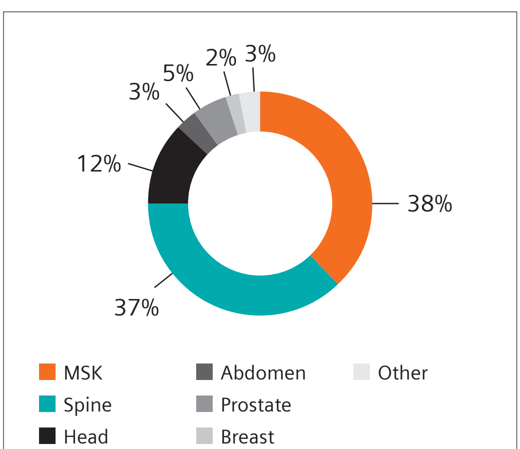
New work environment

The upgrade not only brought many hardware changes, but also a completely new work environment and changes to our workflows. In our medical imaging department, we have six technologists working with the MRI system. To help them become comfortable in working with the new equipment, we ordered online pretraining via the PEPconnect training platform from Siemens Healthineers, and two weeks of onsite training. After this training period, our technicians felt quite comfortable scanning in the new environment.

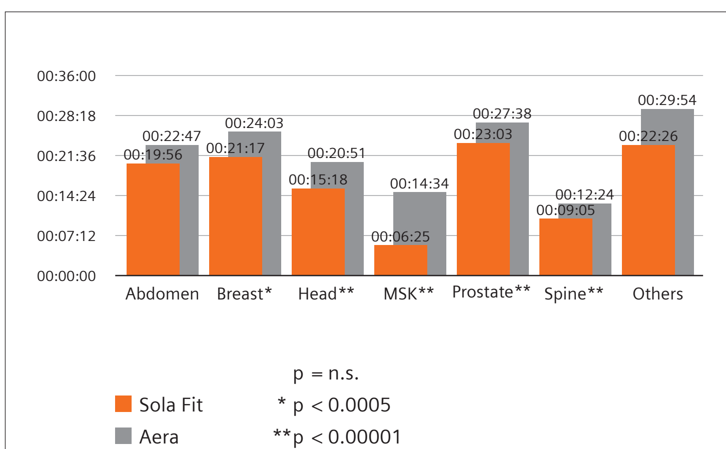
We gave ourselves really challenging goals for the time slots of our different examinations. In an intensive iterative approach between myself, head of the MRI unit, and the local Siemens Healthineers application specialist, each of our protocols were adapted to make use of the new sequences and acceleration techniques. In the end, we succeeded in performing all examinations in the given time slots while maintaining our high image-quality requirements.

Before-and-after comparisons

Our case mix before and after upgrading to the MAGNETOM Sola Fit system stayed more or less the same, though the period we chose for our productivity comparison showed a small shift from spine examinations to musculoskeletal (MSK) examinations. Generally, our case mix mainly consists of MSK (~40%), spine (~35%), and brain examinations (~15%) (Fig. 2). We also perform prostate, pelvis, breast, and abdominal scans. After the upgrade, we achieved significant improvements in all these clinical areas. As shown in Figure 3, the median examination times per body area were reduced across the board. The reductions are statistically relevant. In the following sections, we will show selected results as examples for the different regions.



2 Example case mix for MAGNETOM Sola Fit (Oct – Nov 2019).

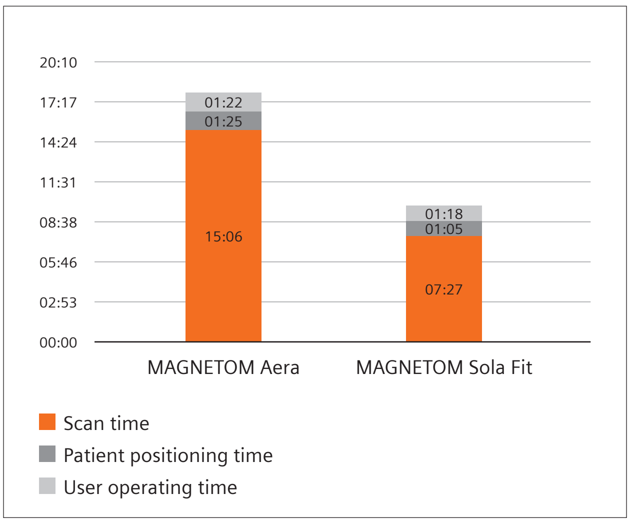


3 Mean exam duration for MAGNETOM Aera vs. Sola Fit per body region; statistical significance tested with Wilcoxon rank sum test for equal medians.

1. Musculoskeletal examinations

For standard MSK examinations, we mostly used 2D proton density (PD) sequences and fat-saturated T2 sequences in the different planes. After the upgrade, we adjusted, for instance, our knee protocols to one 2D PD sequence using Simultaneous Multi-Slice and one 3D SPACE sequence using Compressed Sensing acceleration and reconstruction of the different planes. Depending on the indication, we also follow this strategy for ankle examinations.

For routine knee examinations, this strategy allowed us to reduce the median examination time from 18 minutes to 10 minutes (Fig. 4).



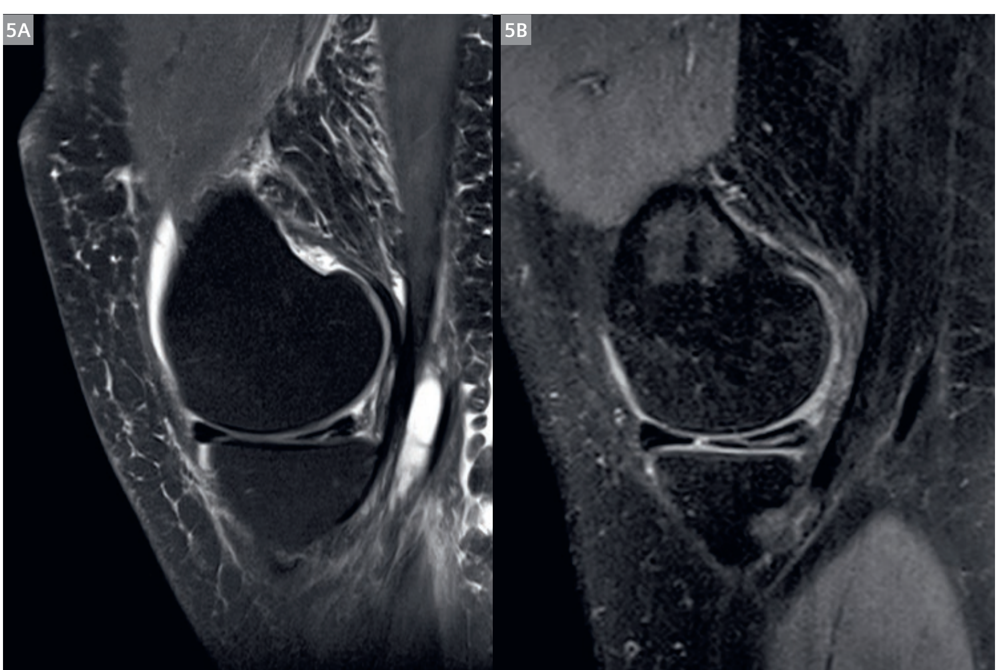
4 Median examination times for routine knee examinations before and after the upgrade.

The following knee examinations (Fig. 5) of horizontal tears of the posterior horn of the medial meniscus performed before and after the upgrade demonstrate how we reduced the overall acquisition time by 50% while maintaining diagnostic quality and information in our clinical images. Instead of running three T2 TSE FS sequences for all orientations, we now acquire only one 3D SPACE sequence. This allows us to reconstruct all planes and dramatically reduces the scan time.

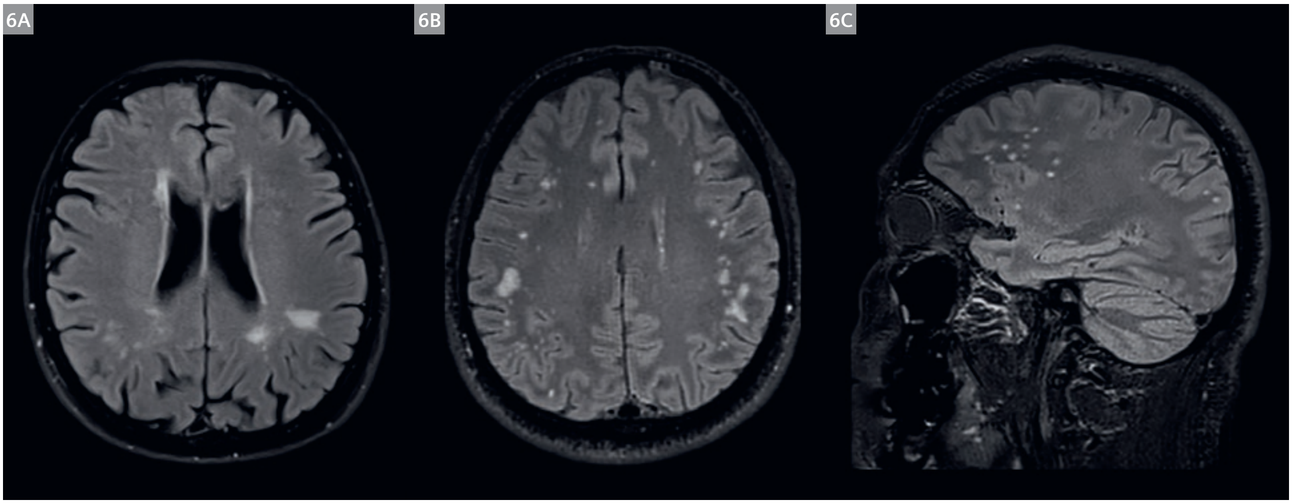
With the upgrade, we also acquired a new transmit/receive knee coil with 18 channels. This coil has a wider opening, which now allows us to scan nearly all obese patients, or knees with large swellings, where before we had to use the body coil. For shoulder imaging, we have the new flexible Shoulder Shape coil which achieves a better fit with the patient's anatomy and leads to a higher signal-to-noise ratio in general.

2. Neurological examinations

Our standard brain protocol consists of sagittal T1, transversal diffusion, T2 TSE, T2 FLAIR, and Time-of-Flight sequences where needed. After the upgrade, we now use Compressed Sensing acceleration for the FLAIR as well as the Time-of-Flight sequences. The following example (Fig. 6) shows two comparable cases acquired before the upgrade using a 2D FLAIR, and after the upgrade using 3D SPACE FLAIR with Compressed Sensing. As well as providing additional information through the different planes, the 3D SPACE FLAIR also has a higher and isotropic resolution of 0.6 mm and shows better white matter delineation.



5 Image **(5A)** is a T2 TSE FS acquisition before the upgrade, with 0.4 x 0.4 x 3 mm³ resolution in TA 4:52 min. Image **(5B)** was acquired for the same indication after the upgrade using CS 3D SPACE with 0.4 x 0.4 x 0,5 mm³ and TA 4:10 min.

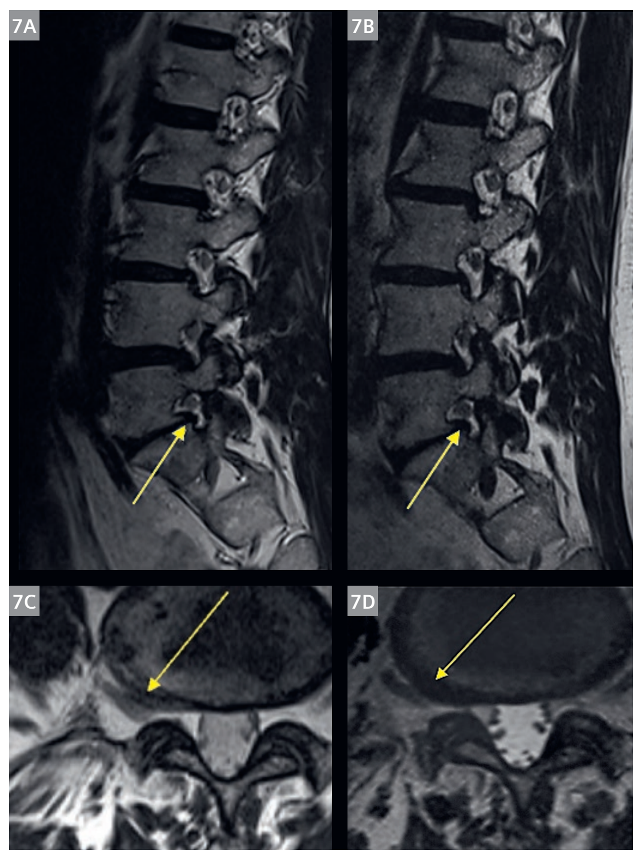


6 Comparison of FLAIR scans before and after upgrade: Image **(6A)** was acquired using a 2D FLAIR with 0.7 x 0.7 x 5 mm³ in TA 4:32 min.; **(6B)** and **(6C)** are from one 3D SPACE FLAIR exam with 0.6 mm iso in TA 4:00 min.

With the BioMatrix upgrade, our head and neck patients now benefit greatly from the new tiltable head and neck coil. Some patients didn't fit in the head coil we used before, but now they can have an MRI exam thanks to the head tilt. Furthermore, we constantly use the coil in the 9° position, which gives all our patients more comfort and reduces motion artifacts.

3. Spine examinations

We have also reduced scan times in spine examinations by shifting to 3D SPACE instead of 2D gradient echo sequences for most indications. The following examples show two L-spine examinations in the same patient with neuroforaminal disc protrusion and discoradicular conflict, before and after the upgrade (Fig. 7). Images 7A and 7C are T2 TSE images acquired on our MAGNETOM Aera before the upgrade with an acquisition time of 3 minutes each. Images 7B and 7D were acquired with one 3D T2 SPACE sequence in 5:43 minutes on our MAGNETOM Sola Fit using Compressed Sensing.

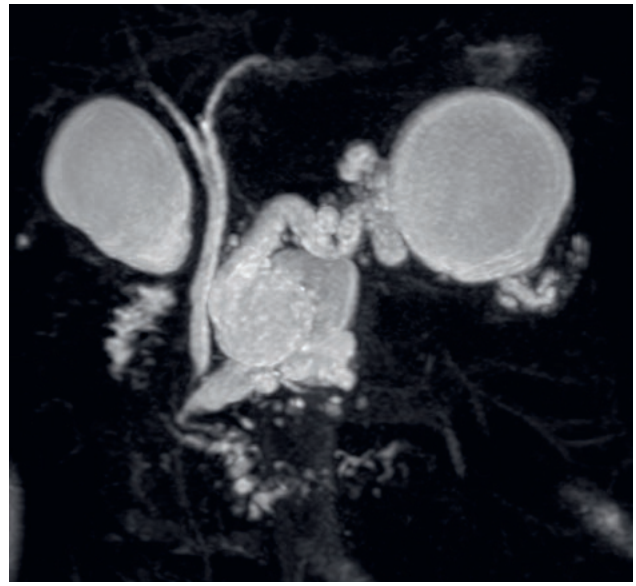


7 L-spine examinations in the same patient with neuroforaminal disc protrusion and discoradicular conflict: **(7A)** and **(7C)** are T2 TSE images acquired before the upgrade in TA 2:57 min and 3:05 min respectively, and at a resolution of 0.7 x 0.7 x 3 mm³; **(7B)** and **(7D)** are 2 mm MPRs from a Compressed Sensing 3D T2 SPACE sequence acquired on MAGNETOM Sola Fit in TA 5:43 min with a resolution of 0.4 x 0.4 x 0.45 mm³.

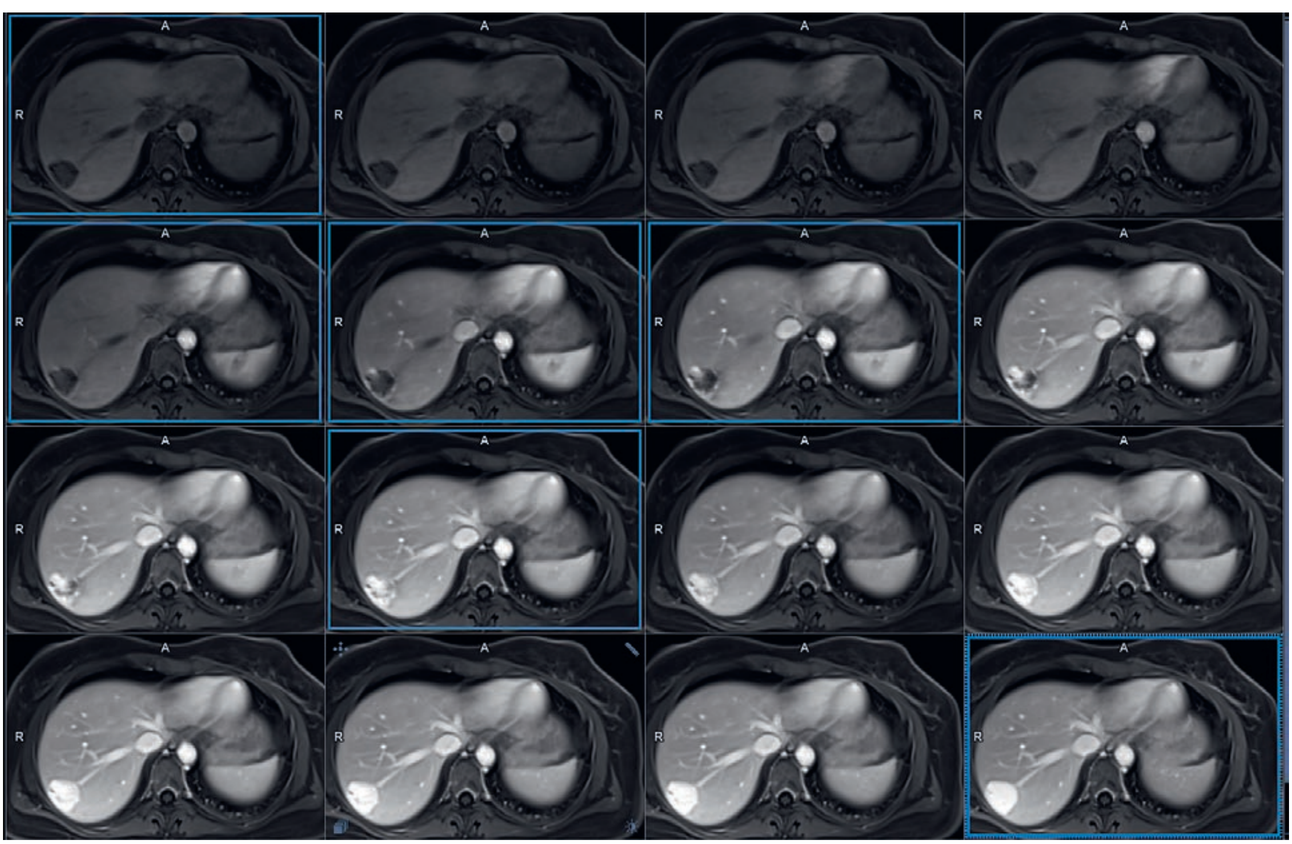
4. Abdominal examinations

For abdominal imaging, we particularly feel the benefits of the BioMatrix respiratory sensor during our MRCP examinations. Technicians no longer have to place the PACE navigator on the liver dome. This results in an easier workflow and faster acquisitions overall. The following example of a respiratory-triggered coronal T2 SPACE MRCP was acquired in 42 seconds using the built-in respiratory sensor (Fig. 8). The main pancreatic duct is dilated, with multiple cystic dilatations of the side branches (= mixed type IPMT).

Nearly all abdominal examinations are now performed under free breathing using the Compressed Sensing GRASP-VIBE technique. As well as being a great relief to many patients who struggle to hold their breath or follow breath-hold commands, it also increases our diagnostic confidence as we have more dynamic phases. In the images of a patient with liver hemangioma (Fig. 9) the high temporal resolution of GRASP-VIBE allows to visualize the gradual centripetal, nodular filling of the lesion in the liver (classical enhancement pattern of a hemangioma). Images with a blue frame are the automatically preselected phases identified by the GRASP-VIBE algorithm: one pre-arterial, three arterial, one portal-venous, and one late phase.



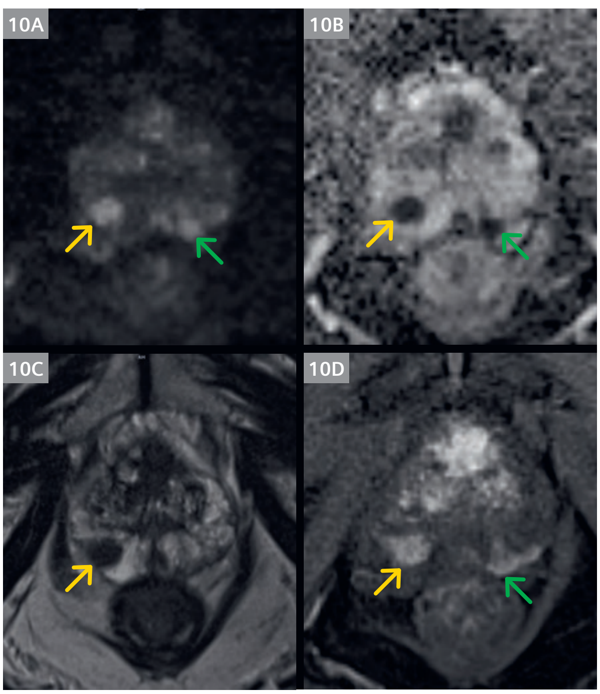
8 Coronal respiratory-triggered T2 SPACE MRCP acquired in 42 s with CAIPIRINHA 4 acceleration and using the built-in respiratory sensor as the triggering device.



9 Liver dynamics of a hemangioma using Compressed Sensing GRASP-VIBE with a temporal resolution of 8.6 s, acquired under free breathing.

5. Prostate examinations

After the upgrade, all routine prostate examinations now have an average examination time of 23 minutes. In our standard prostate protocol, we are now using the GRASP-VIBE technique for our dynamics and have incorporated high-resolution multi-shot diffusion – known as the RESOLVE technique. In this image example (Fig. 10) of a PI-RADS 4 lesion in the right peripheral zone (yellow arrow), a marked focal hyperintensity is seen at high *b*-value and a corresponding hypointensity is seen on ADC. In particular, the hyperintensity on the high *b*-value image of this proven malignant lesion is better appreciated on our DWI-RESOLVE sequence than on our DWI images before the upgrade. Also, a smaller PI-RADS 3 lesion is clearly depicted in the left peripheral zone on the same images (green arrow).

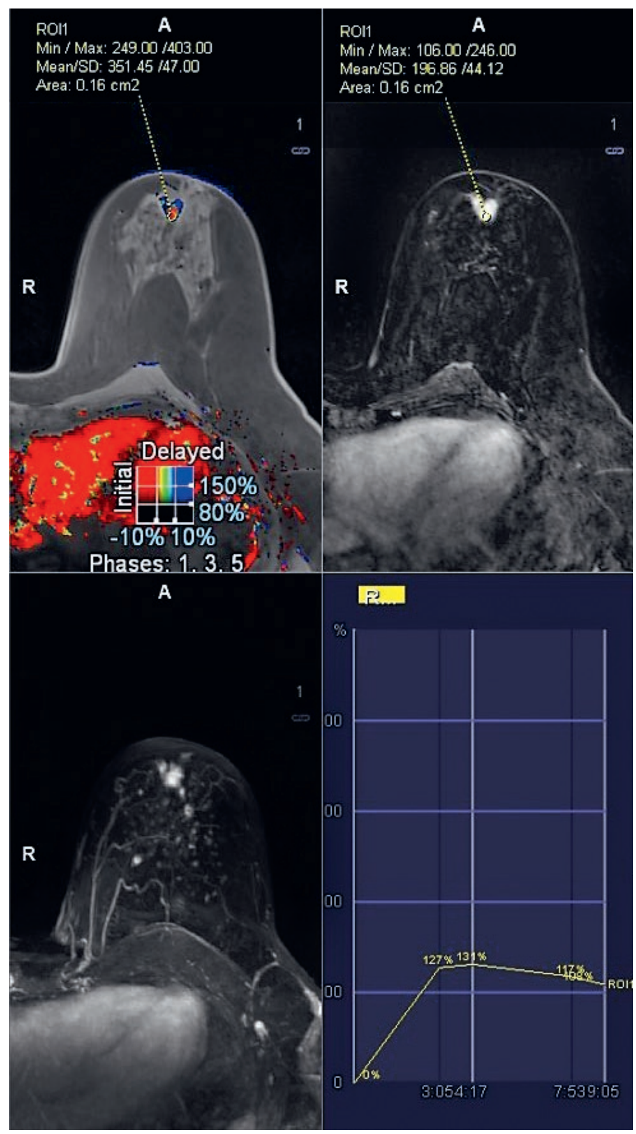


10 PI-RADS 4 lesion in the right peripheral zone and a smaller lesion in the left peripheral zone of the prostate in RESOLVE diffusion with b=1000 s/mm^2 **(10A)**, ADC image **(10B)**, T2 TSE **(10C)**, and Prostate GRASP-VIBE **(10D)** with high temporal resolution (during initial contrast uptake) of 1.8 s per frame.

6. Breast examinations

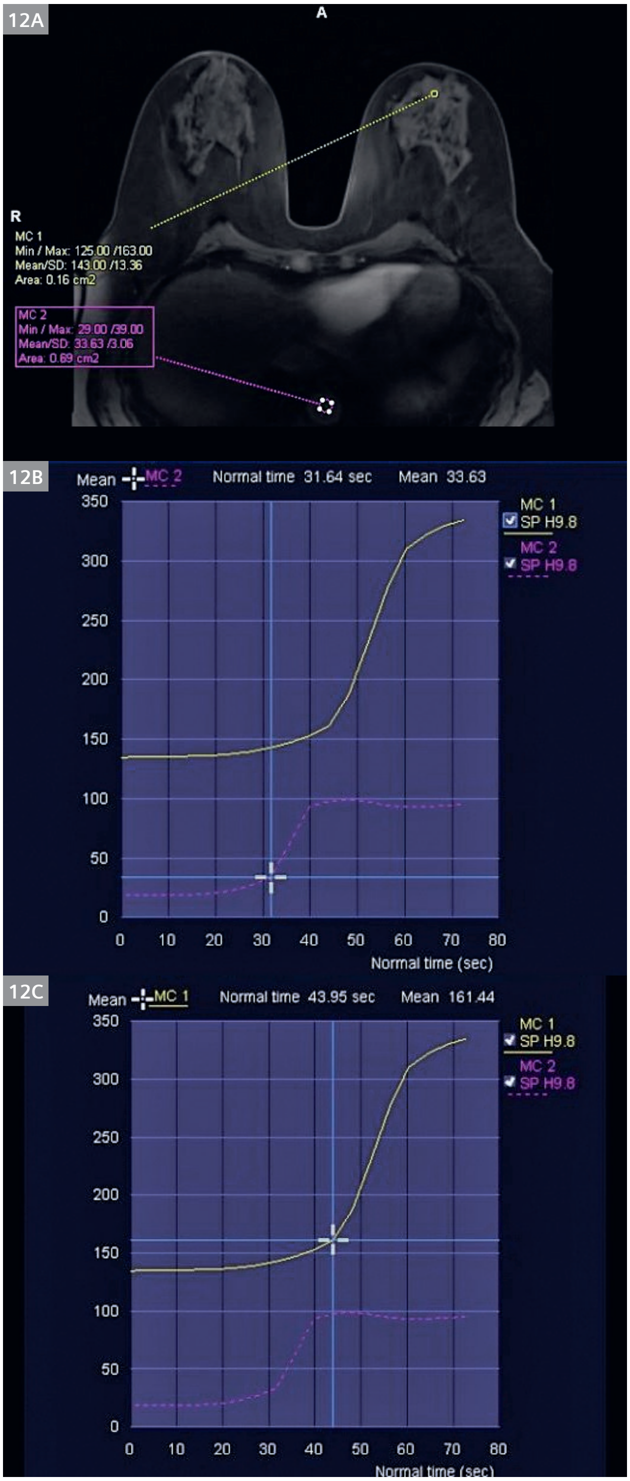
We adjusted our protocol for breast examinations. After contrast media injection, the first dynamic sequence has been replaced by a 1 minute Compressed Sensing GRASP-VIBE acquisition as a supplement in order to compare the outcome of GRASP-VIBE to conventional dynamic analysis. This has been especially useful for proving the benign characteristics of enhancing small lesions (using time-to-enhancement relative to the aorta).

In the following example, the lesion in the retro-areolar region of the left breast showed morphologic features suspicious for malignancy. On conventional dynamic analysis (T1 fl3D FS), this lesion shows a type 2–3 time intensity curve, not entirely convincing for malignancy (Fig. 11).

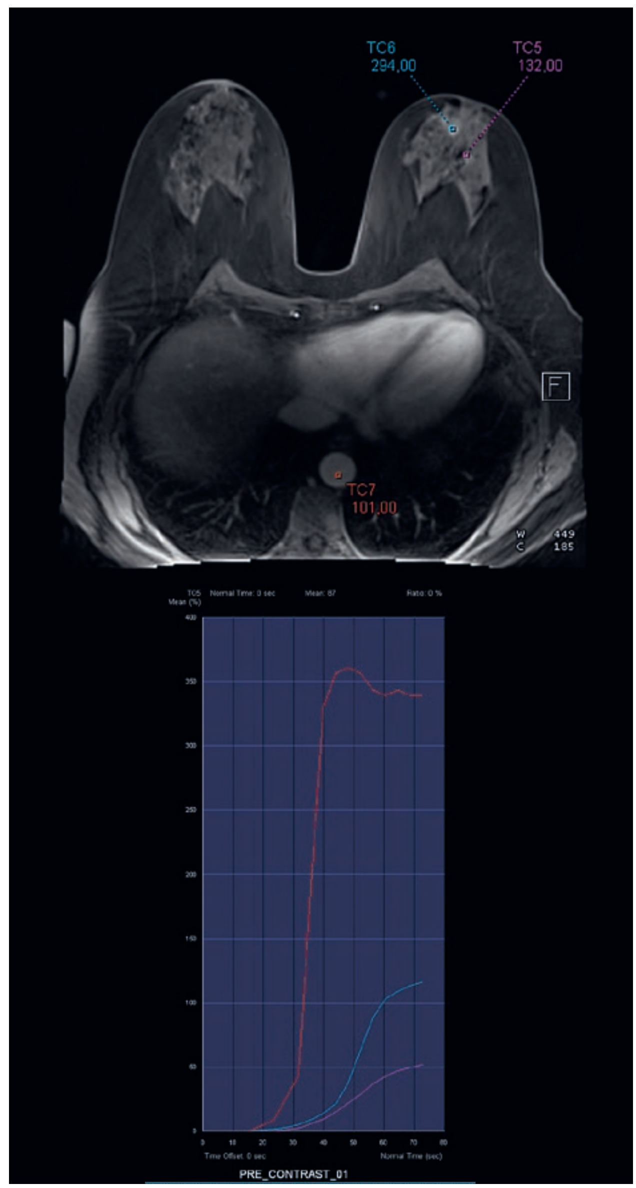


11 Conventional dynamic analysis based on T1 fl3D FS, not entirely convincing for malignancy.

The GRASP-VIBE sequence shows that the time difference between the start of enhancement in the lesion and in the aorta is 12.3 seconds, which is indicative of malignancy based on the 12.96 second threshold established by Mus et al. in Eur J Radiol. 2017 [1] (Fig. 12). This finding added diagnostic confidence, and pathologically this lesion proved to be malignant. There is another, smaller lesion located deeper and more laterally in the same breast, which has more or less the same morphologic characteristics (Fig. 13). The GRASP-VIBE sequence clearly shows the slower enhancement and a different type of enhancement curve compared to the bigger lesion, so we could state that this smaller lesion was probably benign. Anatomopathology of the smaller lesion proved it was benign (a fibro-adenoma).



12 GRASP-VIBE dynamics show a time difference of 12.3 s between the start of enhancement in the aorta **(12B)** and in the lesion **(12C)** below the malignancy threshold [1].

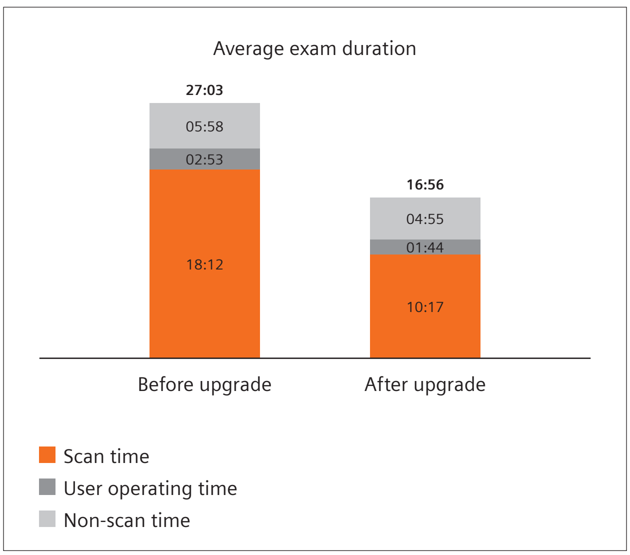


13 A smaller lesion located deeper and more laterally: a GRASP-VIBE sequence with slower enhancement and different enhancement curve led to the conclusion that the lesion was benign.

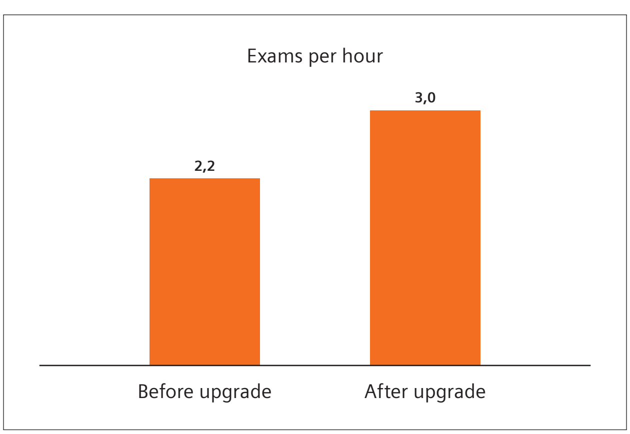
Increasing our productivity

In most of the body areas, we achieved much shorter examination times while maintaining our image quality. This is thanks to new sequence technologies that reduce our average exam duration by 37% (Fig. 14). Additionally, we reduced the patient changeover times from 5:58 minutes on average for all types of examinations to 4:55 minutes. This was thanks to the new patient positioning with the intelligent one-touch positioning that comes with the new system.

Thanks to all of this, we have significantly increased the number of patients that can be scanned per hour. Depending on the type of examination, we can scan up to 4 patients in an hour, which is a 30% increase on average (Fig. 15).



14 Comparison of average examination times.



15 Average number of exams per hour on MAGNETOM Aera (Jun – Jul 2019) and on MAGNETOM Sola Fit (Oct 19 – Nov 2019).

Conclusion

The installation of the Sola Fit upgrade went smoothly and quickly. Throughout the whole process, both I and our technicians could rely on the 24/7 support from the application specialists at Siemens Healthineers. The main benefits of the Sola Fit upgrade for our MRI unit are the accelerated acquisition times, increased patient throughput, and continuing high image quality. The new coils, especially the comfortable and tiltable head/neck coil, are also a major advantage. We see many clinical benefits, especially increased diagnostic confidence in prostate and mammography exams (GRASP VIBE, better diffusion images), abdominal exams (GRASP VIBE for liver lesions, MRCP with free breathing thanks to the respiratory sensors), and MSK exams (e.g., high-resolution 3D images of meniscal tears). Overall, we are glad to have upgraded to MAGNETOM Sola Fit.

Reference

1 Mus RD, Borelli C, Bult P, Weiland E, Karssemeijer N, Barentsz JO, et al. Time to enhancement derived from ultrafast breast MRI as a novel parameter to discriminate benign from malignant breast lesions. Eur J Radiol. 2017;89: 90–96.

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