Fast, Standardized, and Robust Imaging with BioMatrix and Compressed Sensing GRASP-VIBE

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When high-tech applications leave the shelter of the lab and come to the hospital to face real clinical challenges, the question arises: Does it work? Spoiler alert: The answer can be found in the images.

Upon arrival of the 1.5T MAGNETOM Sola, the first thing you notice is the small bump in the back. Since the magnet is such a short bore system, which I can literally hold in my arms, this rear extension is a quite logical way to support table movement beyond the bore.

Indeed, patient friendly magnets should be as short as possible. Speaking of patient comfort, listen when you move the table; you can't hear it. It's smooth and slides silently in place, in sharp contrast to the high-pitched shrieking on older systems. The acoustic isolation from gradient power has also improved. Many patients in follow-up studies spontaneously mention a more quiet noise level throughout the exam.

Another innocuous, innocent looking, but much appreciated change is the head coil. For the first time ever, it's tiltable! Slight tilting of the head is preferred by many patients and helps them to relax. It's also very much appreciated by sick and older patients or those with kyphosis or other malformations, since we no longer need to tilt the patient until the head fits but simply tilt the head coil. Together with the standard leg support, every patient fits. It's a small tilt for the coil, but a giant leap for patient comfort.

Patient comfort is one thing, how about operator comfort? Well, MAGNETOM Sola has some appealing tricks up its sleeve to charm the technologists. Patient positioning, for example, is done automatically; you just acknowledge by pressing the Go button and you're done. Using the laser beam to position suddenly seems so last century. Moreover, this automatic positioning avoids suboptimal positioning or even errors by eliminating interoperator variability, regardless of your patient's body type. As a result, scanning is always in local mode, which is less shim-dependent and hence faster (except for large FOV exams). Together with AutoAlign and AutoCoverage in the Dot engines, a highly standardized and robust examination quality results. DotGO and Dot engines are a match made in heaven! (Actually, a match made in Germany).

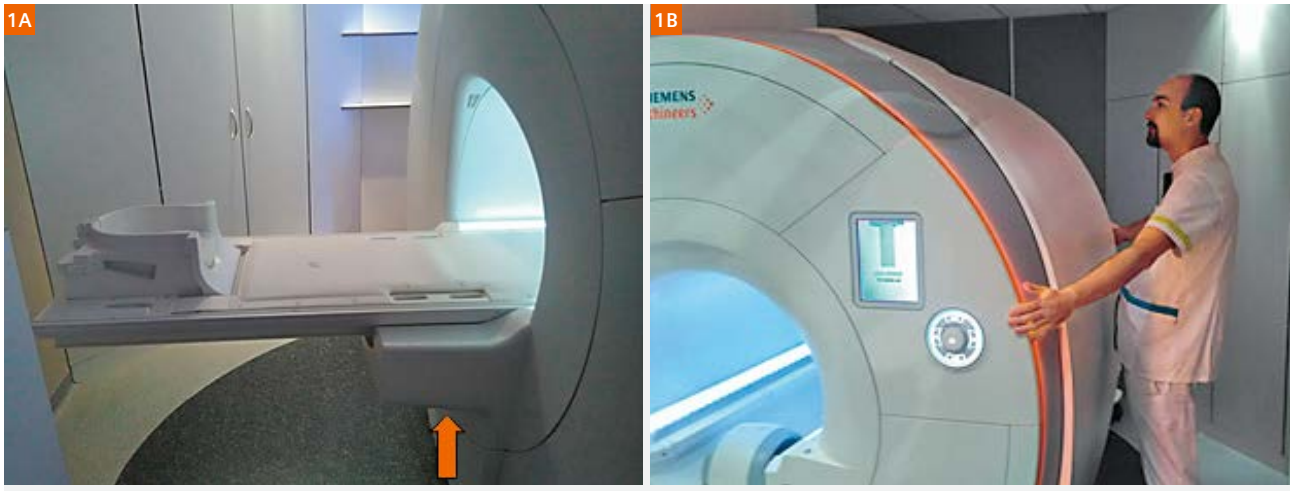
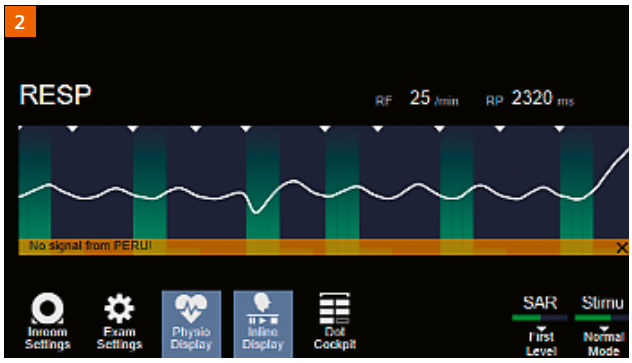


Figure 1:
The support in the back is needed since the magnet is so short that a person can easily hold the magnet in their arms. It may be quite an unusual feature; however it is a reliable parameter to determine if your magnet is patient friendly.

The user interface has changed quite a bit – dramatically in fact; however, we didn't complain about the transformation at all because it has changed for the better! For example, you can actually scroll through the images in the graphic segments, speeding up and improving the accuracy of planning. Or double click and have your planning stack in full screen. The dual screen setup at the console is efficient at separating scanning workflow from viewing, postprocessing, and archiving. Another benefit is the distribution of images where complex multiphase, multiseries studies are neatly presented in a graphic overview, guiding you to send only the relevant series to the PACS system instead of blindly dumping images.

The built-in respiratory sensor is helping us in different ways. First, if you ask your patient to hold their breath, you get a direct view if the breath-hold is properly done. If your patient is sick, you keep an eye on the respiration frequency together with the ECG. Second, the BioMatrix Sensor is robust and reliable for triggering T2 TSE, HASTE, or DWI acquisitions of the liver. There is no need to put on a respiratory belt and no scanning time is lost with the navigator. A kinetic sensor and beat sensor are in the development pipeline and I am eager to see if they perform just as well.



Now that we have touched on the subject of breath-holding, it seems a good time to mention that not every patient is very good at holding their breath, especially on command. On the Aera, we used StarVIBE to minimize respiratory movement artifacts (at the cost of dynamic contrast enhancement information), the Sola with GRASP-VIBE excels at getting rid of these artifacts while maintaining all the dynamic information over time. It turns out image quality that is surprisingly good, giving pristine images in not-so-compliant patients.

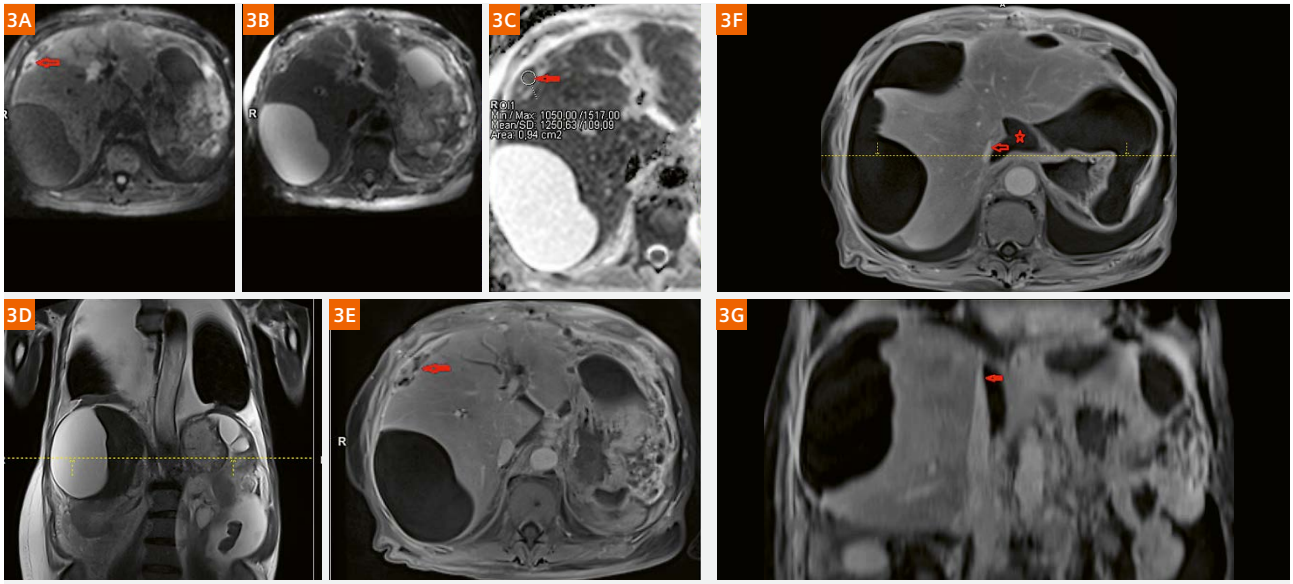


Figure 3: This 73-year-old male presented with shortness of breath and leg swelling. History of pancreatectomy and duodenectomy for pancreas cancer
DWI with high b-value **(3A)**, low b-value **(3B)**, and ADC map **(3C)**. Coronal HASTE **(3D, E)**. Note the coverage was head to feet with GRASP-VIBE for artifact-free free-breathing T1 imaging, demonstrating peritoneal implant (red arrow). Ascites (dielectrical effect) and massive pleural fluid are challenging image quality. Shortness of breath is immediately explained by the massive pleural effusion and compression atelectasis.

GRASP-VIBE free-breathing aquisition in the venous phase **(3F)** depicts the severe extrinsic compression of the inferior vena cava (red arrow) in diaphragmatic hiatus explaining edema and swelling of the lower limbs. Since slice thickness is 2.5 mm, you can reconstruct coronal images to better delineate anatomical landmarks.

To be honest, the gold standard breath-holding acquisition itself is quite limited in temporal resolution (it takes time for the patient to breathe in and out between different phases) and you need to time your acquisition very well to have a crisp arterial phase; whereas in GRASP-VIBE, the acquisition simply keeps going while the patient is quietly breathing; hence, GRASP-VIBE does not simply maintain dynamic information, but actually enhances time resolution giving you, for example, three arterial phases in liver imaging. Here, the time resolution was just 7 seconds.

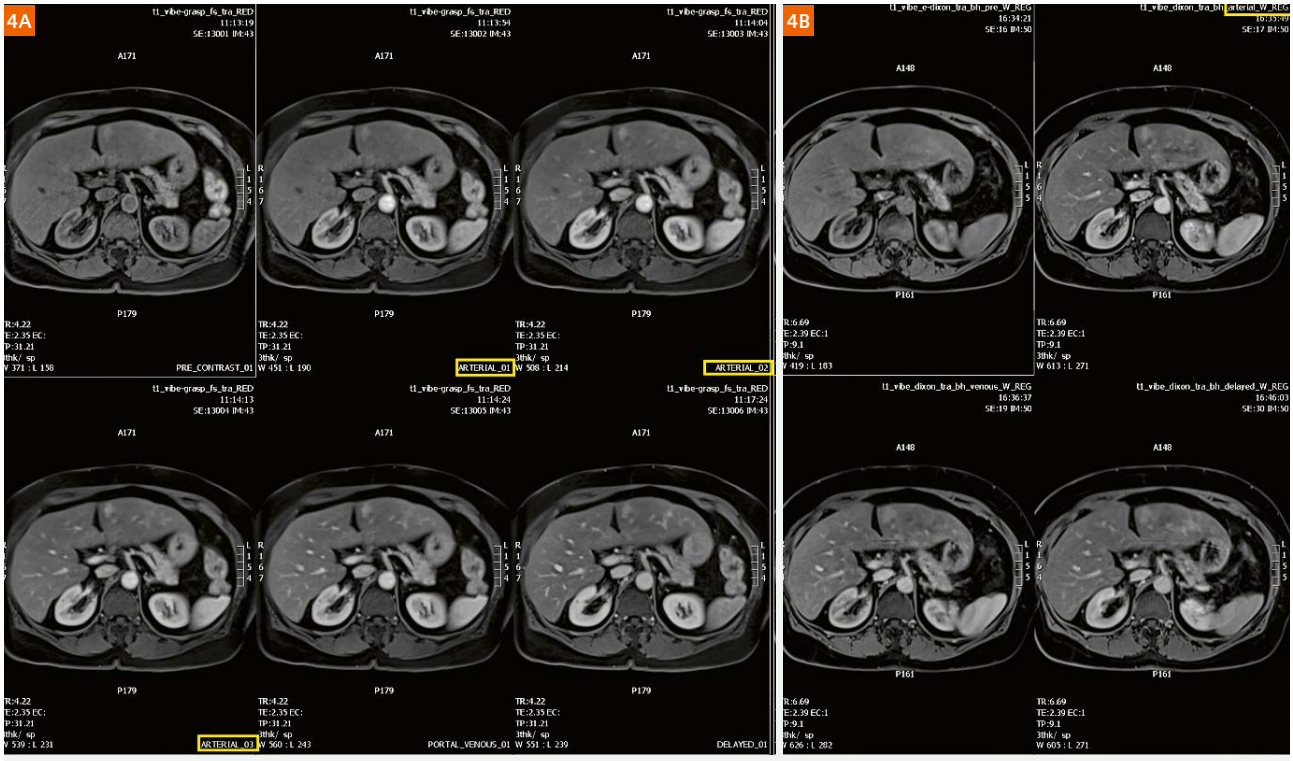


Figure 4:
(4A) Three columns showing reduced reconstruction sets of GRASP-VIBE with three arterial phases (yellow box); **(4B)** two columns showing previous exam using CAIPIRINHA 4 VIBE on the Aera with standard single arterial phase (yellow box).

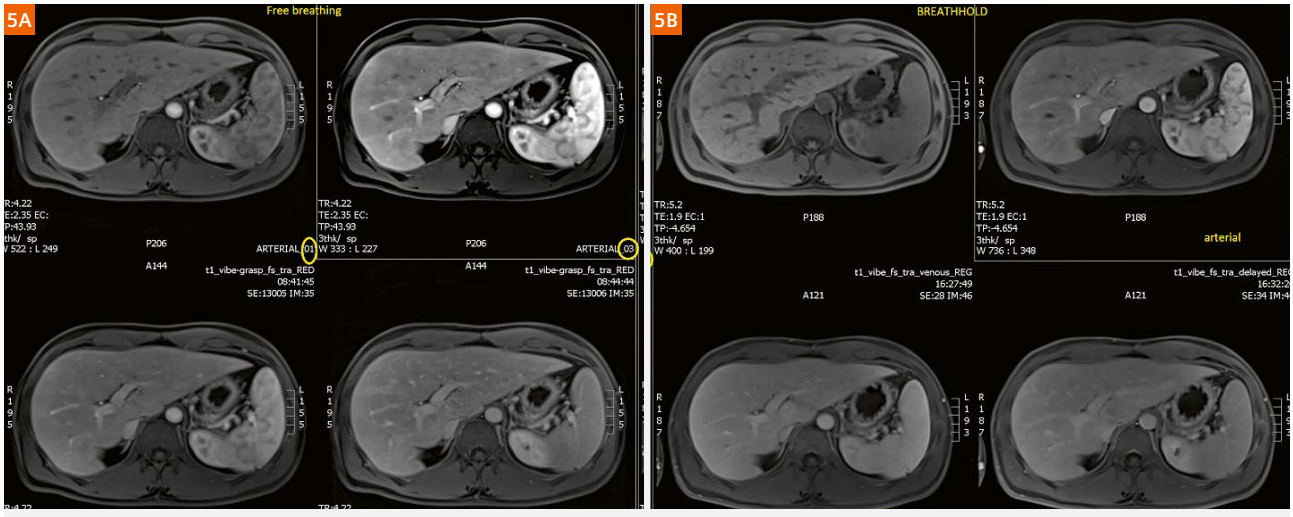


Figure 5:
(5A) When comparing this free-breathing GRASP acquisition in this young and cooperative patient, the quality of the free-breathing series equals that of the best CAIPIRINHIA 4 VIBE technique **(5B)** we had available last year; however, you have much higher temporal resolution with more phases, e.g., three consecutive arterial phases (arterial 01 and 03 are depicted, phase 02 is left out for sake of comparison).

For older and sick patients, free breathing makes an even bigger difference with better image quality in addition to higher temporal resolution.

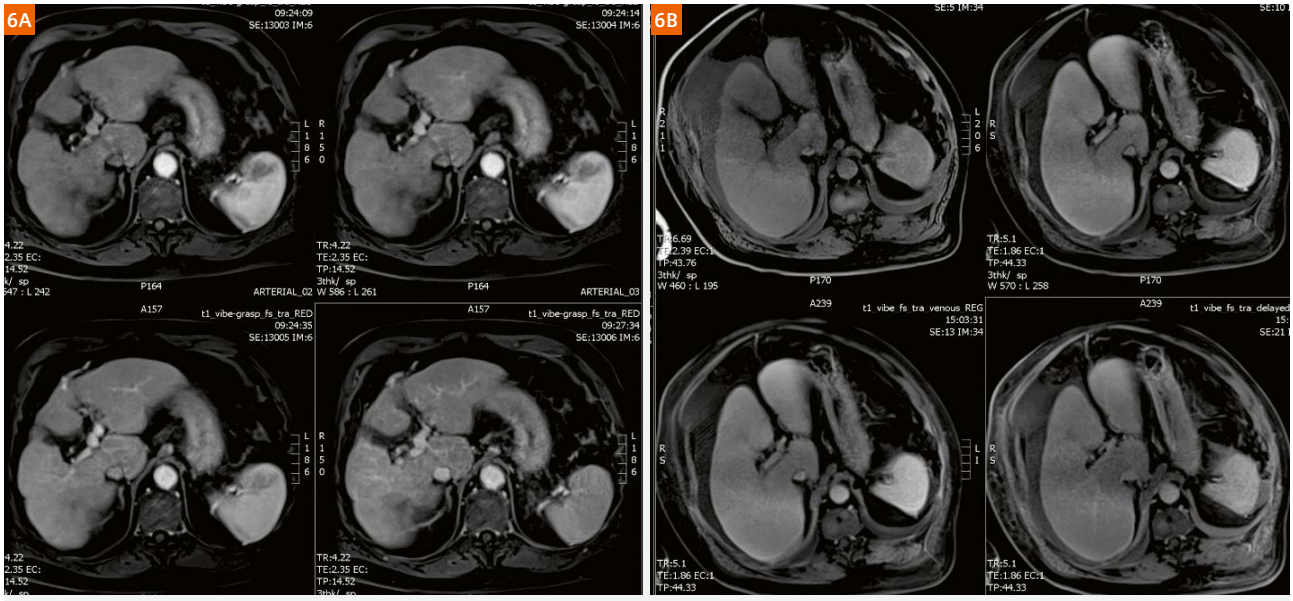


Figure 6:
In this 76-year-old patient with advanced liver cirrhosis, the GRASP-VIBE exam **(6A)** compared side-by-side with previous exam (**6B**; at 70 years) shows the portal vessels and the recanalized umbilical vein to a far better extent. This improved image quality is achieved despite the fact that patient is 6 years older and, worse, at an more advanced stage of cirrhosis. In addition to the image quality improvement, instead of one weak arterial phase, we have three confident arterial phases!

GRASPing dynamic inflow information is actually new and makes GRASP a new tool to help differentiate liver lesions.

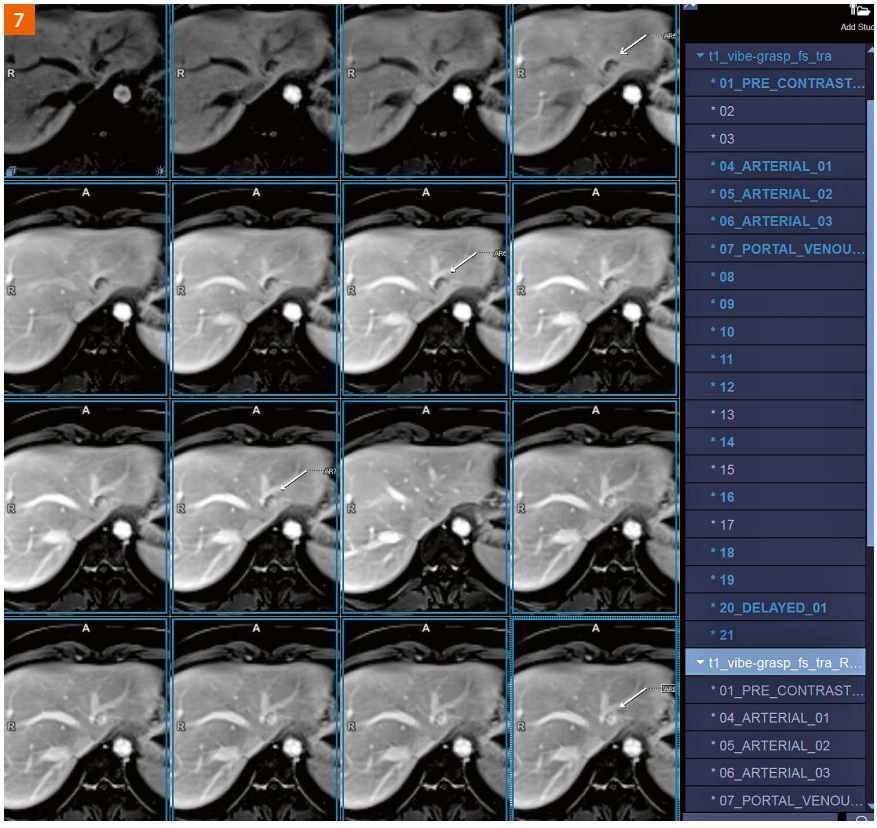


Figure 7:
Classic filling of liver hemangioma (arrow); however, with no breath-holding, time resolution 7 seconds, 3 mm slice thickness. The system automatically detects contrast bolus arrival and labels the phases accordingly. For convenience, a reduced dataset containing only the relevant, labelled phases (scroll down menu on the right side of the image series) is prepared, which can be sent separately to the PACS.

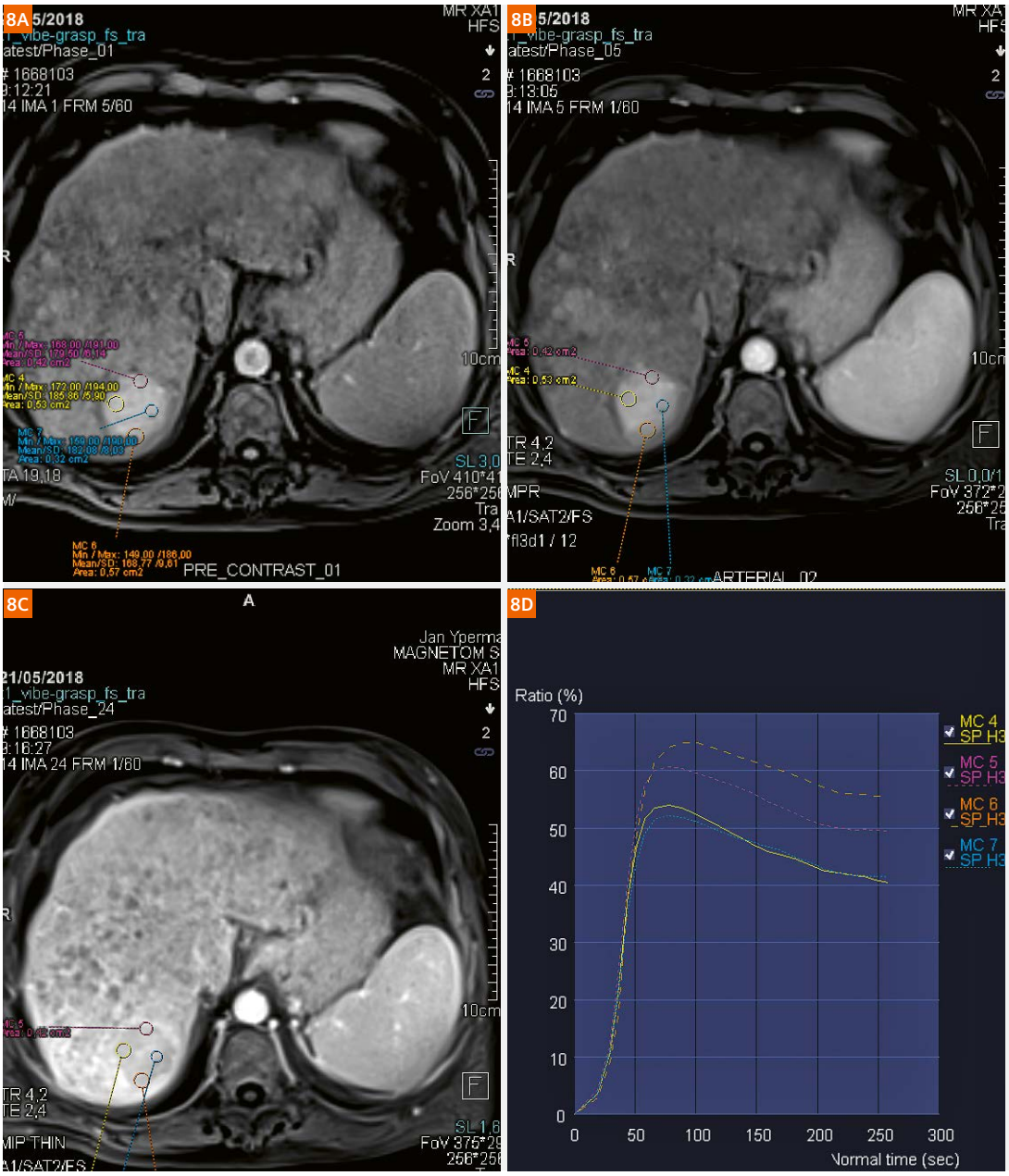


Figure 8: Large HCC with selected images T1 fatsat precontrast **(8A)**, arterial enhancing **(8B)**, and washout on delayed phase **(8C)** with the corresponding high quality contrast enhancement curve over time resulting from the high temporal resolution sampling in 4D GRASP. One can actually see the washin in the upper row and the washout in **8D**.

4D GRASP can also showcase dynamic filling, for example, of the mesenteric vessels, or even give an impression as to how organs are moving or are restricted in movement. In GRASP liver imaging, the reconstructor receives a respiration-dependent fluctuating signal. This respiratory information in the dataset is actually used to gate the reconstructions in expiratory phases only when wanted (our standard approach in liver imaging). This is convenient when reading/reporting the GRASP-VIBE dynamic series side-by-side with T2 and diffusion-weighted imaging, where having the same position in slices facilitates lesion recognition and characterization. GRASP-VIBE is also outperforming breath-hold imaging in this practical reading aspect.

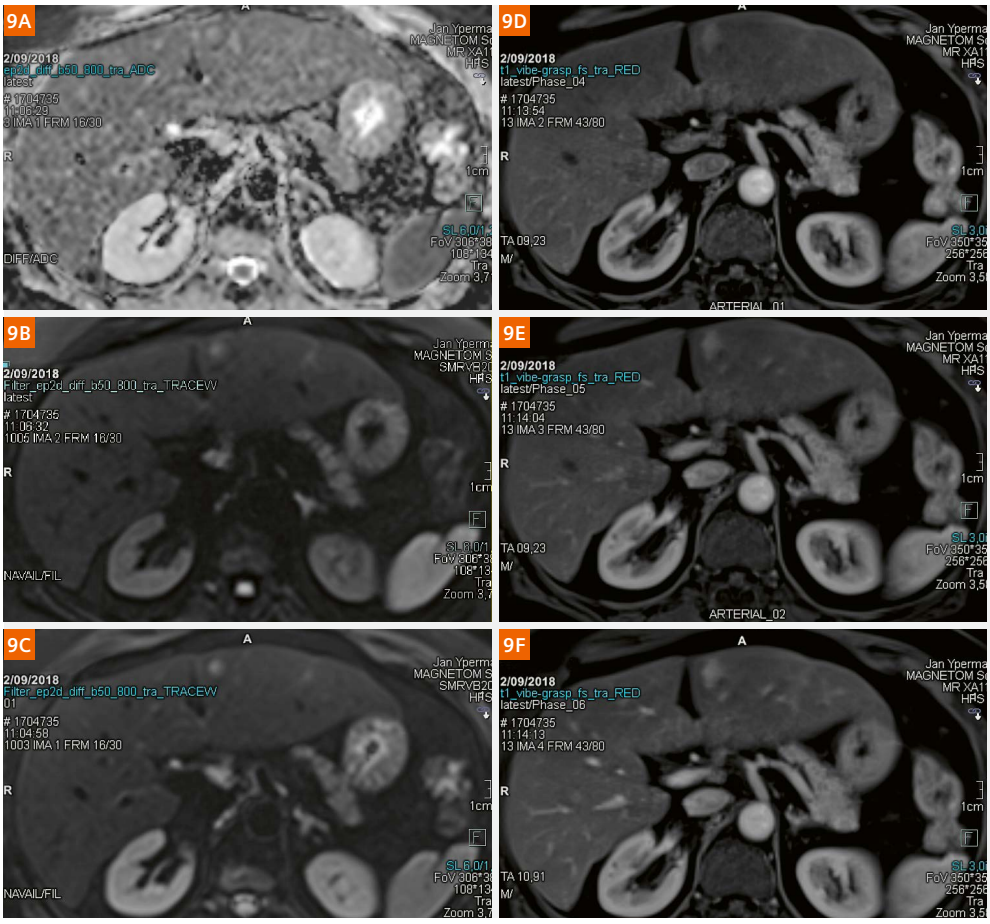


Figure 9:
The DWI **(9A–C)** nicely match the three arterial phases in a row **(9D–F)** making lesion detection and characterization easier and more reliable.

Figure 10:
Macronodular liver cirrhosis with recanalized umbilical vein; effortless dynamic imaging is perfectly aligned with the DWI thanks to the reconstruction in the expiratory phase.

Without respiratory gating in reconstruction, we can take temporal and spatial resolution even higher – as high as 28 slices x 1 mm in-plane, 3 mm thick every 3 seconds as in this case of fibromuscular stroma carcinoma of the prostate extending in the transition zone. Just as in liver imaging, side-by-side comparison with DWI is able to "resolve" prostate issues with amazing simplicity and accuracy.

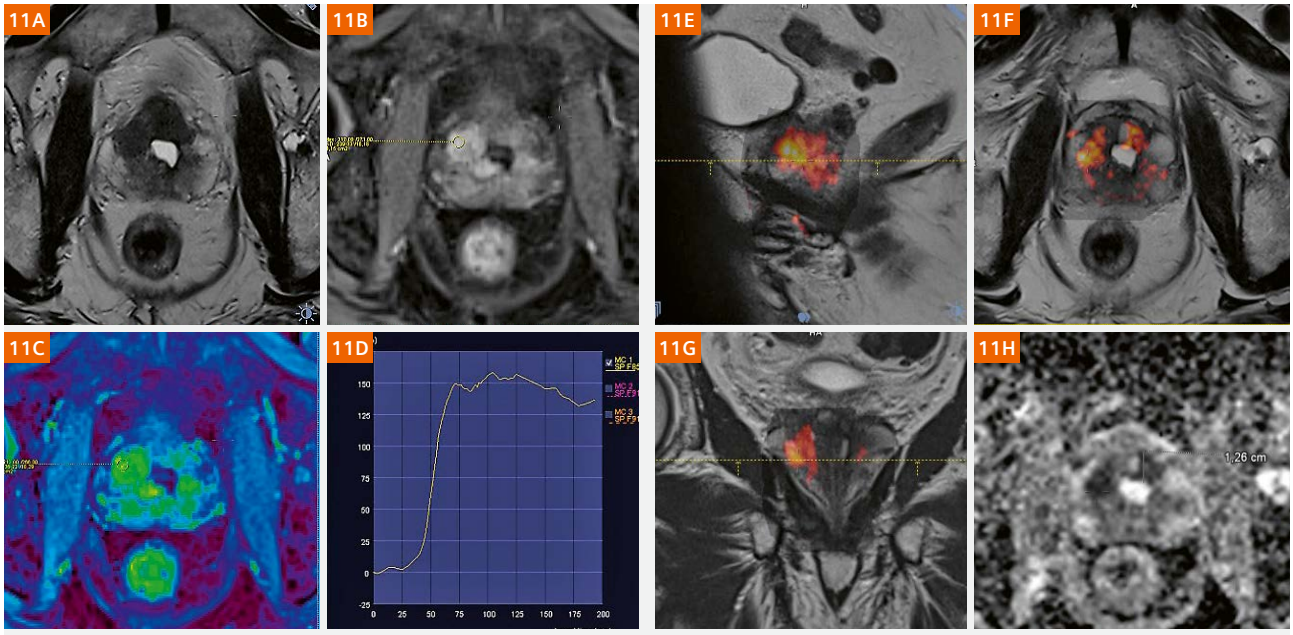


Figure 11:
Axial T2 **(11A)** demonstrating charcoal-like dark mass, capsule retraction. Fusion images of high b-value and T2 demonstrating diffusion restriction in the T2 dark zones Ax 4D GRASP **(11F)**; wash in-wash out pattern depicted on the graph. ADC map **(11H)** with restricted diffusion.

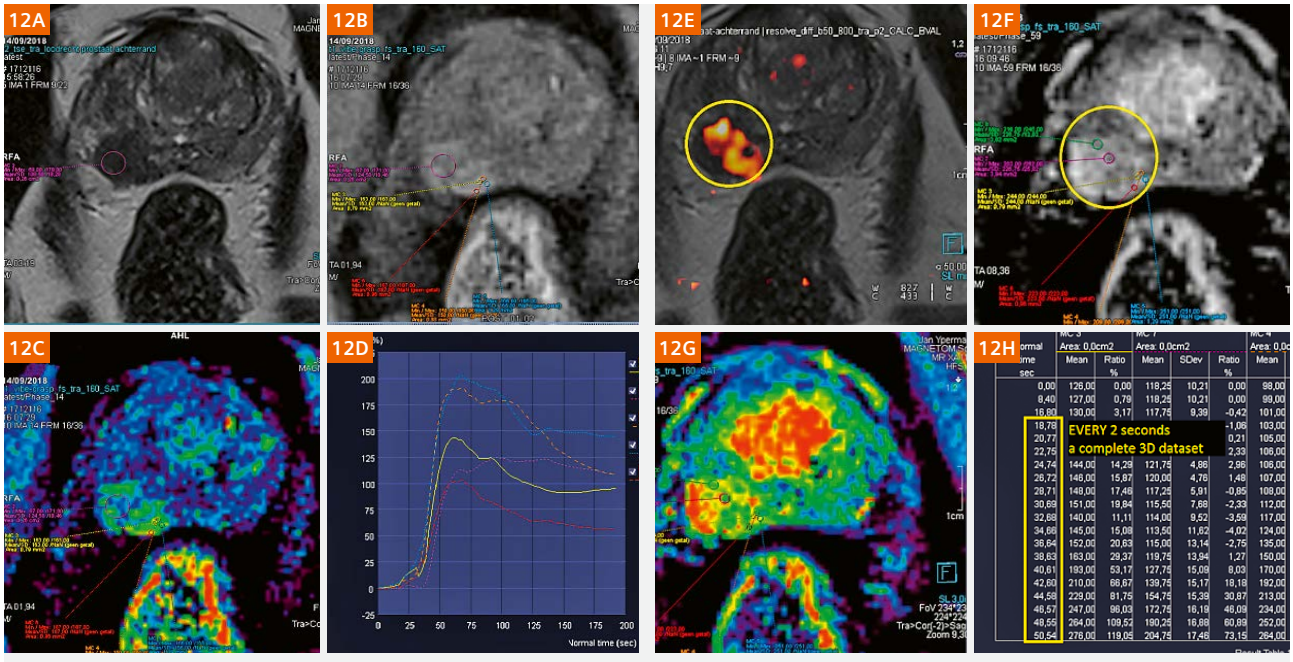


Figure 12:
Besides the contrast enhancement curve, one can see the wash in **(12B)** in addition to seeing the wash out in **(12F)** (yellow circle). Also note the T2 hypointense nodule **(12A)** and corresponding DWI fusion image with high b-value hyperintensity **(12E)** (yellow circle). Note time resolution in the mean curve table: 2 seconds for 36 x 3 mm slices; 1 mm in-plane resolution.

GRASP-VIBE is an excellent solution to counter motion artifacts, on the one hand, and for resolving contrast enhancement dynamics, on the other hand, making it ideal for neck imaging[1]. In radiology, the neck is also known as the "Great Swallowing Region".

1 mm in-plane resolution and slice thickness of 1.1 mm, 144 slices covered every 6 seconds artifact-free. This means not only no swallowing artifacts, but also robust fatsat thanks to the CoilShim. This same CoilShim allows perfect DWI in the neck, which was previously difficult to achieve.

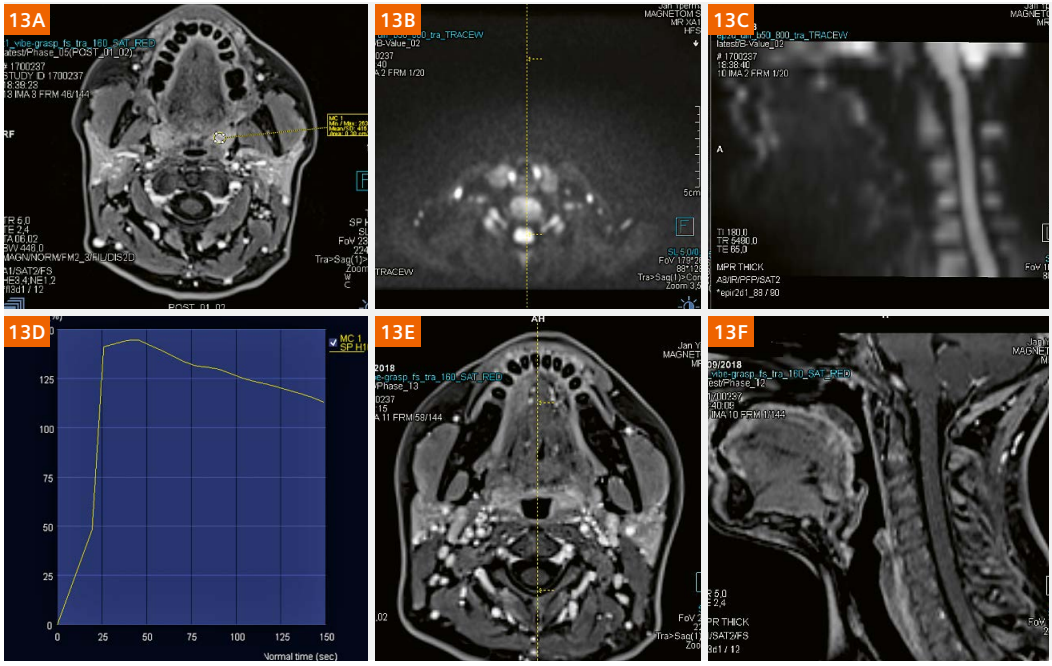


Figure 13:
144 slices in 1.1 isotropic resolution every 6 seconds. **(13B, C)** Axial DWI high b-value and sagittal MPR of high b-value with no distortion.

Contrast enhancement curve in left tonsil, timepoint every 6 seconds. **(13E, F)** Axial GRASP-VIBE and sagittal reconstruction: time-resolved and high resolution for high quality MPR reconstructions.

We can push the speed of GRASP acquisition even further; fast enough to grasp the filling of an aneurysm. 1.1 isotropic acquisition matrix and 2.5 seconds temporal resolution.

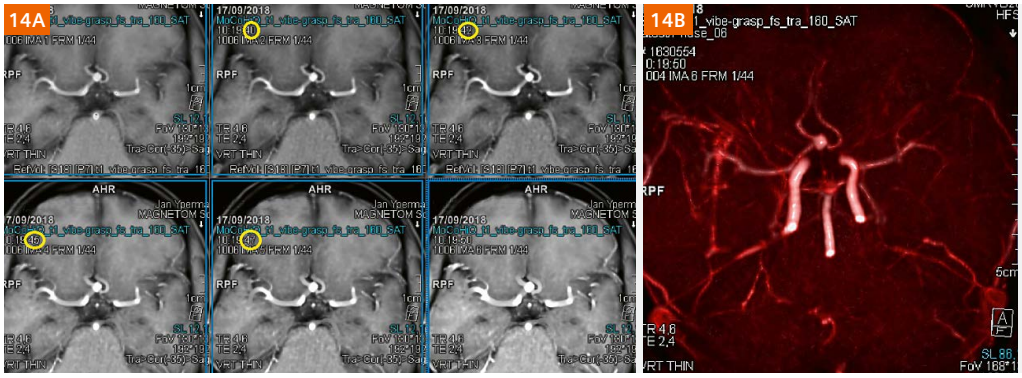


Figure 14:
Thin VRT reconstruction of 4D GRASP, time resolution 2.5 seconds (yellow circle) at 1.1 isotropic spatial resolution. VRT reconstruction single arterial phase from GRASP series; 2.5-second acquisition.

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[1] *Compressed Sensing GRASP-VIBE for other regions than liver is not for sale in the U.S. Intended Use: Compressed Sensing GRASP-VIBE (GRASP = Golden-angle Radial Sparse Parallel MRI) is intended to be used in dynamic and/or non-contrast liver examinations to support patients who cannot reliably hold their breath for a conventional breath-hold measurement.*